Agriculture and Environmental Challenges

Proceedings of the Thirteenth Agricultural Sector Symposium

Jitendra P. Srivastava and Harold Alderman, editors
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The World Bank
Washington, D.C.
The tradition of the Annual Agricultural Symposium is well established and offers an occasion when World Bank agricultural staff have the opportunity of meeting to consider matters of current importance to Bank agricultural policy and implementation. The focus of this year's Symposium - Agriculture and Environmental Challenges -- is no exception. In fact, it is an arena where concern for environmental issues along side those for productivity is most critical. The wealth of information and practical applications of these premises presented in the papers provided a substantial foundation for future project assessments and implementation of new and exciting ideas.

We were again honored by the presence of Bank President, Mr. Lewis Preston, who opened the Symposium. Newly appointed Vice President for Environmentally Sustainable Development, Ismail Serageldin delivered an excellent opening address, "Agriculture and Environmentally Sustainable Development," which was followed by an enthusiastic debate among Bank staff.

By making these papers available in the Proceedings, it is our intention to share this wealth of knowledge and examples with those within the Bank who were unable to attend the Symposium and those outside the Bank who share our concerns for the challenges ahead in advancing the agricultural development process in an environmentally sustainable way.

I wish to acknowledge the outstanding efforts of the coconveners, Jitendra Srivastava and Harold Alderman, their staff members, and the staff of the Training Division under the direction of Surinder Deol, who orchestrated this year's Symposium.

I also wish to acknowledge the special efforts of Mary Horne in editing this Symposium, and for her work in previous years.

Michel Petit  
Director  
Agriculture and Natural Resources Department
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OPENING SESSION
The Challenge of Sustainability

Lewis T. Preston*

Introduction

I'd like to welcome everyone to the Thirteenth Agricultural Symposium. In opening this Symposium last year, I said that I didn't know enough about agriculture to address the major issues in the sector. It's twelve months later -- and I'm still not an agricultural expert. However, I have become increasingly aware of the central role of agriculture in our work -- and I'd like to talk about that this morning.

It's also important for me to have your views. We have agreed to present an agriculture sector review and strategy paper to our Executive Directors. This Symposium can make a valuable contribution to that effort.

Agricultural Challenges

The world's population is projected to expand to about nine million over the next forty years. Demand for food and fuel will rise tremendously. Meeting that demand will require more intensive use of many natural resources -- especially agricultural land, forest, water, and fisheries.

In that respect, agriculture is at the center of development -- cutting across the major themes of poverty reduction, economic growth, and environmental protection. And yet, Michel Petit tells me that he feels agriculture has been treated with "benign neglect" by the Bank in recent times.

He says that we often don't give it the priority it deserves in the policy dialogue, and we don't give enough attention to helping shape long-term sectoral strategies in our borrowing countries. He has also pointed out that agriculture's share of the lending program has dropped from about one-third in the 1970s to around 17 to 18 percent today.

While recognizing that Mr. Petit is not exactly an "unbiased source" on this matter, I do think he raises some questions that we ought to consider. We know that agriculture has been abused and even plundered in many developing countries. But are we doing enough through the policy dialogue, public expenditure reviews, and other instruments to help remedy the situation?

We know that there has been a severe lack of coordination among donors. My own "favorite" example is Tanzania where 120 different kinds of agricultural research projects were discovered -- each supported by a donor. Are we using our analytical skills and knowledge to achieve better focus?

Increasing our lending is not necessarily the answer. As you may know, the Wapenhans Report found that 42 percent of Bank-supported agricultural projects have "major problems." Weak policy frameworks, institutional shortcomings, and external factors have all contributed to poor performance. But we also know -- and Wapenhans confirmed it -- that our projects have often been too ambitious and complicated; too "top-down"; and that we have too often failed to ensure local ownership and follow-up.

I'm aware of some of the efforts being made to improve performance in the sector -- the emphasis on helping to support smallholder farmers and, particularly, the role of women in

* President, World Bank.
agriculture. The innovative work being done in social forestry, integrated pest management, and in involving local communities in environmental protection is also important and exciting. The name of the game, however, must be implementation. There are just too many examples of perfectly sensible policies and programs that have not been followed through in order to have the needed impact.

Why is that? Is it a lack of commitment on our part? Or on the part of our borrowers? Are our agriculturalists and country economists communicating with each other?

I hope you can devote some time to discussing these questions -- because they're vital to our future work in the sector.

Environmental Challenges

The link between agriculture and the environment is also very important -- and it will be the major theme of your discussions over the next few days. In the long run, development and environmental protection are mutually reinforcing objectives. In the short run, however, there are many difficult tradeoffs and issues to be resolved, including the effects of pricing and incentives, population growth rates, the role of women, and the balance between agricultural productivity and environmental sustainability.

We are far from having all the answers. We need more research at the national and international level -- through the CGIAR, for example. We need new technologies. We need to place the concept of sustainability at the center of our work.

Meeting the Challenge

The Reorganization should help us meet the challenge. In particular, the new Vice Presidency for Environmentally Sustainable Development specifically links agriculture with the environment. It will give added focus to our research and operations.

The recent completion of IDA-10 at a level of US$18 billion, a remarkable achievement under the circumstances, should also help. The IDA Deputies emphasized, for example, that resources should be linked to the preparation of National Environmental Action Plans in our borrowing countries.

The Global Environment Facility (GEF), which has recently been placed on a more permanent footing and opened up to universal membership, can also help by working to integrate environmental and development objectives at the global level.

Conclusion: Challenge for the 1990s

A major challenge facing us in the 1990s is going to be keeping up with the increasing demand from our developing member countries for assistance in helping them address sustainability issues. Frankly, I don't think we yet have the right "skills mix" to meet that demand. We haven't yet developed all the necessary tools.

We need to do more to incorporate the lessons of our successes and failures. And, again, we need to improve on-the-ground implementation, which is where development really counts. We're still on the steep end of the learning curve.
However, I believe that there is already considerable knowledge and experience within this institution on which successful programs can be based. I believe that we have begun to move in the right direction.

This Symposium is an important step along the way.
Introduction

Mr. Preston has painted a broad-brush canvas of the challenges we face in the rest of this decade if we are to fulfill our developmental mission, to help reduce poverty, and to improve well-being for billions of unfortunate souls on this planet.

Mr. Preston said: "We need to place the concept of sustainability at the center of our work." Because that is very much the raison d'être of the new Environmentally Sustainable Development (ESD) Vice Presidency, let me start my remarks by discussing the concept of sustainability and how we can operationalize the concept.

Defining Environmentally Sustainable Development

For a first cut at an operational definition of sustainable development, we may begin with the Brundtland Commission's definition: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." It contains within it two key concepts:

- The concept of 'needs,' in particular the essential needs of the world's poor, to which overriding priority should be given
- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present needs.

Or put another way: "To say that a development path is 'sustainable' means, at least, that its patterns of production and consumption can be reproduced indefinitely without doing increasing or irreparable damage to essential natural ecosystems."

These two definitions are cautious in that they are static: they suggest holding the line on degradation of future opportunities but do not necessarily promise any hope for improvement.

Challenges for Conventional Neoclassical Economic Analysis

To be meaningful guides for the design of policies and investments, these definitions must be translated into the language of economic analysis. This is not an obvious task because mainstream neoclassical economics has had little to say about sustainability. In fact, one can argue that, at least until about a decade ago, it has been singularly shortsighted.

Indeed,

- While most of us readily recognize the obvious links between economic behavior and environmental quality, mainstream neoclassical economics treats these as externalities.

The author is Vice President, Environmentally Sustainable Development, The World Bank.
While most of us readily accept the idea that economic behavior both affects and is affected by changing technologies, time horizons, and values, tastes, and preferences (including those regarding family size), mainstream neoclassical economics continues to treat these as exogenous variables.²

So, where do we start? Perhaps the most obvious point is the concept of capital, and the need to sustain the capital base of humanity, including:

- **Manmade capital**, both physical and immaterial (such as information)
- **Natural capital**, with proper valuation of the environmental services that natural resources provide (not just as inputs into productive processes)
- **Social capital**, not only in the conventional terms of investing in people but also in terms of the institutional and cultural framework that makes civilized transactions possible. The disintegration of societal institutions and structures in Yugoslavia and Somalia are stark reminders of what extreme neglect of that aspect can lead to. (This links up with concerns of poverty reduction and equity.)

Today, certainly in terms of natural capital, possibly in terms of social capital, we are depleting it rapidly. For example, tropical forests are being lost at the rate of 17 million hectares annually, 60 percent of that due to agriculture (shifting cultivation).³ This means that we are living off our capital, not just our income. Therefore, our children will have less capital from which to derive their income. Therefore, once we have begun to feel the impact of this capital depletion, and until the healing effects of a new path can take hold, there will be a downward trend. Even after the "right" policies and technologies are in place, it will take time to build up a capital stock compatible with a new way of doing things.

Incidentally, this is not a revolutionary departure from conventional economic analysis, which has always maintained the distinction between capital and income. But there, capital (only manmade capital) was to be kept at a level to produce income in the next reporting period. This definition merely extends that one from manmade to natural and social capital.⁴

I will not belabor the point here, but more generally, our economic accounting must adequately reflect these environmental and social concerns if the policies and the investments we recommend are to effectively promote sustainable development.⁸

Let me now move back to another part of the Brundtland definition -- the concept of needs. This undergirds the link between environmentally sustainable development and poverty reduction in a rapidly changing world.

**Environmentally Sustainable Development and Poverty**

Keeping the poor in their misery, while protecting the environment and promoting economic growth, is *not* sustainable development. We must strike at the roots of poverty.

What is poverty? It is not just having low incomes. It is not just the absence of means of social participation. It is not just the persistence of massive inequities. It is not just deprivation of decent shelter, clothing, and diet; too frequently, it is much more than that. Too frequently it is oppression, hunger, sickness, and death—extreme conditions that defy our capacity to imagine them much less measure them.

I could speak at length on the issues of poverty and the design of strategies to deal with it.⁹ But my purpose here today is simply to remind us all that doing our job right in this area is not
merely a matter of a few additional percentage points of income growth per year. It is literally a matter of life and death for millions of people.

- Literal reminders of the terrible cost of failed policies shocked a complacent world a decade ago with images of starvation in Ethiopia.
- That it happened at all was a tragedy.
- That it happened again in Somalia was beyond belief.
- And that it could still happen again elsewhere would be an unspeakable crime.

But even if outright famine is averted, the problems of poverty are no less pernicious for the unpublicized way in which they claim, at the margin, hundreds of thousands of lives. How much of infant mortality and morbidity bred of ignorance and malnutrition could be averted by better attention to basic health and nutrition? By better attention to the meaning of poverty and the means of its alleviation?10

Our subject is indeed a matter of life or death for countless thousands whose silent, hopeful presence should permeate our discussions here.

The Role of Agriculture

Agriculture is the key to address these issues of

- Reduction of poverty
- Food security
- Natural resource management
- Environmental sustainability.

In most parts of the world, poverty and malnutrition are still far more pronounced in rural areas than in urban areas. The bulk of the world’s poor are in rural areas. Thus the percentage of the poor found in rural areas is: 91 percent in Indonesia, 79 percent in India, 67 percent in the Philippines, 86 percent in Côte d’Ivoire, and 52 percent in Peru.11

In the rural areas, the poor account for significant numbers of the total population:12 60 percent in Latin America and the Caribbean, 60 percent in Sub-Saharan Africa, 31 percent in Asia, and 26 percent in the Middle East and North Africa.

Between the late sixties and the late eighties, food staples self-sufficiency declined from 99 percent to 94 percent in Asia (excluding China and India), from 98 percent to 93 percent in Sub-Saharan Africa, from 92 percent to 76 percent in the Middle East and North Africa, and from 112 percent to 93 percent in Latin America and the Caribbean.13

The fact that the title of the department concerned with agriculture no longer refers to rural development cannot imply that these poverty concerns have been reduced. An entire new vice presidency has been created to emphasize this point. Within the ESD vice presidency, many opportunities will arise for much better coordination of strategies for agricultural production, for conservation and development of the land and water resources available to support rural livelihoods, and for improved access of the rural poor to clean water, roads, and other infrastructure necessary for a productive and healthy life. We will also strive to improve coordination with our colleagues working on human resources to improve badly neglected rural education, population, health, and nutrition programs.

You must take the lead in this cross-unit endeavor to reach out to the rural poor of the world.
Agriculture and Environment

What about agriculture and the environment? Agriculture, in many ways, embodies the idea of interaction among people, land, water, and air (climate). That is the same immediately accessible conceptual framework for environment. Environmental activism was initially labeled "green."

The kind of environmentalism we are concerned with is one that guarantees people the right to pure water, to clean air, and to fertile soil. In many parts of the world, these rights are being denied. Today:

- 1 billion poor people are denied easy access to clean water.
- 1.7 billion poor people live without adequate sanitation. (The diseases stemming from these conditions kill 2 to 3 million children every year.)
- 1.3 billion people in the cities of the developing world -- many of whom are rural migrants fleeing pervasive rural poverty -- suffer from inhaling soot and smoke in the air at levels considered dangerous by the World Health Organization.
- 700 million women and children are suffering from indoor air pollution from biomass burning stoves -- with health impacts equivalent to smoking three packs of cigarettes a day.
- Hundreds of millions of poor farmers are suffering the cause of declining soil fertility -- not because they are greedily exploiting the land but because they simply do not have the resources to make the simple investments to protect and replenish the soils, their source of livelihood.

These rights to pure water, to clear air, and to fertile soil have to be given to those groups who currently lack the power of voice: the poor and the generations to come.

The key is empowering the poor, especially women. When poor farmers are given legal tenure or legally binding user rights to their land, rather than keep it as state-owned collective farms or open access, they are more able (because they get access to credit) and willing to invest in protecting the soil. Examples abound: from hill farmers in Kenya, to slash-and-burn smallholders in Northern Thailand, to pastoralists in Senegal and Burkina Faso.

But more often, the needed empowerment relates to access to services and resources.

- Access to education has a remarkably positive impact on incomes and the environment. The agricultural productivity effect of education is well documented. But there is much more. Providing education to slash-and-burn farmers in Northern Thailand was found to be a most powerful policy to reduce deforestation. Education of girls is especially important. Better educated mothers provide better nutrition in Brazil even if their income is the same. Education is the strongest form of empowerment. This is why the World Bank is providing over US$2 billion per year for education programs. Ninety percent of these education programs have special provisions for female education.

- Other crucial forms of empowerment include access to extension services and credit. Again, providing these to the poor and to women has extraordinary economic and environmental returns. Example: women manage half of the natural resources in Africa (70 percent of the farms in Congo), yet are often denied extension and credit services, education, and legal protection. No wonder investment in soil protection is inadequate!

- The right to clean air and the absence of pollution requires a different form of empowerment. There must be accountable government responsive to the needs of all
citizens, and competent to put in place cost-effective policies and investments. This is
difficult -- but very encouraging developments are taking place. The World Bank is
working with about forty countries to strengthen environmental institutions, including
major efforts in Chile, China, Indonesia, Mexico, Nigeria, and Poland. Beijing's
industrial output has doubled in the past eight years, while its output of hazardous
waste has halved. Malaysia, Mexico, and Thailand have introduced lead-free
gasoline. Air pollution from particulates (soot and smoke) and from sulphur dioxide is improving on average in middle income countries. (But not enough and not in low
income countries.)

How can the rights of future generations be protected? By protecting the natural capital stock
so it can continue to provide incomes and services into the indefinite future. For example:

- Make sure that fish stocks are not depleted irreplacably. (The Bank is supporting a
  new fishing law in Chile to ensure a sustainable harvest.)
- Protect aquifers from irreversible depletion or pollution. (The Bank is assisting
dozens of countries in improving water management.)
- Protect forest ecosystems so they can provide economic, social, climatic, and
  ecological services for generations to come. (Forest protection and enhancement is
  at the core of the Bank's forest sector work around the world.)
- Protect the fertility of the soils from depletion, erosion, and water-logging.
- Protect the atmosphere from excessive accumulation of greenhouse gases and from
  ozone depletion. (The Bank chairs the Global Environment Facility and is the
  major executing agency of the Montreal Protocol Fund.)

While in many instances pro-poor development policies and projects also increase
sustainability, as in the case of soil conservation via vegetative barriers and agroforestry programs,
such is not always the case. Conflicts between development and conservation are likely to occur, at
least in the short-term. Conflicts are embedded in most programs aimed at indigenous groups.
Conflict arises in buffer zones of national parks. And there are potentially large conflicts if
development of wetlands is to be restricted in areas with rapid population growth, because this is the
main opportunity to add high quality land to agriculture.

I believe that in such instances we must first check whether the poor would truly benefit from
the proposed development, or whether the rich will reap the benefits. If the poor will reap significant
benefits, then some compromise that does not sacrifice high-priority conservation objectives can be
found. This will be an important area of intellectual research for the Development Economics Vice
Presidential Unit (DEC) in the Bank and of policy analysis for ESD. The earlier comments I made
about improving our economic analysis can and should be brought to bear on such issues.

However, it is important to note that with 100 million people added to the planet’s population
each year, simply protecting the environment is not enough. We need to improve the productivity of
all kinds of "capital" -- natural, manmade, and human. This is why it is essential to change the focus
from the environment towards sustainable development.

The Promise of Technology

Are we shortchanging the promise of technology, of a new "green revolution," while listening to the
Cassandras who preach the "limits to growth" gospel? I do not think so. What I have sketched out
are only prudent and responsible approaches to management of natural resources in a period of rapid
change and future uncertainty. You will be devoting some time in the next few days to this issue so I shall not expand on it here. But what about technology and what it can do for the future?

In an excellent essay Neva Goodwin raises the question of the role of technology in helping humanity out of its apparent bind. Malthusian pessimists see a global system of diminishing marginal returns, which "technological optimists" are convinced will be overcome by new (and unspecified) technologies that will maintain the momentum of ever-greater productivity of all (classical) factors of production (land, capital, and labor). Both may be right! Goodwin suggests that the concept of technology be *unbundled* to differentiate between two types of technologies:

- The mostly material inputs group of technological resources whose marginal returns are declining, most markedly in modern agricultural systems such as those spawned by the green revolution. These include chemicals, machinery, imported (that is, off-farm) energy, and other purchased material inputs.
- The information-intensive, immaterial inputs group of technological resources that appear to retain significant potential to enhance the productivity, and reduce the intensity of use, of most or all other factors.

Examples of such information-intensive agricultural technologies include:

- Pest control strategies that employ natural interactions of plants and pests
- Crop rotation and diversity
- The selection and creation of improved animal and plant varieties (including modern techniques of bioengineering as well as older breeding methods)
- Complex farming systems, including staple grains, legumes, fodder, and, importantly, livestock
- On-farm reuse of organic materials, including composted plant byproducts and animal wastes
- Agroforestry and other types of three-dimensional design to maximize use of sunlight in plant "layers"
- "Fine-tuning" of inputs, for example, in timing as well as in quantity of applications of water and fertilizer.

Many of these areas are not likely to be promoted by the private sector alone because they cannot be appropriated and marketed. A conscious government effort to promote and disseminate such approaches is needed.

### A Vision for the Future

Without pinning too much hope on untested new technologies, but without dismissing their potential benefit, we can outline a vision for the future that builds on the concepts of ESD, namely, recognizing that:

- Long-term sustainability is at the heart of any development strategy.
- The linkages among poverty, environment, and agriculture are important.
- The links between economic activity and environmental quality are powerful.
- The key to effective change on the ground — implementation — resides in empowering the poor, especially women, to take effective action to improve their well-being.

Embracing these concepts would lead us toward a new and more "holistic" vision of development. A vision that would revolve around a broad development strategy whose elements include the following prescriptive items:
People are both the means and the ends of the development process -- human resource development and capacity building are priorities.

There is no alternative to continuous economic reform and adjustment.

Economic growth is necessary but not sufficient to bring about improvements in human well-being.

Aggressive antipoverty policies must go hand in hand with pro-growth policies.

Increased agricultural productivity and food security are essential, as are diversification and competitiveness of exports.

An enabling environment -- political and legal -- for individual initiative and private enterprise is fundamental.

The most efficient use of scarce resources is imperative, including a review and reduction of military expenditures.

Empowerment of people through good governance and accountability is vital.

Adequate population policies must be pursued.

A larger role for women is essential.

Immediate action on environmental issues is critical.

Increasing economic integration is necessary.

Short-term measures must be embedded in a long-term perspective.

Adequate external financing and imaginative treatments of outstanding debt are needed.

**Next Steps**

This group here today has a massive responsibility to make this lofty vision a reality. I have already highlighted the centrality of agriculture to the problems of poverty and environmental quality. It is also clear that in many countries -- especially Sub-Saharan Africa -- the key to growth is effective modernization of agriculture. Yes, what you will be doing in the next few years will be decisive. How decisive?

The World Bank currently administers a portfolio of 413 agricultural projects, representing US$26 billion in loans and US$60 billion in total investments. It is further planned that over the next five years, US$23 billion in new commitments will be made for this sector.

But this is not all. Not only is the question of implementation essential -- as Mr. Preston underlined in his opening remarks -- but the framework within which these investments take place is, and must be, a prime concern of yours.

This will involve giving much greater emphasis in the Bank’s policy dialogue and lending programs to a country’s overall strategy for the sector. It will also require much greater attention to the quality of a country’s entire expenditure for agricultural and natural resource development and for food assistance to the poor. It is not sufficient to focus only on the expenditures directly associated with Bank-assisted projects.

One implication of such an approach is a far greater need for donor coordination. Another implication is that the policies advocated for agriculture must be compatible with -- and indeed part of -- national policies aimed at creating an enabling environment to empower the poor, spur investments, and promote private sector development. All this is very much in line with the proposed Board paper on agriculture, which you all have discussed at length.29

- We must now move from words to action.
- We must make use of the knowledge and experience we have gained. We must:
• Learn from our mistakes
• Build upon our successes
• Spread "best practice" approaches to different parts of the whole.

The new ESD Vice Presidency enables us to do so better:
• We can strengthen the links between the staffs of Agriculture, Environment, and infrastructure.
• We can promote bridge-building with other thematic vice-presidencies.
• We can help cross-fertilization across regions and across sectors.
• We can provide the strongest and most effective support for the work of the regional staff to make this strategy a reality.

Whatever we do at the management level, the challenge of the future is in our hands:
• How can we best integrate the concerns of Agriculture and ESD into macro and sectoral strategies for our borrowers?
• How can we develop responsible approaches to Natural Resource Management that will improve agricultural production and sustainability?
• How can we improve our economic measurement and analysis to take into account ecological and social concerns?
• How can we ensure that what is already known in terms of technology is effectively disseminated and used among the poor farmers of the world?
• Do we have the right skills and knowledge and experience among the staff of this institution, or do we need to revisit the issues of skill mix and staffing in Agriculture?

Your work will define the future. The Bank is committed to put up about US$4.5-$5 billion per year to back up your recommendations based on your analysis.

Envoi

The future is on our doorstep. What we do today and tomorrow will help define the world of the third millennium for hundreds of millions of people currently living in rural poverty, without voice or power, in a deteriorating and deleterious environment.

We must bring to bear the rigorous discipline of analysis and the wisdom of vast and pragmatic experience in dealing with these issues. But I beseech you at all times not to forget the precarious reality of the human condition:
• The vulnerability of unskilled labor
• The soul-destroying impact of poverty and homelessness
• The ease with which the rich and powerful subvert law enforcement to their own ends.

Hard and complex as the issues are, there is a compelling and crushing reality out there:
• Every passing day of misguided policies deepens the misery of wretched millions of human beings.
• Every incomplete package adopted represents a lost opportunity to reach out to those millions of kindred souls.

We cannot claim to have all the answers and must be humble about the scope of our possible interventions -- but we must dare to be bold, dare to be imaginative.

With vision and commitment we can help empower the long-suffering rural people to take charge of their own destinies for, ultimately, progress lies in enabling the weak and the marginalized
to become not the beneficiaries of aid or the recipients of charity, but the producers of their own bounty and welfare.

Endnotes


7. See World Bank Sustainability Group with Johan Holmberg, Consultant, "Operationalizing Sustainable Development" (Unpublished memorandum, April 24, 1992), 5-6.


13. The number of food deficit countries in Sub-Saharan Africa almost doubled from 28 to 41 between 1965-67 and 1986-88. The IFAD study of 108 developing countries found that the proportion of countries whose per capita energy supply fell below requirements has declined significantly in all regions. Between 1965 and 1985, of the 23 developing countries in Asia, the number whose per capita energy supply fell below requirements declined from 21 to 9 countries. In Sub-Saharan Africa, the number declined from 33 to 30 countries. In the Near East and Africa, it declined from 9 to 2 countries while in the Latin American and Caribbean countries, it declined from 19 to 10 countries.


16. This issue of land tenure and land user rights should be looked at carefully, especially where communal (as opposed to state) lands exist. See Kevin Cleaver and Götz Schreiber, The Population, Agriculture, and Environment Nexus in Sub-Saharan Africa (Washington, D.C.:


20. The Bank is the Administrator of the GEF, the repository of its two trust funds, and undertakes investment projects. For the official delineation of the Bank’s role in the GEF see "Procedural Arrangements among the International Bank for Reconstruction and Development, the United Nations Environment Programme, and the United Nations Development Programme for Operational Cooperation under the Global Environment Facility," signed on October 28, 1991.


25. See C. A. Francis and M. D. Clegg, "Crop Rotations in Sustainable Agricultural Systems"; and Benjamin R. Stinner and John M. Blair, "Ecological and Agronomic Characteristics of Innovative


Technical Considerations for Sustainable Agriculture

Richard G. Grimshaw, Christopher J. Perry, and James Smyle*

For the purpose of this paper a sustainable system of agriculture is one that can maintain production at a sustained and profitable level, if necessary with moderate levels of support from external inputs, without leading to significant environmental damage. To achieve sustainability most agricultural production systems depend on a policy and institutional environment (including pricing, regulation, and tenure) that is conducive to the producer; infrastructure (both physical and support services) that allows effective access to services and the market; and four critical technical criteria -- nutrition, health, genetic material, and water. This paper addresses these technical criteria.

In recent years the World Bank has rightly come under criticism because some projects have not performed well. In looking for leads to improve that performance, it is worth reviewing some successful projects and schemes developed by agencies other than the Bank, examples include:

- Global 2000’s project in Ghana that emphasizes soil fertility and the introduction of improved varieties, primarily maize, and other inputs, clearly demonstrates that African farmers are responsive to inputs.
- SIDA’s Machakos Integrated Development Project in Kenya that gave priority to increasing arable area and unit area productivity through improvements in soil fertility, land management, and water conservation.
- FAO’s integrated pest management project for the control of Brown Plant Hopper in rice in Indonesia.
- WIMCO Ltd’s introduction of high-yielding poplar clones to India’s northwest farmers that has led to a highly successful venture in private sector wood production.
- The World Food Program’s successful soil and water conservation program in the Loess Plateau Region of China that reduces sediment flows in the Yellow River, expands cultivable land, and improves soil fertility, soil moisture, and crop production.
- CARE International’s Dry Land Farming projects on the outer islands of Indonesia that focus entirely on water and soil moisture conservation technologies resulting in important land-use change from degrading, near monocropped cassava land, to lush perennial farm gardens supporting cocoa, coffee, bananas, coconut, and so forth, on a sustainable basis.

These projects have a common feature -- they all focus on a narrow band of technologies that are fundamental to agricultural growth and the sustainability of the agricultural resource base.

In the discussion of technical considerations for sustainable agriculture it is worth dwelling on development strategies of the past. Two thousand years ago in China it was imperative for the Han government to increase agricultural production (and thus its tax receipts), for not only was the population expanding, but expensive wars were being fought. An intensive campaign was therefore mounted both to improve agricultural methods and to expand the agricultural area. The campaign was specifically designed to benefit smallholders, and to improve peasant agriculture by providing the necessary technical inputs and physical infrastructure. Wu-Ti was the first emperor of unified China.

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to realize the importance of water control, and he carried out an enormous program of canal building... that irrigated over a million acres of arable land. The government also provided peasant farmers with seed-grain, tools and draught animals, sometimes on credit, sometimes on loan, and sometimes as outright gifts (Needham 1984). It is interesting to note that China’s approach to agricultural development hasn’t changed much since Emperor Wu-Ti’s time, and today China has the world’s fastest sustained growth of agriculture averaging 4.5 percent since 1950, and about 6.5 percent per annum since 1980 following market reforms and return to privatization of production. It is estimated that research generated technology has, since 1965, contributed to 20 percent of this production growth (Fan and Pardey 1992).

In the history of agriculture, sustained agricultural growth has always been associated with new technology introductions that increase factor productivity. At this time when rural populations are increasing in relation to virtually static land resources, and when more is expected of agriculture in the alleviation of rural poverty, there is a need to take a new look at those four critical areas of technology described in the opening statement of this paper.

Nutrition — Soil Fertility

The failure to apply adequate amounts and/or balanced levels of nutrients leads to loss of actual and potential production and income. In addition an increasingly occurring phenomena, especially in irrigated areas, is the misuse of fertilizers leading to ground and surface water contamination from phosphates and nitrates.

There are no magic solutions to maintaining soil fertility — soil nutrients removed in the form of crops, residues, trees, and livestock and livestock products have to be replaced. The farmer is looking for low-cost and efficient replacement. That is why farmyard manure, and in some countries human manure, when suitably composted, continues to be an important replacer of exported soil nutrients. Various green manures, including the leaves of leguminous hedge plants, that have other uses as well, are also becoming more widely applied.

In rainfed areas where production risks are higher and the opportunity cost of labor is low, farmers are reluctant to use purchased inorganic fertilizer. The need to produce and use organic manures under such conditions is important. High-yielding forage (such as napier grass) production for “resident” livestock, particularly draft animals, is probably the key to maintaining a sustainable fertility cycle. Where such practices are used, as in Machakos District of Kenya, livestock can be supported on small areas of land, typified by the average smallholder farm that rarely exceeds one hectare. The contribution of livestock, as part of a small farm system is essential for draft power and for manure (Tiffen 1992). In China, pig manure has a similar key role in maintaining soil fertility. It recycles soil nutrients eroded from the uplands that support lowland crop (rice) production, the byproducts of which are recycled to pigs, as well as for mulch on upland farms. The ammoniation of rice straw, a technology being widely used on Bank projects in China, enhances its feed value and can undoubtedly contribute indirectly to increased soil fertility.

Soil fertility issues, particularly in the tropics, are of importance to rural people, especially for those associated with approximately 1.7 billion hectares of acid tropical soils in seventy-two developing countries. These soils, commonly yellow or red in color, are often characterized by high acidity, aluminum toxicity, and, when mismanaged, high levels of degradation. Reducing acidity through deep liming; using aluminum tolerant plants; the introduction of mycorrhiza that increase the uptake of soil nutrients, particularly phosphates (the inoculation of tree seedlings with mycorrhiza greatly enhances tree growth on acid degrading soils) (Malajczuk, Jones, and Neely 1992); using a better balance of NPK; all add to increasing crop yields.
Currently there is a mass of investigations relating to tropical soils, including outstanding work by the University of North Carolina's TropSoils in association and collaboration with other international research groups such as IBSRAM and ICRAF, as well as national research agencies. A good summary of this work is found in TropSoils Technical Report 1986/87 (1989). A detailed investigation at Sitiung, Indonesia, is described in a recently published TropSoils paper (Arya, and others 1992), and establishes rather nicely the soil structure/moisture/fertility relationships under the conditions at that site. It confirms the difficulty of establishing shallow rooted food crops on highly acid, aluminum toxic soils, and demonstrates why deep rooted trees, shrubs, and grasses are successful. It recommends breeding and selection of crops that can grow in aluminum toxic soils, and the deep application of lime if food crops are to be successful. For example, Amaranth as a grain and fodder crop, and Vetiver grass for soil conservation, fodder, and mulch, both deep rooting and adapted to aluminum toxic soils, may be useful plants for this type of condition.

Most country policies and programs relating to soil nutrients are deficient. In areas of high soil acidity liming programs are rudimentary, and often nonexistent; fertilizers are rarely matched to soil type or crop demands; farmers take what fertilizer is offered -- the offering often being determined by inappropriate national fiscal and foreign exchange policies, as well as inadequate distribution systems. For example, because phosphates and potash are generally imported, in contrast to locally manufactured nitrogen, farmers often receive unbalanced, nitrogen dominant, fertilizer. Additionally micronutrients such as sulphur, copper, boron, and so on, are generally not taken account of, with resultant loss of potential yields.

Table 1 summarizes the yield response and potassium (K) balance in corn-wheat-corn cropping system at an experimental site in north China to different levels and types of nutrients (Lin, Ji-Yun, and Dowdle 1989) and demonstrates the incremental physical gains from a balanced fertilizer approach on these soils.

Data from China's National Network of Chemical Fertilizer Experiments revealed that on the basis of field trials conducted during 1981-83, 74 percent of China's cultivated land was deficient in phosphate (available P less than 10 ppm), about 40 percent was severely deficient in P (available P less than 5 ppm), and about 23 percent was deficient in potash (available K less than 70 ppm).

This scenario of imbalance is, outside of the large alluvial plains and deltas, typical of most developing countries, and is one of the reasons for stagnating yields, poor quality crops, increasing incidences of certain diseases, and soil degradation. It should be corrected through wider soil nutrient analysis, as well as appropriate actions including policy changes to modify fertilizer subsidies, and investment actions that promote better fertilizer production mixes, distribution, and technical support to farmers in relation to fertilizer application (introduction of low cost seed/fertilizer drills where appropriate and general soil management practices including a greater use of organic manures).

With few exceptions, organic manures alone will not support the yield increases in crop production that are required to meet grain demands and enhanced farm incomes. To achieve sustained agricultural growth where land is limited there is no option but to use inorganic fertilizers. Chinese data show close correlation to the use of inorganic fertilizer and increased grain production as in the following graph (Lin, Ji-Yun, and Dowdle 1989).

In China over the past twenty-five years the use of inorganic fertilizers has increased twelve times, as compared to only a 30 percent increase in organic manure (180 kilograms per hectare application rate) (Fan and Pardey 1992).

The Bank should pay much more attention to soil fertility; detailed country by country subsector analysis is required to assess production foregone due to inappropriate fertilizer strategies and policies, and analyze the economics of doing things right. Annual budget savings from reduction in fertilizer subsidies could be reinvested in, for example, improved soil testing facilities, decentralized fertilizer blending and packaging plants, and improved technical advice.
**Table 1: Yield Response and K Balance in Corn-Wheat-Corn Cropping System**

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Treatment</th>
<th>Yield Kg/ha</th>
<th>Increase</th>
<th>K (Applied) Kg K/ha</th>
<th>K (Removal) Kg K/ha</th>
<th>Balance Kg K/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Crop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>Spring</td>
<td>NP</td>
<td>4,546</td>
<td>-</td>
<td>0</td>
<td>32.4</td>
<td>-32.4</td>
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<tr>
<td>Corn</td>
<td></td>
<td>NPK</td>
<td>7,588</td>
<td>66.9</td>
<td>93.4</td>
<td>69.9</td>
<td>+23.5</td>
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<td>6,235</td>
<td>37.1</td>
<td>21.0</td>
<td>42.7</td>
<td>-21.7</td>
</tr>
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<td></td>
<td></td>
<td>NPKM</td>
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<td>74.2</td>
<td>114.4</td>
<td>72.1</td>
<td>+42.3</td>
</tr>
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<td>2nd Crop</td>
<td>Winter</td>
<td>NP</td>
<td>2,665</td>
<td>-</td>
<td>0</td>
<td>49.5</td>
<td>-49.5</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>NPK</td>
<td>3,466</td>
<td>30.1</td>
<td>93.4</td>
<td>79.5</td>
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<td></td>
<td>NPKM</td>
<td>3,750</td>
<td>40.7</td>
<td>107.8</td>
<td>86.7</td>
<td>+21.1</td>
</tr>
<tr>
<td>3rd Crop</td>
<td>Summer</td>
<td>NP</td>
<td>1,948</td>
<td>-</td>
<td>0</td>
<td>24.0</td>
<td>-24.0</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td>NPK</td>
<td>4,471</td>
<td>129.5</td>
<td>93.4</td>
<td>95.1</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>NPM</td>
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<td>61.9</td>
<td>0</td>
<td>34.9</td>
<td>-34.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NPKM</td>
<td>5,179</td>
<td>165.8</td>
<td>93.4</td>
<td>89.3</td>
<td>+4.1</td>
</tr>
</tbody>
</table>

Data adapted from Jin Ji-yun, 1989.

1 For NPM, NPKM treatment, cattle compost manure (M) was applied at rate of 13.5 t/ha dry weight.

2 No manure applied for this crop.

Figure 1. Grain Production and Fertilizer Consumption in China 1952 to 1987
Health -- Crop Protection

As crop yields increase, and cash crops (particularly fruit and vegetables) are introduced, so does the use of protective chemicals. This is leading in some cases to: overuse of chemicals; and increasing insect and plant resistance to insecticides and herbicides, as for example the cotton bollworm in China. The cotton bollworm has four generations every year. The second and third generations are most destructive in the Yellow River cotton belt. Cotton bollworm developed resistance to DDT due to excessive application over a long period of time (1950s-1970s). Pyrethroids were introduced for control in 1982; by 1987 the cotton bollworm had developed high levels of resistance to pyrethroid insecticides. Dependency on chemicals can be reduced through such management practices as Integrated Pest Management (IPM). The successful Indonesian/FAO IPM program for the control of Brown Plant Hopper in rice is just one such example where spraying regimes have been reduced by two-thirds, which together with yield increases has resulted in incremental income of US$100 per hectare per season (World Bank 1992a). As a direct result of this program, pesticide subsidies were removed, saving US$150 million a year, and extension methods were reversed from a top down to bottom up approach, with farmers fully participating in technology transfer and research. In Brazil, IPM trained farmers have reduced their insecticide applications on soybean, from nearly six to less than one on average, with no loss of yield. The introduction of disease resistant soybean varieties has virtually eliminated the need for fungicide.

IPM is an approach that requires a range of appropriate technologies (tools) so that the mix can be adjusted according to the perception of the problem. It is not an easy option to implement in practice. It often needs time, money, and research. Most importantly, it requires knowledge and understanding of pests.

Most Bank projects are large and complex and are unable to give proper treatment to plant protection and related issues. There is a need to review the overall plant protection subsector, assess critical problem areas, review alternative pest control methods, develop effective regulatory systems, and use savings in pest control subsidies for directed research activities that can support targeted IPM programs and for better communications with farmers. Currently the Bank is attempting this approach in Indonesia, and with modification, it might be a model for other countries as well.

Germplasm -- Crop Varieties, Seeds, and Planting Materials

The Green Revolution was a result of the breeding of high yielding varieties (HYV) of rice and wheat that were introduced to the irrigated areas, and, because they were self pollinated and were responsive to management, they spread rapidly from farmer to farmer with minimum support from extension (Antholt 1990). The challenge of the future will be the maintenance as well as the improvement of HYV germplasm for irrigated agriculture (as is being undertaken in China’s hybrid rice program that has increased yields from 4.8 tons per hectare to 6.5 tons per hectare); and the introduction of high quality plant material, and its dissemination to enable improved levels of production in rainfed areas and to support crop and livestock diversification. The majority of perennial species planting stock (including in some instances industrial crops such as rubber and oil palm) supplied to many farmers today are generally not genetically optimal. Neither is sufficient attention or rigor given to production of top quality seeds nor to culling of substandard perennial plants in the nursery. As a result, farmers forego annual income and make long-term investments in perennials that may only achieve a fraction of their full potential.

It is important that special emphasis is given to addressing the technical issues involved.
Some are complex using modern biotech approaches; on the other hand many are simple and involve primarily low-cost management techniques such as the selection of good seed or clonal material, the application of known nursery technologies, and improved field establishment techniques.

Development planners and researchers need to revisit past experiences. Farmer demand for crop varieties is often very different to that perceived by the scientist. In Machakos, Kenya, supposedly a semiarid region, with an average rainfall probability of 600 millimeters, farmers showed little interest in improved varieties of traditional drought tolerant crops such as sorghum and millet, but preferred (in response to market driven forces), and were able, through adapting their farm system with the aid of effective conservation systems, to successfully grow higher value cash crops that included maize, fruit trees, coffee, vegetables, cotton, sisal, and high-yielding fodder for livestock (Tiffen, Mbogoh, and Ackello-Ogutu 1992). The introduction of higher value crops led to better livestock control and management, and perhaps may be a key factor in the successful land stabilization that occurred in the district.

**Water -- Soil Moisture**

Last of the critical criteria, and the most important is soil moisture. If soil moisture is inadequate the other three criteria can never contribute optimally to a sustainable agriculture system. It is an indisputable fact that without adequate soil moisture agriculture is not sustainable.

As one of the oldest and most successful agricultural economies, China has depended on technology innovation (Needham 1984). In particular Chinese agriculture has given great attention to soil fertility and water for crop growth. Irrigation systems, still in use today, were developed over 2,000 years ago, as was soil moisture conservation, including unique soil mulching and terracing systems (in China terraced fields are known as "three fold conservers," that is, they prevent erosion and conserve nutrients and moisture). On the semiarid Loess Plateau, where terraces have been used for 3,000 years, grain yields on nonirrigated terraces are 200 to 400 percent higher than those on unterraced hillsides, while in times of drought they may be even ten times as high (Needham 1984). Seed placement (the famous Chinese official, Chao Kuo, introduced the seed drill to northern China in 89 BC with one objective to maximize production from available soil moisture) has been an important part of Chinese agriculture.

China had the equivalent of this century's "Green Revolution" during the Sung Dynasty (AD 1012) with the introduction of new varieties of quick ripening rices in irrigated areas of the Yangste Delta. Seeds, together with written instructions, were distributed to master farmers (today’s equivalent of village farmer technicians). At the same time land improvement capital was made available to farmers, and major improvements were made in flood control, drainage, and irrigation distribution systems (Needham 1984). Likewise in Bali and the Philippines unique terracing for rice has been developed over the millennia. Today’s Temple-managed proportional distribution systems of Bali are renowned for their simplicity and effectiveness. Crucial to these developments were farmer involvement in innovative measures both in farmer managed research and irrigation, terracing, and other developments. Such capability exists today when farmers are given the opportunity and encouragement.

**Irrigation**

The Bank is currently wrestling with its "Water Policy Paper." There has been much debate, and no doubt much more in the future, but clearly institutional reform that addresses a more comprehensive
approach to water, its allocation, price, and management is necessary if the irrigation sector is to perform its critical function in the long term.

The large water carriers, as found in a number of Asian countries, not only provide vital irrigation water that results in 70 percent of Asia's food production, but also supply water to meet the ever increasing demands of towns and cities. Similarly large carriers in the Middle East, Central Asia, and the western United States serve both irrigation and municipal and industrial (M&I) use and face similar crisis.

Asia Region's recent Asia Water Resources Study (World Bank 1992b) shows the growing demands for water for nonirrigation purposes. In some areas, such as Haryana in India, as much as 30 percent of current supplies to irrigation will be diverted to M&I in the foreseeable future, while in Madhya Pradesh, a substantial proportion of carry over storage in many dams is now preempted on a regular basis for M&I needs. It is not only important to know when these reallocations will be necessary, but also what investments and improvements have to be made in current use of agricultural water so that production levels can be sustained or even improved. The following paragraphs describe just two of many areas where technology and technology choices are important for Asian irrigation.

While the objective of most Bank-financed irrigation projects in India is to assure reliable and predictable deliveries to all farmers, the reality is that usually few farmers take water at will, while others get little or none. Irrigation infrastructure (particularly the smaller canals, gates, and other structures) are seen at best as inadequate, and at worst an obstruction to farmers realizing individual needs, and are frequently 'modified,' or simply destroyed, by the project beneficiaries.

An early attempt to directly address such performance failures through technology innovation was the Uttar Pradesh (UP) Public Tubewell Project in India. Well operators of existing traditional well designs were able to manipulate supplies to preferred customers -- water was not reaching tail enders due to preference of upper reach farmers and seepage from the farm ditches. The proposed new design automated the well operation, stabilized discharges in the distribution system, and made operators redundant. In a subsequent development the Government of West Bengal has, with Bank support, introduced a highly successful system of making public investment in ground water a cooperatively managed and maintained operation. Simple technology combined with careful attention to defining the responsibilities of the farmers and the irrigation department has yielded immediate benefits (200 percent plus irrigation intensity in the first year). The importance of matching technology to environment (social, technical, and economic) is clearly demonstrated by the different experiences of Uttar Pradesh and West Bengal.

A great deal of attention has been devoted to the improved operation of large surface systems. Technology can make significant contributions. A common flaw in the design of surface systems is to plan complex management with very limited infrastructure. The infrastructure (even when not subjected to farmer modification) is inadequate to give steady flows to relatively large contiguous areas, let alone varying flows to small individual plots. The technical challenge is to achieve a match between the plan of operation, and the physical performance of the system. This can be achieved by reducing the complexity of the plan, improving the performance of infrastructure, or both. In practice a combination of both approaches has been successful, based on careful diagnosis and definition of those parts of the system which the authorities must operate (for example, the head regulator at the dam), those parts of the system that the farmers must be responsible for (distribution among individual fields), and those parts of the system which can be designed to be self managing (for example, proportional dividers, which provide planned allocations between channels without operator intervention, and long crested weirs, which maintain flow levels independently of flow rates). In each case the choice of technology is critical to success.
The simple intervention of ensuring automatic distribution (as has been done in Bali for thousands of years) of water in proportion to area — reducing the load on the authorities, and consequently increasing the reliability of supplies to farmers — has shown remarkable success. One project, funded under the Bank’s National Water Management Project (NWMP) in southern India has shown productivity increases per unit of water of 30 percent over a three-year period. Water now reaches the tail ends, because headenders are more confident that future delivery schedules will be met (and peer pressure operates far more effectively when the supply is clearly defined). Increases in area irrigated for project and nonproject distributaries are shown in figure 2.

Figure 2. Comparison of Percentage Increases in Irrigated Areas Between Improved and Unimproved Management of Distribution Systems
A point that should be stressed is that without careful analysis and discussions with farmers, and a full understanding of the broad range of technical considerations from hydrology to distribution system design, the results would not have been possible.

These examples show that a careful match between operational objectives and technology is a key element of successful irrigation. Generally, technology exists within or is external to developing countries; a critical issue to be addressed is to improve application and transfer of technologies to countries such as India and China. For example while a large number of computer-based systems for hydrological analysis are well proven and accepted throughout much of the world, none is widely available to water planners and operators in India. Thus flood analysis, as well as real time operations, continues to be done by hand, or using locally developed rules of thumb.

\textit{In Situ Moisture Conservation}

Farmers who do not have access to surface and groundwater are dependent on rainfall for successful farm production. Seventy percent of India's cultivated land is rainfed, as is 50 percent of China's. All but 3 percent of African agriculture relies on rainfall only. The dependency on rainfed agriculture is growing as potentially new irrigation land becomes scarce, and water supplies for irrigation are restricted by availability. Rainfed farmers are cultivating marginal lands that are often classified as nonarable. They will continue to cultivate them until they are either destroyed or a system of management is established that will assure sustainability. In most countries with high rural populations, unless sustainable systems are established there will be little hope in preserving forested lands. In western Java and some of the smaller islands of Indonesia, land is being cultivated from the bottom to the top of hills and mountains that have slopes often exceeding 25 degrees. Forest has been cleared and has been replaced by a system dominated by cassava and as a consequence erosion is extreme -- up to 400 tons per hectare. Drought is often a reflection not of lack of total annual rainfall, but of within-season shortages and the failure to conserve rainfall in situ.

Asia Region's study "Watershed Development in Asia" (Doolittle and Magrath 1990) reviews research studies relating to soil and water conservation, and links soil conservation closely with water conservation.

For at least 3,000 years, farmers from ancient Mesopotamia to China have resorted to bench terracing with a high degree of success, particularly in respect to moisture conservation, whether in the wet tropics or in semiarid areas. Bench terracing has induced dramatic changes in societies and in the economics of their agriculture. Subsequently the technology has fallen victim to economic and social changes. A recent case of the rapid degeneration is the Yemen’s "Hanging Gardens of Arabia" because of the out migration of labor (responsible for terrace maintenance) to the oil rich Gulf states. In other countries such as Kenya, India, Indonesia, south China, Thailand, and elsewhere terracing is becoming less effective and more difficult to introduce because of the high cost of labor, the increased subdivision of land that makes the planning of engineered structures extremely difficult, poor maintenance, and neglect. In some countries such as north China it is still possible to mobilize the "masses" to create new terraces as on the Loess Plateau; elsewhere, such as in Indonesia, large financial incentives (US$300 per hectare) (FAO/World Bank Cooperative Program 1992) have to be given to farmers to assure terrace construction. As a large-scale intervention, terracing is therefore generally not appropriate; yet too often, it is still viewed as such and is promoted as a key conservation activity with poor results.

Clearly there are technology options that can be applied to enhance soil moisture conservation. First, such techniques as traditional mulching (rice straw in particular is a very
effective mulch and has a positive impact on soil structure), stubble mulching, and contour cultivation are often easily applicable at minimum cost, and all are very effective for in situ soil conservation. Compared to bench terracing, cultural and vegetative systems are cheap, involve minimum movement of top soil, and can be carried out by the farmer as a part of normal farm management practice. However, vegetative systems are not always able to survive the stress of uncontrolled high density livestock grazing as in the drier areas of India and Africa. All systems of conservation, some more than others, need a level of management to assure long-term sustainability.

As a substitute for constructed terraces, vegetative barriers have been developed as important conservation technologies. As a key approach a wide range of trees, shrubs, and grasses can be utilized as hedgerows, as long as the farmers are prepared to manage them. On very steep slopes a small farm may require one kilometer or more of hedgerow per hectare to provide adequate protection. Potentials for high labor inputs; sensitivity to grazing; occasional drought, fire, pests, and diseases; reduced yields from crop area reduction and hedgerow/crop competition; and disruption from normal farming practices all led to hedgerows being a technological approach whose successful introduction requires a level of flexibility and support far beyond project or agency capability. This is particularly true where hedgerows are not an indigenous technology on which initial efforts can be based.

In the mid-1980s John Greenfield, of the Bank’s New Delhi staff, identified a grass whose history of traditional use in south India seemed to indicate a good potential for its application as a hedgerow species. Subsequent investigations found the species to be pan tropical both in its distribution and its traditional use as a conservation plant. This grass, *Vetiveria zizanioides* (Vetiver grass), displayed a number of characteristics which avoided many of the problems (mentioned above) associated with hedgerow introduction and management. The grass and its application are described in a number of papers (Grimshaw 1991; Smyle and Magrath 1990). Further experience showed the species’ potential for extending hedgerows as a key technology. Because Bank staff’s early work with trial, demonstration, and dissemination of this technology, follow on research by IARCs, universities, and government agencies has confirmed Vetiver’s utility for soil and moisture conservation. Interest by individuals, nongovernmental organizations (NGOs), governments, and most recently in a publication by the U.S. National Academy of Science (1992) confirms the widespread applicability and potential of the species. In reference to the latter, a scientific audit was carried out by Dr. Norman Borlaug primarily to confirm World Bank staffs’ contentions regarding Vetiver as a key technology. By utilizing its technical expertise, Bank efforts resulted in the identification, verification, and dissemination of a new technology within a short span of eight years (it is generally recognized that the introduction of a new cereal variety can take twelve years or more).

A comparison, by Bharad and Bathal (1990) of GKVK University in Akola, India, between contour cultivation, graded bunds, tree (*Leucaena* sp) hedges, and grass (Vetiver) hedges, showed, respectively rainfall runoff percentages as follows 26, 24, 22, and 17. More recently work at ICRISAT (Rao, Cogle, and Srivastava 1992) that measured rainfall runoff and soil losses demonstrated, under a rainfall of 680 millimeters, the advantages of Vetiver grass hedges over other grasses and stone barriers. Vetiver grass hedges reduced runoff by 57 percent, followed by lemon grass with 29 percent. Under the site conditions stone bunds were not effective in reducing runoff (in Africa the use of “digettes” as a means of moisture conservation may need to be revisited), although they reduced the transportation of erosion sediments. These results are summarized in table 3.
Table 3. The Effect of Slope and Barriers on Runoff and Soil Loss During Natural and Simulated Rainfall on an Alfisol in 1991

<table>
<thead>
<tr>
<th>Period/rainfall</th>
<th>Treatment</th>
<th>Runoff (mm)</th>
<th>Soil loss (t ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulated rainfall¹</td>
<td>2.8% slope</td>
<td>20.9</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>0.6% slope</td>
<td>18.6</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>+1.33</td>
<td>+0.18</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>24.2</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>Stone bund</td>
<td>21.7</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Lemon grass</td>
<td>19.3</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Vetiver grass</td>
<td>13.8</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>+1.19</td>
<td>+0.31</td>
</tr>
<tr>
<td></td>
<td>Slope x barrier</td>
<td>**</td>
<td>NS</td>
</tr>
<tr>
<td>Natural rainfall²</td>
<td>2.8% slope</td>
<td>293.1</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>0.6% slope</td>
<td>182.8</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>+13.9</td>
<td>+1.2</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>307.1</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td>Stone bund</td>
<td>294.6</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>Lemon grass</td>
<td>218.3</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>Vetiver grass</td>
<td>131.7</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>+19.7</td>
<td>+1.7</td>
</tr>
<tr>
<td></td>
<td>Slope x barrier</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

** Significant at P < 0.01 level; NS = Not significant

¹ Between Feb-Mar 1991 with 80 mm h1 intensity
² Between Apr-Oct 1991 with 689 mm rainfall

Note the relation between runoff and soil conservation. The lower the soil loss the greater the in situ moisture conservation. In stark terms the area, without conservation, had an actual effective rainfall of only 382 millimeters, but with a stiff grass hedge, Vetiver in this case, had an effective rainfall of about 557 millimeters. This level of incremental soil moisture can make the difference between a good crop and a crop failure.

Nonagricultural surveys (Ochs 1992, personal communication) indicate that improved moisture conservation in south India has resulted in substantial improvements in the level of the groundwater table and the consequent benefit to rural water supply (farmers are digging wells where they have been unable to do so before). This can be reinforced from the same set of experiments that
generated the data in figure 2. Comparative hydrographs (figure 3), were developed which showed how the different barriers affected rate of runoff, and the total amount during individual storm events. It should be noted that even on near flat ground, 0.6 percent slopes (0.25 of a degree), release of water was slowed down significantly, and infiltration increased substantially. Currently, conventional wisdom relating to soil conservation in the United States and elsewhere does not require or even recommend conservation structures on slopes of less than 3 percent. It is recommended that agencies involved in dealing with groundwater recharge problems take a hard look at the possibility of using stiff grass hedges as a means of improving ground water recharge.

Figure 3. ICRISAT Experiment - Impact of Porous and Vegetative Barriers on Storm Hydrograph

In Indonesia indications are that moisture conservation is of greater importance than soil conservation in rehabilitating degraded slopes, and in establishing farm systems that are sustainable and based on perennial crops. Since 1987 CARE International has been managing a project on the island of Lombok (eastern Indonesia). This area has 1,800 millimeters of rainfall and an eight-month dry season. Population pressure is sending farmers up the steep mountain slopes, destroying forests and creating erosion hazards and increasing runoff. The CARE project has recognized the need for moisture conservation through antisoil erosion measures. CARE has concentrated on the establishment of tree hedges using mainly *Gliricidia* sp. (other species include *Calliandra*, *Albizia*, *Leuceana* sp). Government has provided farmers with perennial fruit tree seedlings such as mango, avocado, cocoa, jack fruit, and coffee.

As a result, some 5,000 farmers, have established over 3,000 hectares sustainable farms that now are mainly perennial cash crop based, and are not unlike the tropical garden farms of eastern Java and Kerala. Farmers report threefold increases in yield of maize and soybean; and fodder is
available for improved livestock feeding. In addition the improved situation on farm has contributed locally to increased dry season stream and spring flows. The project clearly demonstrates the primary role of moisture, and the secondary impact of soil conservation. Farmers are too poor to use pesticides and fertilizer, and from all appearances hardly need them, under the particular site conditions, including the dominance of perennial cash crops. The stabilization that has occurred on this project clearly demonstrates the need to stabilize farm land prior to, or in parallel with, action to maintain the status of adjacent forest lands, in fact without stabilization of farm land there is little chance of protecting forests. The latter can only be best dealt with on a community basis to assure that the benefits of the resource remains available to the local community.

Another case demonstrating very successful moisture conservation techniques was the Bank’s "Watershed Development Project in Rainfed Areas" located in a number of south Indian States. The introduction of contoured ‘V’ ditches that spread the water evenly over large areas of land gave remarkable increases in tree survival rates and growth, even in the worst years, when compared to other methods. As a result, the technique is spreading widely in India. Figure 4 demonstrates the results from Maheshwaram Watershed in Andhra Pradesh, India (World Bank 1991).

Figure 4. Comparison of Survival and Growth of Trees in Relation to Different Water Conservation Treatments

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DS = Dalbergia sissoo; Al = Azadirachta indica; AA = Acacia auriculiformis; SJ = Syzygium jambolana; LL = Leucaena leucocephala; CS = Cassia siamea; AM = Aegle marmelos; TI = Tamarindus indica; PE = Phylanthus emblica.

Recent studies of Machakos District in Kenya (Tiffen 1992) suggest that moisture conservation, through soil conservation measures, may be the key reason why farmers have been able to intensify production and maintain production levels under mounting population pressures.
Development strategies that fail to address satisfactorily soil moisture conservation are likely to be more risky and are less likely to achieve sustainability objectives. Nowhere is this more important than in the rainfed areas of Asia and Africa.

Technology Transfer and Generation

In the review of these critical technology areas one is struck by the fact that once a farming community has accessed technology, either through internal generation or external acquisition, the technology seems thereafter, primarily farmer driven, self generating, and needs little outside support. This is supported by experience in Lombok (Indonesia), Machakos (Kenya), and the Loess Plateau (China) where agencies focused primarily on conservation technologies, and once the technology, which in these cases was an agricultural sustaining technology, was established, the agencies were basically able to withdraw. A role for the external agency, together with the client farmer, should be to identify critical technologies suitable for sustainable agricultural development, demonstrate them to a level of reasonable acceptability, and then see them internalized by the community.

There are many ways of getting information to farmers. Public extension services are a common method, though not always successful. Other methods include: farmer training, farmer experimentation, market penetration, films, school programs, demonstrations (universally "seeing is believing"), written communications, master farmers, village technicians, NGOs, and farmer-to-farmer word of mouth. All have a place, and all under the right circumstances have documented successes; unfortunately the Bank has not paid enough attention to this menu of delivery, and has instead probably put undue attention on government extension services.

One of the transfer areas that has not been sufficiently used is direct knowledge transfer to farmers through written material. The Chinese (because of the widespread nature of their written language) have depended on farmer publications. One thousand years ago prominent Chinese agriculturists (landowners) manualized farming instructions so that the small tenant farmers might be more productive. China does the same thing successfully today. A survey in the United Kingdom showed that 70 percent of farmers, mostly the smaller farmers, were dependent on publications for their technical information.

It should be noted that in some countries the intransigent nature of the bureaucracies in transferring new technology to the user can be a real constraint. Technology change often impacts on individual agendas and vested interests. Nowhere is this more apparent than in some soil conservation departments in their reluctance to move away from past engineering practices toward more environmentally benign and low-cost vegetative systems.

Research

The four technical areas that are described in this paper could be better served by targeted and competitive research that would confirm farmer practices as being sound, and research other relevant technologies that could be offered to farmers and to the specific areas concerned. The World Bank should be instrumental in identifying some of these topics, and directing funds toward them. In some instances client countries would probably be better served if the Bank desisted in underwriting national research programs, but instead supported targeted research though a selective and competitive approach. Incentives and rewards are part of this process. There still remains a lot of repetitive and rather irrelevant research being undertaken because of lack of innovation in identifying useful topics,
lack of accountability for performance and failure by scientists to work closely with farmers and extension agents. Linking technically sound and practical information networks to research systems can trigger off new lines of research. If one accepts the farmer as the ultimate researcher it would seem that scientific information networks should consider including selected "master farmers" in their networks.

An area of research that has been badly neglected in relation to the four technological areas discussed in this paper is that effecting community lands -- grazing and forest lands in particular. Most of these lands are badly degraded and have no real identifiable owners. To put them back into production requires appropriate tenurial policies to be enacted and development of technologies that will be effective under what are normally ecological adverse conditions.

Conclusions

This paper has highlighted some important features in technology and sustainable agriculture. The combination of the technologies has in nearly every case led to a sustainable form of agriculture. Mary Tiffin's review of Machakos District concludes that the land use and agriculture is better now than sixty years ago. The area supports five times the number of people, incomes have improved, and the degradation process has been reversed (Gichuki 1992). In Lombok, CARE International is able to withdraw from a specific conservation area after only three years of support knowing that the conservation works have changed a degrading land-use situation into a sustainable farming framework based on long-term perennial tree crops (Gibney 1992, personal communication). In China, conservation works on the Loess Plateau have for hundreds of years created stable agricultural conditions, and with the help of new technologies (varieties, tools, and fertilizer) have enabled significant production increases to be achieved on a sustainable basis (World Food Program 1991). These are just three of many programs, mostly small, that are making progress in reaching sustainable agricultural objectives for the small and poor in many parts of the world. The Bank has an important role in learning from these successes and in assisting governments to develop appropriate policies and investment programs that can extend such technologies to much wider areas and to many more beneficiaries.

The capture of rainfall to improve soil moisture in upland areas, and the improved performance of irrigation systems for the lowlands are critical to sustainable agriculture. Improved crop water management enables the farmer to move to a higher level and value of production, a step that often leads to better overall resource management and conservation. Soil moisture is linked closely with soil fertility. Both relate to the effectiveness of adequately protected and quality germplasm. The trick to sustainability is to keep them in balance. Too much of one input can have a detrimental impact elsewhere. Basically the need is to practice good husbandry; good husbandry equates to sound resource management by the user. It has been achieved in the past and can no doubt be achieved in the future.

References


During the next twenty to thirty years, the agricultural sector of developing countries will be faced with the biggest challenge ever. In fact, several big challenges. First, it must provide food at affordable prices for almost 100 million more people every year, the largest annual population increase in history. Second, a large and increasing share of the production increases must originate from higher yields per unit of land. Third, the increasing production capacity must be sustainable, that is, the additional food must be produced at the same time as the future productive capacity is enhanced. Fourth, in most low-income developing countries, the agricultural sector must provide employment for a rapidly increasing labor force, either directly or indirectly through linkages with nonagricultural sectors, and thus serve as the lead sector for general economic growth and poverty alleviation. Add to these future challenges, the current challenge of reducing food insecurity among the 700 million people who do not now have access to enough food for a healthy and productive life. This paper will focus on one of the many facets of the above: the socioeconomic and policy aspects of the sustainability of future agricultural development.

Without entering into a discussion of the merits of the various definitions of sustainable development currently found in the literature, I propose that agricultural development should be considered sustainable if it assures that the productive capacity of the agricultural sector will be sufficient to meet current and future needs. This corresponds to the more general definition suggested by the Brundtland Commission: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). This definition implies that sustainability is compatible with the reduction of the stock of natural resources if and only if the productivity of the stock of human-made resources increases sufficiently to compensate for the loss of natural resources and, together with natural resources, to meet future needs. Because future needs cannot be predicted with great certainty, reductions in the stock of nonrenewable natural resources is a very serious matter, even when future generations are fully compensated for the loss in productive capacity through enhanced human-made capital. However, both current and future generations are best served by an agricultural development strategy that enhances sustainable productive capacity of the combined set of resources, that is, natural and human-made resources, even when that implies a reduction in the stock of natural resources. An overriding goal of conserving the stock of natural resources may result in stagnation while a focus on opportunities for substitution between natural and human-made resources and expanded productivity through research and technology is likely to result in a higher rate of sustainable growth in agricultural output.

In addition to the productive capacity, two other factors are important in considerations regarding the future stock of natural resources. First, scarce natural resources may have an intrinsic value over and above their productive value due to their mere existence. This "existence value" increases with increasing scarcity. Closely related is the desire to avoid reduced biodiversity not only for the existence value but also to assure future access to biological materials for further enhancement. Second, changes in the stock of natural resources may be associated with externalities not immediately reflected in agricultural growth, for example, the effects of deforestation on

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* Director General of the International Food Policy Research Institute, Washington, D.C.
climatical variables. I believe these two factors should be dealt with explicitly as premiums placed on the implicit or explicit discount rates.

Production Considerations

Sustainability aspects of agricultural development must be considered within the context of past and current production performance and the future demand for agricultural products.

Although food production increased at an impressive rate in developing countries during the 1980s, it failed to keep pace with population growth in two-thirds of the developing countries and in more than 80 percent of African countries. Most of these countries do not have the foreign exchange to import the production shortfalls. On average, per capita food production in developing countries increased by 9 percent during the first eight years of the 1980s, while it decreased by 6 percent in Africa. Although net food imports increased, the 1980s saw an expansion in the number of people, currently in excess of 700 million, who do not have access to enough food to meet energy and protein requirements for a healthy and productive life.

Keeping up with increasing needs due to population growth and increasing resource requirements in food production due to income increases and dietary changes is a formidable challenge to the agricultural production and marketing sectors. Opportunities for sustainable increases in food production through area expansions are gradually being replaced by the need to depend exclusively on yield increases as the source of production increases.

Future perspectives for per capita food production are grim for Africa because of the expected continuation of high rates of population growth and slow transition from area to yield dependence for production expansions. Between now and the year 2000, the African population will grow at more than 3 percent per year while food production will grow annually by only 2 percent. The International Food Policy Research Institute (IFPRI) projects that the difference between food production and demand in Sub-Saharan Africa will be 50 million tons by the year 2000. Today this gap is 12 to 14 million tons. It is extremely unlikely that the region will have the necessary foreign exchange to import such large amounts of food. It is equally unlikely that the governments will be able to count on food aid in these amounts.

If the current food production and population growth trends continue, the World Bank estimates that the food shortage for Africa will be 250 million tons by the year 2020. That is more than twenty times the current food gap. The World Bank also projects that if the annual increase in food production could be doubled to 4 percent and the annual population growth reduced by half -- or 1.5 percent -- then the region could be self-sufficient by the year 2020.

While opportunities for bringing new land under cultivation have compensated for slow crop yield increases in the past, continued attempts to expand agricultural land will entail increasing investments, accelerated deforestation, and land degradation. Thus, as has already happened in most of Asia, Africa must rely on increased yields to meet most of its future production expansions.

But even in Asia there is trouble ahead. Rice yields increased at an annual rate of about 3 percent between the mid-1970s and the early 1980s. Those increases have dropped to less than 2 percent in the 1980s. In Southeast Asia rice yields increased at an annual rate of 3.2 percent during the late 1970s. These increases are now down to half of that -- or 1.6 percent per year. In China annual yield increases dropped from above 4 percent in the late 1970s to about 1.6 percent during the 1980s. Growth in incomes and urbanization is expected to accelerate current diet diversification in many Asian countries toward more livestock products and related rapid increases in the demand for feedgrain. IFPRI projects that developing countries will need 90 million tons more grain in the year 2000 than they will produce. Some will be able to fill the gap through imports. Most will not.
The international community has become complacent about future food supplies. We have convinced ourselves that there is enough food to go around and that the problem is one of distribution. Real food prices in the world market have decreased, the European Common Market and North America have excess capacity, and some speculate that Eastern Europe and the former Soviet Union will, over the next ten years or so, greatly expand their food production.

Unfortunately, current and expected future excess production capacity in Europe, North America, and the Commonwealth of Independent States (CIS) will be of only limited support to low-income countries with little foreign exchange available for food import. While food self-sufficiency is not an appropriate goal for all countries, most low-income developing countries must rely on their own agricultural sectors for meeting most of their food demands for a long time to come. The agricultural sector may also serve as a major contributor of export commodities needed to generate foreign exchange to support overall economic growth. Furthermore, agricultural development is likely to be the most effective way to generate general economic growth in these countries. Except for those few low-income developing countries possessing large amounts of exportable minerals, a stagnant agricultural sector is a prescription for poor economic growth and accelerated rates of poverty, food insecurity, and malnutrition.

Although these relationships are widely accepted, external assistance to agricultural development and enhanced food production decreased significantly during the 1980s, both in absolute terms and relative to other assistance. Thus, support to agriculture decreased from 22 to 14 percent of all external assistance from Organisation for Economic Co-operation and Development (OECD) countries to developing countries during the 1980s. Similar trends are found in the allocation of public funds in many low-income developing countries. Sharp reductions in both external and national support of agricultural research during the 1980s has resulted in serious deteriorations in the capacity to generate improved agricultural technology, without which the needed productivity increases will not materialize. The trends of the 1980s must be reversed -- and soon.

**Pursuing a Triple Goal**

It should be clear from the above that sustainability in food production is not merely a matter of conserving our natural resources. It is rather a matter of finding a way to meet rapidly increasing food demands without compromising the ability of the total stock of resources (natural and human-made) to meet even larger demands by future generations. But, although usually referring to intergenerational distribution, sustainability is also related to spatial distribution, that is, distribution among population groups at a given point in time. The prevalence and severity of poverty is of particular importance in this regard, not only from the point of view of social justice but also because contemporary poverty will both weaken the justification for conservation of resources for future generations and make such conservation more difficult. The poverty link will be further discussed below. Suffice it to say at this point that sustainable agricultural development should pursue the triple goal of assuring sufficient increases in food production to meet future demand, strengthening the productive capacity of the total stock of resources for agricultural production, and alleviating poverty.

While any one of the three goals can be pursued at the expense of the others, the three can be complementary. For example, rural poverty and low productivity in food production contribute to land degradation and deforestation. Similarly, land degradation contributes to low productivity and poverty. On the other hand, high productivity brought about by inappropriate water management and excessive use of chemicals may result in degradation of natural resources. The role of policy is to pursue the three goals simultaneously, enhance the complementarities among them, and avoid unacceptable tradeoffs.
Socioeconomic and Policy Considerations

Five critical socioeconomic and policy considerations, that is, poverty, externalities, input use, market and policy failures, and population growth are considered in this next section.

Poverty

Poverty is probably the most important source of environmental degradation in low-income developing countries. Poor people have a high internal discount rate. They consume capital, that is, future productive capacity, when it is necessary to survive. It makes much sense for low-income rural people to cultivate fragile soils and to clear forest land for agricultural production, even though they are fully aware that such practices are not sustainable. When survival is at stake, conservation of natural resources for future generations takes on a lesser importance. This is particularly the case when the poor cannot assure that their children will in fact benefit from such conservation.

Regulations and land planning that contradict the poor's survival strategies are unlikely to be successful simply because they are difficult or impossible to enforce. This is one of many examples where incentives are preferable over regulations.

Externalities

One major reason why poverty results in environmental damage is the existence of externalities, that is, a situation where costs and benefits of a particular behavior or action are not borne by the same person or persons. Externalities resulting from inadequate property rights are of particular importance. We may distinguish among four types of property rights to land, water, and forests: open access, communal property, private property, and state property. Resources with open access are particularly prone to exploitation because exploiters may benefit without paying the costs associated with reduced future productive capacity. Regulations may reduce exploitations but enforcement is likely to be difficult and expensive.

The institutions and traditions surrounding common property rights are complex and poorly understood by those not directly involved. Efforts by governments and international institutions to privatize common property are often based more on ideology than on a thorough understanding of how best to achieve sustainability goals. Common property ownership is frequently confused with open access. While private land ownership may be expected to be most effective in achieving the food security, poverty, and sustainability goals in many cases, it should not be assumed that it is always superior to common ownership. Efforts to assure appropriate ownership patterns should begin by understanding what exists and improve on it. Such improvement may but need not necessarily imply a transfer to private ownership. Incentive policies, including taxes and subsidies, combined with common ownership should be considered as an alternative to private ownership.

Incentive policies are also likely to be needed to guide private resource owners such as small farmers toward sustainability goals. These policies should focus on compensating for poor farmers’ high discount rate, reducing or compensating for the risk and uncertainty with which they are faced, compensate for or correct poorly functioning land markets, and provide information to assist farmers in avoiding large errors in their expectations regarding future land and output prices.
State ownership may also result in environmental degradation and failure to achieve the three goals mentioned above. In comparison to the privatization of common property, privatization of state-owned agricultural production and removal of government monopolies in input and output markets is much more likely to enhance food security and sustainability while reducing poverty.

Population Growth

The importance of population growth in efforts to meet future food needs was mentioned above. Because the pivotal role of population pressures in current and future attempts to avoid environmental degradation and to alleviate poverty is well known, suffice to say that failure to reduce population growth rates drastically in Africa and South Asia and significantly in many developing countries in other regions over the next twenty years will render all other efforts to achieve universal household food security, poverty alleviation, and sustainability in agricultural production futile.

In addition to growth rates, a number of other demographic factors are closely related to sustainability. During the last fifteen years, Africa and parts of Asia and Latin America have experienced movements of people of magnitudes never previously seen. Such movements are frequently part of poor people’s survival strategy. Ecological disasters, including drought, along with wars and social strife, have been significant reasons for these movements. Large-scale migration both within and between countries may result from environmental degradation or it may cause such degradation. As populations become more mobile (in part a result of desperation and attempts to survive), the risk of environmental degradation increases because of rapidly increasing population concentrations in areas not yet degraded and associated externalities. Areas benefiting from improvements in rural infrastructure, natural resources, and agricultural productivity are particularly prone to large inflows of migrants from other less productive regions.

Productivity and Input Use

Farmers who do not have access to yield enhancing inputs are more apt to degrade land, water, and forests than farmers who do. Low-input agriculture clearly has a role to play, low-productivity agriculture much less so. Improved cultivation practices, use of organic wastes, enhanced biological nitrogen fixation, integrated pest management, and other means to reduce the need for chemical inputs should be pursued. However, the limitations of these practices should be recognized. Where current uses are low, chemical fertilizers must necessarily play an increasing role in efforts to expand productivity. This is the case in most of Africa, where average fertilizer use is around ten kilograms per hectare. Given the low levels of current use, the environmental risks associated with expanded fertilizer use in most of Africa and much of the rest of the developing countries are low. Efforts to expand fertilizer use are essential to achieve productivity and poverty goals. Furthermore, the environmental effects are likely to be positive, partly because soil fertility will be maintained and partly because farmers will be less likely to cultivate new fragile lands and clear forests for agricultural production.

In some regions of the developing countries, notably areas in Asia with highly intensified rice and wheat production, excessive fertilizer use poses serious environmental risks. While these risks should be effectively dealt with, it is important that they not be confused with the situation on the large majority of developing country farms, where the problem is insufficient rather that excessive fertilizer use.
Inappropriate water management in irrigated areas has resulted in waterlogging and salination. Such land degradation, which fortunately is reversible, contributed to the above mentioned reduction in the rate of increase in rice yields in Asia. Inappropriate water management has also resulted in lowering of the water table and groundwater pollution.

Excessive use of pesticides is another highly location-specific environmental risk. Biological control measures, integrated pest management, and research to incorporate tolerance or resistance into plants should be promoted. However, where such measures are unable to provide the necessary protection from pests, efforts to reduce the use of pesticide may result in unacceptable productivity and poverty effects.

Policy and Market Failures

Policy and market failures are an integral part of the problems already mentioned. Poorly functioning land markets and policies that effectively prohibit land markets from functioning are common. Excessive state intervention in input and output markets currently is being replaced with a stronger private sector. One of the major challenges in these privatization efforts is that of identifying the appropriate role of the state both during and after the transition. A variety of policies that promote environmental degradation are found in developing and developed countries. Some of these are justified on productivity and poverty grounds, for example, subsidies on chemical pesticides for small farmers, subsidies on chemical fertilizers in areas with excessive use, free access to water, payment to farmers for deforestation, subsidies for logging where such practice is not sustainable, taxes on alternatives to firewood, and so forth. The challenge to policymakers is to design and implement policies with positive effects on food security, poverty, and sustainability rather than policies benefiting one to the detriment of the others.

Designing and Implementing Appropriate Policies

The design and implementation of appropriate policies to simultaneously achieve the three goals must be based on a sound understanding of household and community behavior as it relates to food security, poverty, and the management of natural resources. Such understanding is essential because the effects of policies will be determined or heavily influenced by household and community behavior. Without it, policies may be ineffective or their effects may be contrary to expectations. Goals and preferences of households, time allocation, gender-specificity in decisionmaking and power structures, risk behavior, expectations, and implicit discount rates are all behavioral issues of importance for policy choice and implementation strategy. Policies that guide and modify the behavior of households and communities through incentives are much more likely to succeed than policies that conflict with behavior and attempt to achieve their objectives through regulations. That implies that policies should focus on incentives rather than regulations although there are some cases where regulation is likely to be most appropriate. The point is that because there are so many decisionmakers with influence over the environment and because even simple policies are difficult to enforce among people fighting for survival, governments are unlikely to be able to assure sound management of natural resources by fiat.

Another important point related to the design and implementation of policies to assure sustainability, poverty alleviation, and food security is that both agriculture and nonagricultural sectors should be considered. In some cases, the most appropriate solutions to protecting fragile
environments may lie outside agriculture, for example, out-migration or the strengthening of nonagricultural income sources in the regions.

Policies should consider both intergenerational and spatial distribution. Efforts to assure conservation of natural resources for future generations at the expense of the survival of part of the current generation are hard to justify on moral grounds and will be difficult to implement. The potential tradeoffs between alleviation of current poverty and the needs of future generations must be considered and attempts must be made to identify policies and strategies that achieve both goals.

As markets, particularly capital markets, become more effective, one would expect that the needs for corrective policies to assure sustainability in agricultural production will decrease. However, it is naive to believe that market signals will be sufficient to create the right institutions and to assure the right kinds of research and technology in a timely fashion. The public sector will continue to play an important role in guiding research and technological and institutional change.

To facilitate the needed increases in crop yields in developing countries, there is an urgent need for accelerated investment in agricultural research and technology aimed at yield enhancement, stabilization, and reduced dependence on chemical inputs. The dramatic impact of research and technology on the yields of most crops grown in temperate zones and on wheat and rice in Asia and Latin America is well known. Less dramatic, but significant, impact has been made in other crops for developing countries, notably maize, and results from current experiments on various crops are promising.

Accelerated investment in agricultural research and technology is also urgently needed to protect natural resources from degradation. As population, poverty, and food demands continue to grow, failure to develop and implement appropriate technology in production will lead to either more food insecurity and hunger, for which the current generation of poor people will pay, or to further degradation of natural resources, for which future generations will pay.

While development and use of appropriate technology is necessary to meet future food demands, it is not sufficient. Investment in rural infrastructure, institutional change, and appropriate government policy are needed to strengthen savings and credit institutions, to facilitate access by farmers to modern inputs, improve farm management, develop a marketing system capable of assuring access to sufficient food by the rapidly growing urban population, provide the necessary production incentives, promote economic growth in rural areas, and enhance the exchange of goods and services between urban and rural areas.

Public sector investment should also be accelerated to pursue short-term poverty alleviation, including labor-intensive public works programs; credit programs targeted on the rural poor; poverty relief programs; and long-term human resource development, including education, primary health care, nutrition, water and sanitation, and family planning.

Renewed emphasis must be placed on efforts to reduce population growth in the developing countries in general and in Africa in particular. Although the rate of population growth is falling in developing countries as a whole, the decrease is insufficient to counter absolute increases. Thus, over the next ten to twenty years, the world population will increase by almost 100 million people annually, the largest annual increase ever. The pressures on food production and distribution will be immense, particularly because the majority of the population growth will occur in urban areas of developing countries. Failure to significantly reduce the current high population growth rates in Africa within the next twenty years will render all other development efforts insufficient to avoid future famines, degradation of land and forest resources, poverty, and human misery of much greater magnitudes than experienced to date.

Incentives and -- where they are unlikely to achieve the objectives -- regulatory policies must be strengthened to endogenize or compensate for externalities related to natural resources. The nature of such policies will vary across countries and over time and may include appropriate water pricing.
and watershed management, elimination of exploitation of land and forests resulting from free access, and a variety of other policy measures. While usually preferable to regulatory measures, subsidies, taxes, and other incentives should be used selectively and advisedly because of possible unintended market distortions, opportunities for rent-seeking, and high fiscal costs. Market reforms, institutional change, and investment in infrastructure to assure effective and efficient markets and reforms of property rights to eliminate externalities in the management and use of natural resources will play a major role in successful efforts to assure long-term sustainability in food and agricultural production.

While this paper has attempted to identify a number of socioeconomic and policy issues to be considered in efforts to assure sustainability in future agricultural development, the design and implementation of a sustainable strategy in a particular country will require national capacity in short supply in most low-income developing countries. It is essential that both institutional and human capacity be strengthened through policy research, training, short- and long-term technical assistance and other relevant measures. Sustainable agricultural development will be successful only if based on sound analysis and location-specific understanding of the relevant factors.

References


AGRICULTURE AND ENVIRONMENT: RESPONSIBLE MANAGEMENT
Does Population Growth Inevitably Lead to Land Degradation?

John English*

Introduction

In this paper I intend to discuss this issue by drawing on the results of two studies that we have undertaken in Sub-Saharan Africa, one drawing on data from Ethiopia, and the second in Kenya. These were very different types of studies, undertaken under quite different circumstances, but which have bearing on the issue. I will argue that the answer to the question is "no," and that the real concern should be on those steps that can be taken to ensure that land degradation does not follow population growth. The paper briefly reviews the results of these two studies and discusses the general view on the links between population growth and environmental degradation, and the importance of human capital in avoiding degradation under conditions of population growth. It then discusses possible preconditions for successful adaptation to increased population, relates the two case studies to the model outlined, and finally discusses the implications of the findings for development policy.

The Ethiopia Study

This study was undertaken because of concerns over possible population-degradation links in Ethiopia and to take advantage of the considerable data on land degradation and related indicators developed by the Food and Agriculture Organization of the United Nations (FAO) in the mid-1980s in their Ethiopian Highlands Reclamation Study. As a part of the FAO work, a Soil Erosion Severity Index (SESI) was developed. For our study it was possible to prepare estimates of the SESI for each of the forty-seven "highland awrajas" (districts) where most of the population live. A data set covering a range of physical and socioeconomic variables was prepared for these districts (see appendix 1). The objective of the study was to see if the variations of the SESI could be explained by variations in the other variables. Starting from the hypothesis that erosion would be positively related to population pressure, a simple correlation of the variables indicated a relationship in this direction.

More detailed analysis was handicapped by the fact that SESI was a polychotomous ordinal variable. This is a constraint on the direct application of least squares methods, because the basic methodological assumptions, on which such methods are based, would be violated. An ordinal logit analysis was therefore chosen. In the model with the most satisfactory results, the variables that were significant (see appendix 1) were (in declining order of significance): animal pressure; population pressure; farming system; and the proportion of forest in total land use.

In this model, population and animal pressure variables were expressed as negative reciprocals. This means that there is a hyperbolic relationship and that the probability of a given area being in a higher SESI class increases at an accelerating rate with increased population pressure. The farming system variable is a dummy distinguishing between those districts with populations

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predominantly in the Ethio-semitic or Cushitic language groups. The former are concentrated in the northern highlands and practice an agriculture based on animal traction and a predominance of seed-based annual crops. The latter, concentrated in the south, is based on a hoe culture dependent more on perennial and root crops. In the model used, the annual cropping system is linked to greater erosion severity, but this may also capture some differences in settlement history and population density.

In this study, the estimate of the population pressure variable was based on a notional carrying capacity reflecting the existing low productivity agricultural systems being used, and essentially assuming static technology. This may be a reasonable assumption in this case. At the time the data was generated (the mid-1980s) the country had been under the Mengistu regime for about a decade. In this period there was little effort to foster technological change and growth of commercial production. There was also great uncertainty regarding land rights. In fact, general conditions in the countryside fostered subsistence production and discouraged innovation and investment. Under such conditions, increased population pressure does appear to be accompanied by land degradation.

The Machakos Study

In contrast the Machakos study was 'longitudinal' rather than cross-sectional and studied land management over an extended period. In the late 1930s Machakos District, a semiarid area of East Central Kenya, inhabited by the Akamba people, was considered by the colonial administration to be degrading alarmingly and to be rapidly approaching, if not exceeding, its capacity to support its inhabitants and their livestock. Today the area has a population five times as great and the value of agricultural output per head (at constant prices) is estimated to be three times larger than it was then. At the same time food production in the area is less susceptible to drought than before, although it is still subject to it. The objective of the study was to review the experience of this district in relation to management of its land resources over the past fifty years and to attempt to identify the factors responsible for these changes.

While population has grown, there also has been some redistribution in the district. Movement has occurred into the lower, more arid area, previously tsetse infested and virtually unpopulated, which now houses about one-third of the population. The area under cultivation has expanded by four or five times and there has been a corresponding reduction in the area of bush, scrub, and general grazing area. Much of the area used is now under continuous cultivation, and almost 100 percent of the area cultivated is now subject to some form of terracing. In the 1930s the main focus of the population was on livestock herding with subsistence cropping to meet basic needs. This has now changed to a primarily crop-oriented production of which a significant proportion is sold.

One of the objectives of the study was to assess the current status of the land resource base. This indicated that the rate of erosion has been sharply reduced, although it does still occur. While soil analyses do show that the chemical content of the soils is lower than in the soils under natural vegetation, their productive capacity has clearly been raised substantially, and there is no evidence to suggest that their quality is declining under current use practices. In fact, the farmers of Machakos have made a very large investment in their land resources. More than 200,000 hectares has been terraced in some way, most without external support. The rangeland areas appear to have a higher proportion of woody species than earlier. This could indicate poor grazing practices and reduced capacity. However, it is not clear that this is the cause, as prohibitions on bush fires, reductions in game populations (especially of elephants), and actions by users to encourage tree growth have all
played a part. There are certainly more trees than before and they are being actively managed by farmers. Projections made in the 1950s, the 1960s, and again in the 1970s all foresaw severe fuel wood shortages, but there is no evidence that such have occurred. Therefore, the conclusions of the study are that the agricultural growth, which has occurred, has not been accompanied by resource degradation.

The increased per capita value of agricultural production has almost entirely been in the form of cash crops. Initial emphasis was on coffee in particular, and cotton, with a subsequent shift over the past decade into fruit and horticultural crops as the relative price of coffee collapsed. Staple food production appears to have stabilized at about the level required for basic subsistence, about 200 kilograms of maize equivalent per head per year. Trade in these items does take place between those with surpluses and deficits. Substantial changes have occurred in agricultural practices. The study enumerated about forty-five new technologies that have been adopted, half of which are new products. In addition to terracing and the main cash crops, some of the most important of these have been use of ox-drawn plows requiring only two animals for traction (and their modification for weeding), early maturing maize varieties, use of crop residues for forage and use of animal manure (that is, development of mixed farming systems), and monocropping the main annual crops in rows to facilitate weeding. These types of developments are closely in line with the hypotheses of Boserup, Ruthenberg, and others on the changes and intensification induced by population growth.

Since the 1950s, there has been an almost continuous process of agricultural innovation and change in the district. Some of this has resulted directly from governmental efforts, for example, breeding early maturing varieties. Others, such as use of ox plows and many of the introductions of new crops, have had virtually no official support. These agricultural changes also have not taken place in a social vacuum. Major changes have occurred in the social structure of the society. The importance of the nuclear family has increased, relative to the extended one. The absence of men in the 1940s and 1950s required women to take a more active leadership role and this has continued, and also influenced family roles, including traditional agricultural tasks. Traditional self-help groups have been modified (partly under the influence of the early terracing programs) to have more development-oriented goals and women became more active in leading them. The Akamba have always placed emphasis on education and development of local, vocationally oriented schools has been marked. This has helped widen the range of available skills and assisted in the broadening of the range of small-scale commercial and artisanal activity and in technological innovation, and undoubtedly had a significant impact on the capacity of the society to change.

The Common View of the Link Between Population Growth and Degradation

We have here then two very contrasting examples. In one, under conditions that did not foster social and economic change, the analysis suggests that greater population pressure is accompanied by a greater likelihood of land degradation. In the other, great technical and social changes have occurred and the area studied has accommodated a markedly increased population while reducing the perceived level of land degradation.

The view that population growth is an important factor in land degradation is held widely. Its impact is frequently seen as being linked to that of poverty. This type of view has been well summarized in a recent report (Shammugaratnam and others 1992), which includes figure 1 as an illustration. "At the macro level, the cumulative effects of historical factors and policy and market failures lead to a situation characterized by four sets of factors: unequal access to resources, conditions favoring demands for large families, undeveloped human capital, and technological
stagnation. These factors interact among themselves. At the micro level, individuals act within the institutional and resource constraints set by these factors. That is, their actions are conditioned by structures of incentives and disincentives generated by the larger environment. An important determinant of the status of individuals or households and their behavior is their entitlements and capabilities" (Shammugaratnam, p. 2-3).

Population growth does not have to lead to natural resource degradation. What it does automatically do is increase the ratio of population to land in the aggregate. Because in the initial stages of population growth, not all of the available land is occupied, the group can continue to exist as they have by expanding their area of occupation. Sooner or later, however, they will come up to some limit of land, and the ratio of population to effectively available land will start to rise. In all likelihood this change will begin, in some way, to degrade the resource base being used by the group. In the simplest case a hunting society begins to hunt out the species on which they have relied for food. In order to survive they have to make changes in their diet to utilize other, previously ignored or less preferred, species. In other words they have to innovate, and possibly reorganize themselves in some way in order to successfully hunt or gather other foods or useful products. No doubt if one looked, one could find a nexus of problems these primitive societies had to overcome. Some did overcome them. Some, no doubt, did not.

Thus, it seems to me that, in a general sense, one can look at human history as being a process of population growth leading to innovation designed to avoid degradation of the resource base. In most cases societies have managed to adjust to their circumstances and one should perhaps consider that successful adaptation is to be expected. However, the implication of the views typified by figure 1 is that success is not expected, or at least is virtually impossible to achieve. The problem with this perspective is that it tends to lead to the conclusion that only a massive, externally initiated, effort will be able to overcome these problems and enable a more benign process to get underway.

The General Issue

What enables groups or societies to reach conditions consistent with support of higher rates of population growth? Perhaps we should consider the key questions to be, "what results of population growth increase the likelihood of innovation and successful adaptation to the changing circumstances/environment (that is, to development), and therefore, avoid a descent into environmental degradation and destitution?" And, conversely "what circumstances (including government actions) are likely to reduce the likelihood of successful adaptation?"

An attempt has been made in figure 2 to indicate a set of interacting changes, which flow from population growth within a limited area, that is, the growth leads to an increase in the density of population. Some of these effects have been discussed by Esther Boserup (1965) and others, with specific reference to agricultural change, others in the more general context of overall economic and social change, by authors such as Julian Simon (1977, 1992).

Most obviously and directly the increase in population results in an increase in the number of bodies to be fed, (that is, an increase in the demand for the products of agriculture) and an increase in the number of workers (that is, in the supply of labor to agriculture). The initial increase in demand will be for the traditional basket of goods used for subsistence in the region. However, for the reasons noted above, the region will come up against constraints in production of some elements of this package and the consumption pattern will have to change unless substitute sources of supply can be found.
Indirectly an increase in the density of population means that the number of people who can be served from an individual location (other things being equal) increases and conversely, the cost of providing a service to a given number of people falls. At the same time the number of other individuals, with whom one person is likely to interact, will rise, which will tend to increase the exchange of ideas and flow information and increase the likelihood of new ideas being generated. This in turn will assist in solving the supply problems generated by population growth.

This increased population also is likely to increase the appeal of the area for external parties and thereby improve the access of the area to the wider world and, thus to external markets. The latter effect will increase the demand for some of the goods the region is able to produce. The result will be that the region has a wider range of potential combinations of products, each of which will make different demands on the labor supply and the resource base. This will allow farmers to change their farming system with little or no economic cost. In these circumstances there is no reason to suppose that a group will not take long-run resource conservation into account when choosing what product combinations to adopt. Under normal circumstances, depletion of the resource, if it is occurring, will be gradual and allow for some experimentation in methods to avoid it.

Many of the relationships in figure 2 are mutually reinforcing. Once external sales begin, this will allow for some purchase of previously home-produced items and other new items. This begins to develop new aspirations, which begin to increase the emphasis on further improvement in the future, and in consequence, the development of longer-term perspectives by the population. This may be reflected in less emphasis on maintaining the traditions of the past and more on the means of supporting the group in the future; less emphasis on fate and more on conscious planning for the future. Thus, investment will be undertaken both to offset problems resulting from past changes and to improve future capacities.

However, it quickly becomes apparent that the continuation of this process is not a result of population per se but of the reaction of the society to the changes required to accommodate the growth in population. This is a function of the human capital (in the broadest sense of the term) of the population, that is, their technical and organizational skills.

These issues are clearly complex and a simple model may help to give us a useful starting point. Supporting an increased population means (if living standards are not to decline) that production must be increased. This requires investment in order to increase productive capacity. Stein Hansen (1992) has noted in a recent paper that Haavelmo, in a 1961 paper, outlined a simple aggregate model with only labor and capital as the two inputs to explain the ability to support population growth.

The model assumes that each unit of labor needs a fixed amount of capital to produce, so that output is proportional to capital. The more capital is needed, the more savings are needed. Per capita output increases only if savings, and thus capital accumulation, are great enough to boost output faster than the growth in population. The table above shows the maximum population growth rate that can be sustained at constant per capita incomes, under varying assumptions about capital requirements and current savings rates. The left-hand column shows different incremental capital-output ratios (ICORs), which measure the amounts of additional capital needed to produce an extra unit of output. Then the body of the table shows the maximum population growth that can occur, if output per capita is not to decline, for a range of ICORs and savings rates.

Thus, the higher the savings rate and the lower the ICOR, the faster the rate of population growth that can be accommodated. The incremental capital output ratio is a function of the innate productivity of the natural resources being used (that is, the natural capital) and the extent of the human capital, which can be drawn on. The circumstance illustrated in figure 1 is likely to result in a low savings rate and a high ICOR. That is, a poor population with a high dependency rate, probably poor nutrition and health, is attempting to scratch a living from poor soil using manual
Figure 1. The Interacting Nexus Factors

- Historical Factors + Policy & Market Failures
- Unequal access to resources & services
- Conditions Favouring Large Families
- Undeveloped Human Capital
- Technological Stagnation
  - Institutional Failures
  - Unhygienic waste disposal
  - Water Pollution

- Poverty
  - Rapid Population Growth
    - Land Scarcity
    - Erosive Cash Cropping Systems
      - Lack of inputs
        - Low Productivity
          - Land Fragmentation
            - Short Fallow
              - Fuelwood Demand
                - Extensive Cultivation -> Marginal Lands, Pastures, Watersheds, Reserves
                  - Deforestation
                    - Loss of biodiversity
Figure 2. Interacting Changes Flowing from Population Growth

Note: (a), (b), etc. refer to points made in the paper.
Table 1. Maximum Population Growth That Can Be Achieved Compatible with Constant per Capita Income Under Constant Returns to Scale

<table>
<thead>
<tr>
<th>Incremental Capital-Output ratio</th>
<th>Net domestic savings rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net domestic savings rate</td>
<td>0.05</td>
</tr>
<tr>
<td>2.0</td>
<td>0.0250</td>
</tr>
<tr>
<td>3.0</td>
<td>0.0167</td>
</tr>
<tr>
<td>4.0</td>
<td>0.0125</td>
</tr>
<tr>
<td>5.0</td>
<td>0.0100</td>
</tr>
<tr>
<td>10.0</td>
<td>0.0050</td>
</tr>
</tbody>
</table>


There are then two sets of issues that need to be addressed: what types of conditions are likely to foster the types of positive and mutually reinforcing change outlined in figure 2; and what are the public policies and programs that can impact positively on the relationships outlined?

Preconditions

A first attempt to define some areas in which such change is likely is outlined in table 2. These can be subdivided into three broad categories, physical, economic, and social.

Physical Factors

Perhaps most basically, physical conditions vary and some create barriers to successful adaptation. Under very arid tropical conditions the ability to adapt is restricted in two ways. First, conditions are highly variable from year to year, and droughts (that is, seasons when rainfall is insufficient to sustain a plant fully through its normal life cycle) are common. Thus, what works one year may not the next. Second, the range of plants or animals adapted to the conditions is relatively small. Thus, because risks are high a spread of alternatives has to be produced in order to offset it, and specialization, an implication of the processes outlined in figure 2, is usually too risky to be effective.

On the other hand, under very humid conditions in the tropical rainforests, ecological systems are very complex. While the range of species that can be used is high, their degree of
Table 2. Conditions Conducive to a Positive Impact of Population Growth on Agriculture and Land Resource Management

<table>
<thead>
<tr>
<th>Physical</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>High basic carrying capacity</td>
<td></td>
</tr>
<tr>
<td>(a) Reasonably reliable rainfall in the intermediate range</td>
<td></td>
</tr>
<tr>
<td>(b) Moderate or better soils</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economic</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td></td>
</tr>
<tr>
<td>(a) Significant internal market (urban) or access to external markets</td>
<td></td>
</tr>
<tr>
<td>(b) Opportunities for nonfarm income sources</td>
<td></td>
</tr>
<tr>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>(a) Active private trading network in the region</td>
<td></td>
</tr>
<tr>
<td>(b) Reasonable physical infrastructure in the region (significant share of farmers can get products to market at appropriate seasons)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reasonable social and political stability</td>
<td></td>
</tr>
<tr>
<td>Forward looking society</td>
<td></td>
</tr>
<tr>
<td>Entrepreneurial-development oriented leadership</td>
<td></td>
</tr>
</tbody>
</table>

National Factors

interdependence is also high and attempts to increase use of preferred species may soon come up against these limits. Thus, while complexity and variety of the system may be high, flexibility is low. Some indigenous crops of rather low productivity have been cultivated in these areas for several thousand years, but, in general, the climate had been unhealthy for both introduced cereal crops and for livestock and, therefore, for dense sedentary human populations.

This leaves the intermediate areas as the most conducive to adaptation, that is, the subhumid to humid regions and the montane regions at higher elevations. These are characterized by savannah/forest fringe, or woodland/pasture, vegetation types. Here rainfall is more reliable and a moderate range of species are adapted to the conditions.
Economic Factors

These should, perhaps, be further subdivided into national and local factors, which are quite different from a policy point of view.

National Factors

The basic economic factors linked to the ease of innovation are related to the ability to trade and thus to widen the potentials for both production and consumption. At the national level this means that there should be a significant internal market (that is, an urban area) or access to external markets. Thus, the process is difficult in a situation like the highlands of central Africa (Burundi, Rwanda, and Kivu), where soils and climate are good but lack of market access severely restricts the economically viable options open to farmers. At the same time there should also be a demand for labor for nonfarm purposes. This allows for increased flexibility in production and is likely to encourage new skills that may be applicable to agricultural use.

Local Factors

Even if markets are accessible from a region in the physical sense, there is still need for an active trading network within a region for that potential demand to be made real at the farm gate, and the traders of the region need to have effective access to the market. To back up this commercial infrastructure there also needs to be adequate physical infrastructure, in particular the ability to actually ship goods to or from the region at reasonable cost. This does not have to be in the form of all season motorable access to every ten-acre plot, but lack of access for long periods clearly reduces the effectiveness of potential demand. Thus, a significant share of producers should be able to ship products out or obtain inputs at appropriate seasons.

Social Factors

Physical and economic conditions as outlined above are not likely to lead to successful innovation and development of sustainable farming systems in the absence of a society that has the ability to identify and solve the problems that confront it.

First, there needs to be reasonable social and political stability. Individuals should not feel that anything they do may be countermanded or destroyed at any moment or their lives put at risk.

Second, there needs to be an entrepreneurial or development oriented leadership for the society, that is, not one that is primarily concerned with maintaining its own power or with expanding its area of control by conquest. The latter is likely to result in the commandeering of labor or resources for the military effort and in placing emphasis on maintenance of discipline and the established order, and not on fostering change. Similarly, theocracies or other societal structures mainly concerned with maintaining an existing order or mode of life will not provide much scope for innovation. Furthermore, a societies' leadership should be forward looking so that problems are identified quickly, before they have become crises, and responses developed before disruption is caused.
The Two Cases in the Context of the General Model

How do the findings of the two case studies relate to the model suggested in figure 2 and table 2? The physical preconditions in Machakos were not encouraging. Even in the more settled areas rainfall per crop season is relatively low (about 500 millimeters) and highly variable. Drought seasons, or sequences of them, are common. In the nineteenth and early twentieth century, severe droughts, which resulted in heavy loss of livestock and people, were not infrequent. If the rainfall had been in the 1,100 millimeters to 1,600 millimeters range, as in the higher potential districts of Kenya, the task of overcoming the incipient disaster faced in the 1930s would certainly have been mitigated. In this case the economic conditions undoubtedly helped to offset the difficulties of the physical environment. While transport within the district was not all that it might have been, external links and access have been good. Proximity to Nairobi gave access to a significant market as did the accessibility to external markets assisted by the internal road and rail and external sea and air transport links developed over the course of this century, and by the open trading regime fostered by successive administrations in Kenya.

Looking at the social situation, it is intriguing that the 1930s, 1940s, and 1950s in Machakos were far from stable, although few may have feared for their lives or property. During World War II significant numbers of younger men were absent in military service and this imbalance continued after the war as external employment was sought both for income and to avoid either forced labor for land conservation or getting involved in the insurrection of the time. This caused great disruption, but did have some positive effects. Those who went abroad were exposed to new ideas and a number of new technologies resulted from that experience. In addition the situation meant that women had to take a more active role in the society and as a result the nature of some of the traditional self-help groups changed reflecting this. Women's groups were particularly active in soil conservation work.

Overall, however, there has been a fair degree of continuity in overall government economic and social policy with a general orientation toward private business, commercialization of agriculture, and individual rights over land. In this context it has proven possible for overall leadership in society to evolve and broaden in a direction conducive to development.

Turning to the Ethiopian case, it should be noted that the analysis was based on the assumption of a low, and generally constant level of technology across the country, which was used as the basis of the estimation of carrying capacity. In other words, it showed that, in conditions where carrying capacity is fixed, when population exceeds this carrying capacity, erosion is increasingly likely. As noted earlier, at the time the data were generated the general conditions in the countryside fostered subsistence production and discouraged investment and innovation. In that sense the conditions may have approximated a constant technology across regions much more closely than would be the case in most countries.

The Machakos study indicated the ability of a society, under appropriate conditions, to respond to population pressure and adopt new technologies, increase the carrying capacity, and modify the farming system in ways which do reduce degradation. Some authors (for example, Boserup 1965; Simon 1977, 1992) have gone so far as to suggest that population growth itself, in creating the pressure for intensification, is a factor impelling agricultural change and increased productivity. If such a process had worked perfectly, one would not expect to have found a significant relationship between population pressure and land degradation, even in a cross-sectional analysis such as that carried out in Ethiopia. As noted above, the overall policy environment in Ethiopia was hardly conducive to agricultural innovation in the period prior to the analysis. In addition, a sociological survey carried out among Ethiopian farmers indicated that farmers were aware of the degradation problem, but not the underlying causes (Constable 1984). Awareness of the causes
of degradation is indispensable for the development of effective technologies and, under such conditions, there is a clear gap for extension efforts to fill.

Conclusions and Implications for Public Policy

The results of the Ethiopia study suggest that under the set of conditions, which have recently been experienced there, there is a probability of erosion with increasing population pressure. However, the Machakos study showed that under appropriate conditions populations can adapt to increasing population pressure and avoid land degradation. The two studies suggest strongly that, in a low income region where population pressure is raising concerns about land degradation, this problem is unlikely to be resolved by a narrow focus on improved land management technologies. More general economic and social changes will be necessary to create conditions under which there are clear benefits to land users in changing technologies. This paper has in part discussed the types of physical, economic and social/political conditions that appear to be conducive to a positive outcome.

In our report on land resource management in Machakos (English, Mortimore, and Tiffen 1993), based on the results of the study, we recommended a number of policies to foster improved land resource management. These may be summarized:

- Primary emphasis should be given to measures which will assist in raising the value of farm products at the farm gate (for example, improved road access, and elimination of marketing bottlenecks or unnecessary controls and costs), and in widening the range of economically and technically viable land use options for farmers (for example, through experimentation on potential new crops and livestock, including focus on their impact on land resource management).
- These agricultural research and extension efforts might be better placed on a range of possible technologies rather than a very limited number of 'best' technologies in order to increase the range of choice available to farmers.
- Research by other than official government stations should be encouraged.
- Emphasis should be placed on other measures that will facilitate the development of other economic activities, for example, the extension of transport, electricity, and telecommunications networks.
- Where, because of remoteness or physical limitations to production, few if any viable land uses can be developed, emphasis should be placed on facilitating outmigration on a seasonal or permanent basis, or on other measures to improve economic and social links with the rest of the economy.

To what extent can policy further encourage such a situation? If we return to figure 2, many of the changes posited in that model are clearly impacted upon by policies or actions of the type outlined in the previous paragraph. For example (the letters of the following paragraphs refer to the notations in figure 2):

(a)--The development of greater accessibility to goods and labor markets will be dependent on government action on: transportation infrastructure; and fostering the trading system (avoidance of impediments such as restrictive licensing, security road blocks, and so forth, and development of standards and improvement and dissemination of market information).
(b)--The translation of the reduced per capita costs of infrastructure provision into more accessible knowledge and wider skills is a function of educational and training policy.
(c)--The translation of access to increased demand outside the region and internationally will be encouraged by the avoidance of impediments to interregional or international trade.
(d)—Support to agricultural research and extension will assist in the generation of new technology, especially once increased accessibility to ideas and skills has helped in the acceptance of the notion of the potential benefits of change.

(e)—The real increase in labor supply resulting from increase in population will be dependent on the health and nutritional status of the population. Public efforts could be significant here at a minimum in reducing outbreaks of epidemics or mitigating impact of droughts or other disasters.

(f)—Increased sales of local products will translate into increased diversification of the local economy if this is not impeded by excessive registration, licensing, or other barriers to start-up.

(g)—Investment in land is impeded by lack of security of occupancy. This will require appropriate tenure policy.

These examples undoubtedly do not exhaust the list of possible government actions which might encourage or impede the process of change outlined in figure 2, but illustrate the pervasiveness of the potential impact of government. A number of interesting points may be noted: (a) comparing these impact areas with the preconditions outlined in table 2, it is noticeable that the impacts relate primarily to what have been defined here as the economic preconditions, to a lesser extent to the social ones, and very little to the physical conditions (or their amelioration); and (b) that the points of impact are clustered in the early stages of the chain, that is, education, basic health, transport, and the stimulation of trade, are essential to get the process moving and are highly susceptible to governmental action or inaction.

An approach of this type has a number of positive aspects from the point of view expressed in this paper. First, it is aimed at producing a framework that will facilitate change and not protect a status quo. Second, it is geared toward creating developmentally oriented interactions between individuals and groups, in which the relationships between parties are balanced and freely arrived at, but facilitate a move in a commercial direction. Third, they encourage the development of an open structure which is the effective basis of development and of the ability to adapt to change.

References


Conservation Tillage as a Tool to Conserve Soil, Moisture, Energy, and Equipment in Large and Small Crop Production Systems

John F. Hebblethwaite*

Introduction

Driven by the 1985 Farm Bill, a part of the 1985 Food Security Act, farmers in the United States are progressing on schedule toward implementation of a soil conservation plan when planting crops on highly erodible acres. Complete implementation of this plan is required by 1995 if farmers are to participate in U.S. Department of Agriculture benefit programs. The plan requires that farmers use reduced tillage systems or no-till to maintain adequate plant and crop residue on the soil surface at all times so that annual soil loss will be reduced to a level where soil productivity is maintained. During the course of implementation farmers are discovering that conservation tillage and no-till planting, in addition to soil and moisture conservation, also have significant economic benefits. These benefits include significant reductions in labor, equipment, and fuel costs, together with more timely planting of crops.

On average, yields in both conservation and no-till systems can be similar to those under traditional cultivation systems using the plow. Conservation tillage is a growing trend worldwide. No-till is already being applied on large acreages of soybeans in Brazil and Argentina and reduced tillage in small grains in Canada and Australia. Improvements in seed drills and planters and the availability of more effective herbicides for weed management have made this possible.

Conservation tillage and no-till can be effectively applied in both large and small production systems. The smaller investments needed in tractors and equipment for conservation tillage could help greatly in revitalizing crop production in the Commonwealth of Independent States (CIS). In both the CIS and emerging countries of Africa, conservation tillage could play a major role in reducing rampant erosion of soil.

Sustainability of Agriculture

The major threat to sustainability of worldwide agricultural production is soil erosion and resultant infertility. It is estimated that soil erosion and infertility are degrading 30 percent of rainfed cropland in Central America, 17 percent in Africa, 20 percent in Southwest Asia, and 36 percent in Southeast Asia. In the former Soviet Union it is estimated that two-thirds (about 152 million hectares) of total arable land is affected by erosion and that over 50 percent of the soil profile has been eroded on 64 million hectares of this land. Crop yields in affected areas are estimated to remain, on the average, 20 percent below their yield potential due to erosion. It is estimated that the United States still loses roughly 3 billion tons of topsoil from cropland every year.

Conservation Compliance and Soil Productivity

In 1985 the U.S. government introduced legislation that mandates the biggest attack on soil erosion caused by water and wind in the history of the United States. The 1985 Farm Bill, as part of the Food Security Act, mandates that farmers develop and implement a soil conservation plan when planting crops on highly erodible acres if they are to continue receiving U.S. Department of Agriculture program benefits such as price and income supports, crop insurance, Farmers Home Administration loans, and so on. About 148 million acres out of 280 million acres of cropland are considered highly erodible (table 1). Farmers by 1990 had to develop a soil conservation plan for these acres for complete implementation by 1995. To comply, the maximum average annual soil loss in tons per acre must be reduced to a level where soil productivity is maintained. Driven initially by conservation compliance regulation, we have seen a fast growing trend to conservation tillage in the United States.

Conservation tillage is any tillage or planting system that leaves at least 30 percent of ground covered with crop residue after planting. In the United States this is achieved through mulch-till (leaving at least 30 percent residue), ridge-till, or no-till (direct drilling). In ridge-till one-third of the soil surface is tilled to prepare planting ridges four to six inches higher than the row middles. In no-till the soil is left undisturbed prior to planting and the seed is planted directly into the crop residue.

In 1992 it is estimated that about 60 percent of the highly erodible crop acres (88 million) are under compliance in the United States. The remaining 59 million acres is expected to be in compliance by 1995. Among the compliance methods mentioned, no-till has shown the most dramatic growth (table 2). Among the major crops, corn and soybeans have shown the most dramatic growth in no-till with steady growth on small grain acres (table 3). It is estimated (by Monsanto - with inputs from the Conservation Tillage Information Center (CTIC), Soil Conservation Service (SCS), dealers and farmers) that no-till soybean and corn acres could grow to 46 million by 1996 with soybeans contributing 25.5 million acres, and corn 20.8 million acres.

What is driving this trend? There is no doubt that conservation compliance is the catalyst. However, in implementation farmers are discovering substantial economic benefits such as savings in equipment cost, time, and fuel usage. These savings, together with yield equivalence (to tillage) or even yield increase, have resulted in increased profit.

Purdue University compared the cost of various tillage systems with the following results shown in table 4. In a separate study, the CTIC demonstrated the usage of fuel and labor with various tillage practices (table 5). It is clear from this study that no-till results in substantial savings in both fuel and labor input. Replacement of the plow with shallower tillage implements such as the chisel, which leaves as much as 50 to 75 percent of the crop residue on the soil surface (conservation tillage), will also result in considerable savings in fuel and labor.

Practical farmer experience has shown substantial reductions in equipment and horsepower requirements in no-till planting and drilling systems. For example, requirements for a 1,000 acre no-till farm in the Midwest are as follows: an 80 Horsepower tractor, a 120 horsepower tractor, a spot sprayer, a forty-foot sprayer, a nitrogen tool bar with coulters, a light disc, a no-till drill, an eight-row planter with coulter and starter, and a combine.

Gone is the major tillage equipment such as the plow and also the 280-350 horsepower tractors needed to pull this equipment. They have been replaced by smaller tractors, no-till planters, and light equipment that can cover the same number of acres faster.

In addition to savings in input cost, it has been shown that equivalent yields, or even increased yields, can be obtained from conservation tillage systems. In a study conducted over several years by Purdue University, continuous corn and corn in a soybean/corn rotation in Indiana
Table 1. Crop Acreage in the United States (millions of acres)

<table>
<thead>
<tr>
<th>Year</th>
<th>Planted Acres</th>
<th>Highly Erodible Acres</th>
<th>Conservation Tillage Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>280</td>
<td>141</td>
<td>72</td>
</tr>
<tr>
<td>1990</td>
<td>264</td>
<td>148</td>
<td>74</td>
</tr>
<tr>
<td>1991</td>
<td>281</td>
<td>148</td>
<td>79</td>
</tr>
<tr>
<td>1992</td>
<td>282</td>
<td>148</td>
<td>88</td>
</tr>
</tbody>
</table>

Source: CTIC - Cedar Package

Table 2. Conservation Tillage in All Crops in the United States (millions of acres)

<table>
<thead>
<tr>
<th>Year</th>
<th>No-till</th>
<th>Ridge-till</th>
<th>Mulch-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>14.2</td>
<td>2.7</td>
<td>54.9</td>
</tr>
<tr>
<td>1990</td>
<td>18.1</td>
<td>3.0</td>
<td>52.4</td>
</tr>
<tr>
<td>1991</td>
<td>20.6</td>
<td>3.2</td>
<td>55.3</td>
</tr>
<tr>
<td>1992</td>
<td>28.1</td>
<td>3.4</td>
<td>57.0</td>
</tr>
</tbody>
</table>

Source: CTIC - Cedar Package

Table 3. No-Till of Major Crops in the United States (millions of acres)

<table>
<thead>
<tr>
<th>Year</th>
<th>Corn</th>
<th>Soybeans</th>
<th>Small Grains</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>5.36</td>
<td>4.82</td>
<td>2.43</td>
</tr>
<tr>
<td>1990</td>
<td>6.41</td>
<td>5.99</td>
<td>2.82</td>
</tr>
<tr>
<td>1991</td>
<td>7.56</td>
<td>7.92</td>
<td>3.25</td>
</tr>
<tr>
<td>1992</td>
<td>10.85</td>
<td>11.31</td>
<td>3.64</td>
</tr>
</tbody>
</table>

Source: CTIC - Cedar Package

Table 4. Cost per Acre for Various Tillage Systems

<table>
<thead>
<tr>
<th>System</th>
<th>$/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-till</td>
<td>75.50</td>
</tr>
<tr>
<td>Mulch-till</td>
<td>87.00</td>
</tr>
<tr>
<td>Conventional-till</td>
<td>86.00</td>
</tr>
</tbody>
</table>

Table 5. Comparison of Inputs for Various Tillage Practices

<table>
<thead>
<tr>
<th>Tillage Practice</th>
<th>Fuel gallons per acre</th>
<th>Labor hours per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-till</td>
<td>1.50</td>
<td>0.45</td>
</tr>
<tr>
<td>Till-plant</td>
<td>2.75</td>
<td>0.90</td>
</tr>
<tr>
<td>Rotary-till</td>
<td>3.00</td>
<td>0.88</td>
</tr>
<tr>
<td>Disc</td>
<td>3.00</td>
<td>0.85</td>
</tr>
<tr>
<td>Chisel</td>
<td>3.30</td>
<td>0.89</td>
</tr>
<tr>
<td>Plow</td>
<td>5.25</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Source: CTIC

gave yields in no-till that were equivalent to, or even slightly higher, than those obtained in conventional tillage systems when applied to a poorly structured silt loam soil for four years (table 6). In contrast, on a poorly drained silty clay loam, ridge-till planting or reduced tillage (chisel) was necessary as the conservation tillage practice to obtain equivalent yields.

Farmers with a number of years of experience have obtained excellent yields of corn and soybeans by no-till on well-drained soils. They have also successfully no-tilled poorly drained soils using good management techniques such as winter cover crops to drain moisture from the soil in spring. The cover crop is then killed in spring with a herbicide. Soybeans are very responsive to no-till, and yields, as demonstrated by the CTIC, University of Missouri, and University of Kentucky are similar to those obtained in conventional tillage practice.

Table 6. Corn Response to Tillage and Rotation on Two Soil Types in Indiana (average yields 1983-86 in bushels per acre)

<table>
<thead>
<tr>
<th>Tillage System</th>
<th>Silt Loam</th>
<th>Silty Clay Loam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous corn:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plow</td>
<td>122.50</td>
<td>161.03</td>
</tr>
<tr>
<td>Chisel</td>
<td>128.00</td>
<td>156.10</td>
</tr>
<tr>
<td>Disk</td>
<td>123.30</td>
<td>-</td>
</tr>
<tr>
<td>Ridge-till</td>
<td>122.40</td>
<td>156.10</td>
</tr>
<tr>
<td>No-till</td>
<td>131.00</td>
<td>132.40</td>
</tr>
<tr>
<td>Corn following soybean:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plow</td>
<td>121.90</td>
<td>178.03</td>
</tr>
<tr>
<td>Chisel</td>
<td>120.80</td>
<td>176.70</td>
</tr>
<tr>
<td>Disc</td>
<td>127.70</td>
<td>-</td>
</tr>
<tr>
<td>Ridge-till</td>
<td>130.10</td>
<td>180.30</td>
</tr>
<tr>
<td>No-till</td>
<td>138.60</td>
<td>169.62</td>
</tr>
</tbody>
</table>

Source: Griffiths and others (1988).

In a five-year study in Manitoba, Canada a small grain and canola rotation showed dramatic profit improvements for minimum-tillage and no-till over conventional tillage (table 7). Slightly higher expenses in no-till and minimum-tillage plots are attributable, largely, to the additional
herbicide cost. However, recent reductions in herbicide price have narrowed these cost differences and make average net returns from no-till and minimum-tillage even more attractive. Increased yields and improved gross returns in no-till and minimum-tillage were attributable to improved soil moisture conservation.

In the Western Plains of the United States and the Canadian prairies, soil moisture conservation is an important component for maximizing yield. Leaving upright stubble after harvest is important for trapping snow in the winter and surface crop residue reduces evaporation in the summer.

Table 7. Five-Year Manitoba Study of a Small Grain and Canola Rotation

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>No-till</th>
<th>Min-till Bu/Ac</th>
<th>Conventional tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>Wheat</td>
<td>56.00</td>
<td>56.00</td>
<td>54.00</td>
</tr>
<tr>
<td>1987</td>
<td>Barley</td>
<td>77.30</td>
<td>73.20</td>
<td>66.20</td>
</tr>
<tr>
<td>1988</td>
<td>Barley</td>
<td>77.10</td>
<td>69.60</td>
<td>63.20</td>
</tr>
<tr>
<td>1989</td>
<td>Canola</td>
<td>11.10</td>
<td>8.20</td>
<td>6.50</td>
</tr>
<tr>
<td>1990</td>
<td>Wheat</td>
<td>64.20</td>
<td>61.30</td>
<td>54.90</td>
</tr>
</tbody>
</table>

$/Acre

| Average gross return | 146.91 | 136.60 | 124.18 |
| Average total expense | 116.46 | 113.63 | 110.78 |
| Average net returns | 30.45  | 22.97  | 13.40  |


Conservation Tillage in Other Countries

Soybeans produced by no-till is a rapidly growing trend in both Brazil and Argentina. It is estimated that as many as 3 to 3.5 million acres are already under no-till. No-till is an important tool to control soil erosion on the sandy slopes of Rio Grand Du Sol and Parana of Brazil. In Australia it is estimated that as much as 12 million acres of small grains and fallow are under conservation tillage practice, while in Canada conservation tillage is practiced on 17 million acres or 24 percent of the cropland. Nearly 5 million acres is already under no-till in Canada.

Factors Contributing to the Success of No-Till and Conservation Tillage

There is no doubt that we have seen tremendous benefits from conservation tillage and no-till farming; but what has made this possible? Two critical factors have contributed to this: (a) availability of well-constructed no-till planters and drills capable of handling and planting into surface crop residue; and (b) availability of new herbicide technology able to manage weeds effectively in high residue situations.

Most of these herbicides have very attractive environmental properties and the newer ones can be applied at lower dosages; not several pounds per acre, but in some cases grams per acre. These
properties, combined with less water runoff in conservation tillage or no-till, will greatly contribute to much reduced surface or groundwater residues.

Roundup® Herbicide by Monsanto has been the cornerstone of no-till and conservation tillage practice in the United States, Australia, Canada, Brazil, Argentina, and Europe. Because of its broad-spectrum activity (annuals and perennials) and versatile application timing to weeds, it has become the preferred herbicide for cleanup of weeds prior to no-till or reduced tillage. In no-till it allows the crop to get off to a clean start or its burndown of weeds helps facilitate shallow tillage. Glyphosate, the active ingredient of Roundup®, is rapidly biodegraded in the soil and has low toxicity. These desirable properties, together with the fact that it is tightly bound by soil particles, makes it an environmentally attractive choice in conservation tillage. Wide use is not expected to result in surface or groundwater residue problems. Roundup® can be mixed with residual herbicides or be used in a herbicide system with other herbicides for complete preplanting and post-crop emergence weed control in conservation tillage.

Conservation Tillage in Developing and Less Developed Agricultural Systems

There is no doubt that the conservation tillage and no-till technology, which has been successfully applied in the United States, Canada, Brazil, Argentina, and Australia can also be successfully applied in the inefficiently resourced and declining agricultural systems of the former Soviet Union and Eastern Europe. As in the United States, these systems could greatly reduce these countries’ dependence on heavy tillage equipment and their large and inefficient high horsepower tractors, while at the same time reducing serious soil erosion to sustainable levels.

While people and expertise are available to transfer this technology to the former Soviet Union and Eastern Europe, a major challenge stands in the way of its adoption; namely, availability of hard currency to purchase smaller tractors and no-till drills and planters. It would be best if these countries could produce the planters and drills locally, as well as smaller tractors. Outside investment in these production facilities, accompanied by expertise, could yield very productive results. However, such investment would need to be tied to the availability of other inputs such as herbicide and fertilizer. Availability of no-till planters and smaller tractors and the reduction of heavy tillage equipment could also facilitate a move to smaller farms and, ultimately, privatization of agricultural production.

No-till, or conservation tillage, can also be applied to smallholder production systems in Africa. We have seen successful applications in Kenya, particularly in pasture and corn rotations. In this system, kikuyu pasture (*Pennisetum clandestinum*) is killed with Roundup® Herbicide just prior to seeding corn with a hand hoe. Corn can be planted into a narrow strip prepared with a hoe in the dead kikuyu pasture. The dead grass in the interrow protects the soil from wind and water erosion and acts as a barrier to weed germination. This system of conservation tillage could, with further research, be adapted to many annual cropping situations in Africa.

Herbicides have also contributed to tillage elimination in the interrows of plantation crops in smallholder production. For example, Roundup® has been successfully used to control annual and perennial weeds in the interrows of coffee on the slopes of Mount Kenya. The soil is left undisturbed and the decaying vegetation protects the soil from erosion.
Conclusions

Conservation tillage is a growing trend worldwide. In the United States legislation has been the catalyst. However, in the process farmers have discovered that input cost can be reduced dramatically through reductions in labor, equipment, and fuel costs. At the same time farmers have discovered that corn and soybean yields can be maintained at levels which will result in improved average net returns per acre from conservation tillage and no-till. In the drier Western Plains of the United States, the Canadian prairies, and Australia conservation tillage and no-till have resulted in improved soil moisture conservation that has translated into increased yield. Modern no-till planters and new herbicides, which effectively manage weeds in no-till and conservation tillage situations, have undoubtedly contributed to this growing trend. These economic benefits together with dramatically reduced soil erosion could also apply to the vast acreages of the former Soviet Union and Eastern Europe. The challenge in these countries is the availability of hard currency to purchase no-till drills and planters. The best solution might be local production through foreign investment and here the World Bank could play a key role.

Conservation tillage can also be applied to smallholder production systems. Planting by hand into vegetation managed with herbicides with a minimal amount of surface tillage has been successfully practiced in Kenya and Indonesia. This practice needs development in other countries through such organizations as Winrock International, Global 2000, and so on.

Because of the successful application of conservation tillage and its potential contribution to sustainable agriculture, the World Bank needs to give serious consideration to investments in this area.

References


Moisture Management in Semiarid Temperate Regions

B.A. Stewart, O.R. Jones, and P.W. Unger*

Introduction

The temperate regions are located between the Tropic of Cancer and the Arctic Circle or between the Tropic of Capricorn and the Antarctic Circle. These regions contain vast areas of land in semiarid climatic zones, often classified as areas where the precipitation/potential evapotranspiration ratio is between 0.2 and 0.5 (UNESCO 1977). Dryland farming is often practiced in these regions, but water conservation practices are essential for successful cropping systems. The Canadian Prairie Provinces, U.S. Great Plains, Southern Australia, and parts of Argentina, China, and the Commonwealth of Independent States are examples of dryland farming areas in semiarid temperate regions.

Dryland farming systems emphasize water conservation, sustainable crop yields, limited inputs for soil fertility, and wind and water erosion constraints. The three components of a successful dryland management system are (a) retaining the precipitation on the land, (b) reducing evaporation, and (c) utilizing crops that have drought tolerance and fit the rainfall pattern. Although these components have been known for centuries, new technologies are developing that improve moisture management in these water deficient areas. Some of these technologies will be presented and the principles on which they are based will be discussed.

Semiarid Climate

Although semiarid zones are often classified by the ratio of precipitation/potential evapotranspiration, semiarid is a comparative term implying a moisture state intermediate between truly arid conditions and others that are more humid. Semiarid regions typically receive substantial precipitation for at least a few months of the year, enough to bring soil moisture up to levels sufficient to produce amounts of biomass that far exceeds that produced in arid regions.

The water balance values for annual cropping of wheat at three semiarid locations are presented in table 1. An understanding of these data will provide the base for discussing the development and implementation of new technologies for improved cropping and soil management systems.

The percentage of total rainfall that was used for evapotranspiration was similar for all three locations, approximately 65 percent. Evapotranspiration is the combined loss of water from transpiration and evaporation from the soil surface during the period when the crop is growing. The fallow period is the time between harvesting the crop and seeding the subsequent crop. For the data presented in table 1, evapotranspiration values were calculated by adding the growing season precipitation amounts to the change in the amount of available water held in the soil at seeding time and at harvest time. In all locations, soil water was decreased significantly during the growing season, and increased during the fallow period. However, the change was considerably less for the

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* Laboratory director and soil scientists, respectively, at the U.S. Department of Agriculture Conservation and Production Research Laboratory, Agricultural Research Service, Bushland, Texas.
<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th>Fallow</th>
<th>Total</th>
<th>Wheat</th>
<th>Fallow</th>
<th>Total</th>
<th>Wheat</th>
<th>Fallow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>---Texas, U.S.A.---</td>
<td></td>
<td></td>
<td></td>
<td>---Shaanxi, China---</td>
<td></td>
<td></td>
<td>---New South Wales, Australia---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation (mm)</td>
<td>256</td>
<td>202</td>
<td>458</td>
<td>181</td>
<td>213</td>
<td>394</td>
<td>280</td>
<td>280</td>
<td>560</td>
</tr>
<tr>
<td>Evapotranspiration (mm) (ET)</td>
<td>293</td>
<td>293</td>
<td>264</td>
<td>264</td>
<td>264</td>
<td></td>
<td>360</td>
<td>360</td>
<td></td>
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<tr>
<td>Soil water change (mm)</td>
<td>-37</td>
<td>37</td>
<td>-83</td>
<td>83</td>
<td>83</td>
<td>-80</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaporation and runoff (mm)</td>
<td>165</td>
<td>165</td>
<td>130</td>
<td>130</td>
<td>130</td>
<td>200</td>
<td>200</td>
<td></td>
<td></td>
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<tr>
<td>Potential evapotranspiration</td>
<td>1,140</td>
<td>740</td>
<td>1,880</td>
<td>475</td>
<td>408</td>
<td>883</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mm) (PET)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ET/PET (%)</td>
<td>26</td>
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<td>56</td>
<td>24</td>
<td></td>
<td>45</td>
<td>64</td>
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<td>64</td>
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<td>Precipitation/PET (%)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ET/Precipitation (%)</td>
<td>64</td>
<td></td>
<td>67</td>
<td>64</td>
<td></td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield</td>
<td>0.90</td>
<td>1.25</td>
<td>2.40</td>
<td>0.47</td>
<td>0.47</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water use efficiency</td>
<td>.33</td>
<td>.47</td>
<td>.67</td>
<td>.33</td>
<td>.47</td>
<td>.67</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source:* Adapted from unpublished data, O.R. Jones, Bushland, TX; Shan Lun and others (1992); and Cornish and Pratley (1991).
Texas location. There was less precipitation at this location during the fallow period, and the potential evapotranspiration was very high, resulting in only 37 millimeters of storage, compared to storage at the other two locations of 80 millimeters or more.

The Texas location is the most arid of those presented in table 1. Although total precipitation was more for the Texas site than for the China site, the amount of actual evapotranspiration was only 26 percent of the potential evapotranspiration for the Texas location, compared to 56 percent for the Shaanxi site. The China location had a much higher yield, and a water use efficiency of 0.47 kg m⁻³, compared to 0.31 kg m⁻³ for the Texas location. The yield and water use efficiency values were low for both sites, but the Texas site values were extremely low. Water use efficiency values for wheat grown in humid regions or under irrigation often exceed 1.25 kg m⁻³ and values as high as 1.9 m⁻³ are reported in the literature (Musick and Porter 1990).

The data presented in table 1 are average values for several years. One of the difficulties with crop production in semiarid regions is the extreme variation of precipitation and, therefore, crop yields among years. Annual precipitation in these regions commonly ranges from about 50 percent of average for a dry year to about 200 percent of average for a wet year; yields vary from 0 to about three times average. Much of the precipitation in semiarid regions also occurs during high intensity storms and runoff can be significant. Runoff, combined with evaporation from the soil surface during the fallow period, resulted in a loss of one-third of the precipitation for all three locations discussed in table 1. The development and implementation of technologies that reduce these losses can greatly increase yields. This is illustrated in figure 1 showing the relationship between yield of wheat grain and seasonal water use (evapotranspiration) for a location in Texas and one in northwest China. Data for both locations indicate that about 200 millimeters of water use is required before any grain is produced, but for each additional millimeter of water use, about 12 kg ha⁻¹ of grain is produced at the Texas site and about 25 kg ha⁻¹ for the China location. As already discussed the Texas site is much more arid than the China site, resulting in a lower water use efficiency. These relationships clearly show the great impact that technologies, which increase the amount of water available for crop use, can have on grain yields.

Technologies for Increasing Plant Available Water

Several technologies for increasing plant available water are discussed in this section. They include lengthening the fallow period, mulches, tillage, and runoff control and conservation.

Lengthening the Fallow Period

One of the oldest, and most controversial, technologies for increasing plant available water is lengthening the fallow period. This is generally called summer fallow, defined as a practice wherein no crop is grown and all plant growth is controlled by cultivation or chemicals during a season when a crop might normally be grown. Proponents have emphasized the water conserving, weed controlling, and crop yield stabilizing virtues, whereas critics have emphasized the inefficiency in soil water storage and the wind and water erosion and declining organic matter problems associated with fallow. Only about 15 to 20 percent of the precipitation that occurs during the fallow period is stored in the soil profile. The remainder is lost as runoff and evaporation and, on some soils, as drainage below the root zone. The data presented in table 2, from Bushland, Texas, illustrate the effect that lengthening the fallow period has on increasing soil water storage. When wheat is grown annually,
the fallow period is about three months to four months and, on average, 37 millimeters, or 18 percent, of the 202 millimeters rainfall that occurs during the fallow period is retained as stored soil water as previously discussed in table 1. By changing the cropping system from annual wheat to wheat/sorghum fallow, the length of the fallow period between crops is increased to about eleven months. However, only two crops, one wheat and one grain sorghum, are produced every three years as compared to two wheat crops for the annual wheat system. In this system wheat is seeded about October 1 and harvested about July 1. Grain sorghum is seeded about June 1 the following year and harvested in November. After an additional eleven-month fallow period, wheat is again seeded. The average amount of water stored at time of seeding wheat was increased to 86 millimeters as compared to 37 millimeters for the annual wheat system. The fallow period is even longer when a wheat fallow system is used, producing only one crop every two years and lengthening the fallow period to fifteen months to sixteen months. In this system the average amount of plant available soil water at seeding time is increased to 98 millimeters. While these fallow systems increase soil water contents at seeding and, therefore, increase the amounts of water consumed by the wheat crop from 293 millimeters for annual cropping to 329 millimeters and 354 millimeters for the wheat/sorghum fallow and the wheat fallow system, respectively. Although these amounts are relatively small, the associated yield increases are very significant because of the yield-water use relationship presented in figure 1 and discussed earlier. Each millimeter of additional water use has the potential of increasing yield about 12 kg ha⁻¹, so lengthening the fallow period often increases yields by 50 to 75 percent, and in some cases can double yields. The water use efficiency, expressed as grain/evapotranspiration is significantly increased, but a much smaller amount of the total precipitation is actually used by the crop. For example in the wheat fallow system, only 354 millimeters of the total 916 millimeters of precipitation that occurred during the two-year system was actually used by the growing crop. The other 562 millimeters was lost as evaporation, runoff, and perhaps some drainage. Therefore, summer fallow is very inefficient for conserving precipitation as stored soil water, but efficient for increasing and stabilizing grain yields. Because of these divergent effects, summer fallow remains a subject of controversy.

Figure 1. Relationship Between Wheat Yield and Seasonal Evapotranspiration for Two Semiarid Regions.
Perhaps the biggest concern about summer fallowing is its effect on soil degradation. Until herbicides became available in recent decades, tillage was the only means of controlling vegetative growth during the fallow period. Consequently, it was not uncommon for a field to be tilled eight to ten times during the fallow period. Intensive and frequent tillage buries most of the crop residues and hastens the decomposition of crop residues and soil organic matter. Cultivation increases biological activities in the soil, often as a result of better soil aeration. But cultivation also exposes fresh topsoil to rapid drying and, after each drying, a burst of biological activity occurs for a few days following rewetting (Allison 1973). This is because the drying process releases organic compounds, probably from the breakdown of soil aggregates that are bound together by humic materials. Considerable organic nitrogen is mineralized as ammonia and later oxidized in large part to nitrates. Other nutrients are also made available from the decomposition of organic matter. This is particularly true for phosphorus because much of the phosphorus in soils is present in organic forms. The nutrients released as a result of tillage are readily available to growing plants and increased yields are generally obtained. Therefore, in addition to increasing water storage, summer fallowing also increases available soil nutrients. However, unless the organic matter supply is replenished by plant residues or manures, the system is not sustainable. This is the situation for many soils of the world located in arid and semiarid regions and increased attention to the problem is critical. It is also the underlying principle that resulted in the infamous "Dust Bowl" that occurred in the U.S. Great Plains during the drought years of the 1930s and considered by many as the worst ecological disaster ever exacerbated by man.

The Great Plains region was largely settled in the early 1900s by farmers who migrated from the humid areas of the eastern United States and brought with them their clean-tillage tools and experiences. These worked well the first few years after cropping began because the native soil organic matter content was high and the precipitation during the period of the "big plowout" was above average. However, when annual precipitation decreased to average and below, the annual net loss of soil organic matter accelerated and led to increased vulnerability to wind erosion. The moldboard plow, and many other intensive tillage implements, were developed in Europe where soil organic matter content of soils is high, and the organic matter level can be maintained at a high level because of relatively high precipitation amounts that produce large amounts of biomass and cool temperatures that slow the rate of decomposition. In arid and semiarid regions, high temperatures accelerate the rate of decomposition and the lack of precipitation severely limits biomass production so organic matter loss can be rapid and severe.

Summer fallow, particularly during years of above average precipitation, can infiltrate much more water than can be stored in the soil profile. This can result in substantial amounts of water moving through the profile removing nutrients and, if salts are present, they will be leached and cause saline seeps in certain situations. This has been a significant problem in parts of the northern Great Plains of the United States where spring wheat is the dominant cropping system. The length of the fallow period in spring wheat fallow is about twenty months during each two-year cycle. Saline seep problems are also widespread in parts of Australia.

Summer fallowing has also been used extensively in Australia and China. Cornish and Pratley (1991) stated that fallows have had a long and often sorry history in Australia. The practices described above that were so successful when first implemented in the U.S. Great Plains were imported by Australian farmers in the early 1900s. The primary practices involved deep plowing and frequent harrowing to produce a dust mulch. The plowing was thought to increase the waterholding capacity of the soil, while the dust mulch supposedly prevented water rising to the soil surface by capillary action and evaporating. Subsequent research showed that the major loss of water from soils was through transpiration by weeds and that the benefits of dust mulching were largely due to weed control. These technologies were used to extend the limits of wheat growing into the marginal 250-
Table 2. Water Balance for Various Cropping Systems at Bushland, Texas

<table>
<thead>
<tr>
<th>Continuous wheat (one crop annually)*</th>
<th>Wheat</th>
<th>Fallow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------------------------------</td>
<td>-------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>Precipitation</td>
<td>256</td>
<td>202</td>
<td>458</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>293</td>
<td>293</td>
<td></td>
</tr>
<tr>
<td>Soil water change</td>
<td>-37</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Evaporation (and runoff)</td>
<td></td>
<td>165</td>
<td>165</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Two crops in three years*</th>
<th>Wheat</th>
<th>Fallow</th>
<th>Sorghum</th>
<th>Fallow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------------------------------</td>
<td>-------</td>
<td>--------</td>
<td>---------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>Precipitation</td>
<td>256</td>
<td>462</td>
<td>241</td>
<td>416</td>
<td>1,375</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>329</td>
<td>286</td>
<td>615</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Runoff</td>
<td>13</td>
<td>25</td>
<td>27</td>
<td>43</td>
<td>108</td>
</tr>
<tr>
<td>Soil water change</td>
<td>-86</td>
<td>86</td>
<td>-72</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Evaporation</td>
<td>351</td>
<td>301</td>
<td>652</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>One crop in two years*</th>
<th>Wheat</th>
<th>Fallow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------------------------------</td>
<td>-------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>Precipitation</td>
<td>256</td>
<td>660</td>
<td>916</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>354</td>
<td></td>
<td>354</td>
</tr>
<tr>
<td>Soil water change</td>
<td>-98</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Evaporation (and runoff)</td>
<td></td>
<td>562</td>
<td>562</td>
</tr>
</tbody>
</table>

* Fallow period between crops is three to four months. Runoff was not measured but would be minimal under annual cropping.

b Fallow periods between crops are about eleven months.

c Fallow period between crops is fifteen months to sixteen months. Runoff was not measured but was a minor portion of the total.

Source: O. R. Jones, personal communication; Johnson and Davis (1972).
millimeter to 400-millimeters rainfall zone of the South Australian, Victorian, New South Wales, and Western Australian Mallee. Long fallow periods (fifteen months) were used and the frequent cultivation of these light-textured soils resulted in soil structural breakdown, fertility decline, and ultimately, catastrophic erosion. Li Shengxiu and Xiao Ling (1992) summarized some of the results from the Loess Plateau Region of China and concluded that fallowing was a good practice for the drylands. Summer fallowing was usually combined with summer deep plowing for controlling weeds, keeping the soil loose, and increasing soil infiltration. As a result soil water storage was increased. In addition available plant nutrients, especially nitrates, accumulated in the profile and stimulated growth of the subsequent crop. They did not stress the negative effects such as organic matter decline and deteriorating soil structure that were discussed above. This may be because Chinese farmers have historically used organic wastes on their fields and this may offset the otherwise negative effects.

The steppe area of northern Kazakhstan is another region where fallow has been widely practiced. However, Souleimenov (1992) concluded that fallow in this region of about 350 millimeters of precipitation was not justified. Research showed that the available water storage prior to seeding wheat was only slightly higher for the fallow fields than those for wheat after fallow or for continuous wheat (table 3). Fallow was adopted in this region in 1966 based largely on some selected data of the state farms for extremely dry years (1962, 1963, and 1965). The decision also was influenced by data and experiences from the Canadian prairies. Souleimenov (1992) recommended that most fallow be discontinued with the more marginal lands being returned to grass and the better lands cropped annually. He also pointed out the benefits that such a system would have on the environment. Weed infestation, wind erosion, and other soil degradation processes have been widely experienced in the region where fallow systems were the dominant practice.

<table>
<thead>
<tr>
<th>Preceding crop</th>
<th>Simplified</th>
<th>Common</th>
<th>Improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare fallow</td>
<td>110</td>
<td>137</td>
<td>165</td>
</tr>
<tr>
<td>Wheat after fallow</td>
<td>98</td>
<td>133</td>
<td>153</td>
</tr>
<tr>
<td>Continuous</td>
<td>102</td>
<td>135</td>
<td>155</td>
</tr>
</tbody>
</table>

Source: Souleimenov (1992)

Mulches

The Dust Bowl of the 1930s, described earlier, led to the development of stubble mulching. Stubble mulching uses V-shaped sweeps or blades that are pulled flat about 10 centimeters beneath the soil surface. This operation cuts plant roots and kills the weeds but does not invert the soil. Therefore, most of the crop residue is left on the surface where it can serve as a mulch to prevent wind and water erosion, and slow evaporation losses. Only about 15 percent of the residue is buried by a sweep tillage operation, so there is substantial residue remaining on the surface even after three to four operations, which is often done between the time a crop is harvested and a subsequent crop is seeded. A rodweeder, a square rod about one inch thick that turns about five centimeters to ten
centimeters beneath the surface as it is pulled, is another tool that is sometimes used to kill weeds without intensively tilling the soil. A rodweeder operation can sometimes bury less that 10 percent of the residue present on the soil surface. In recent years herbicides have been used to partially replace tillage with reduced tillage, and completely replace tillage with no-tillage.

Although stubble mulching was developed to address the wind erosion problem, it soon became evident that mulches had beneficial effects on soil water storage. The increase in soil water storage generally is attributed to increased infiltration and reduced evaporation. However, the degree that each of these factors contribute varies with specific conditions. Cornish and Pratley (1991), working on clay soils in Australia, found that plant residues on the soil surface caused a major reduction in runoff, principally by protecting soil surfaces that were prone to crusting from raindrop action. Fallow efficiencies in Queensland were increased from about 21 to 29 percent, almost entirely because of reduced runoff. They reported that only about 4 t ha\(^{-1}\) of crop residues were needed to gain the maximum improvement in infiltration (figure 2). A crop of wheat yielding about 2 t ha\(^{-1}\) of grain will produce about 4 t ha\(^{-1}\) of residue. Because the national average wheat yield of grain is about 1.5 t ha\(^{-1}\), there is sufficient residue on most fields to gain most of the potential benefit from increased infiltration if the residue is left on the soil surface.

Unger (1978), working on a clay loam soil in the southern U.S. Great Plains, also found very significant increases in soil water storage when crop residues were maintained on the soil surface. The residues enhanced water infiltration and suppressed evaporation, thus providing more water for the subsequent crop (table 4). In contrast to the Australian study, however, soil water storage values continued to increase with each additional amount of residue. Following the eleven-month fallow period, dryland grain sorghum was grown and the yields reflected the increases in soil water storage.

### Table 4. Straw Mulch Effects on Soil Water Storage During an Eleven-Month Fallow, Water Storage Efficiency, and Dryland Grain Sorghum Yield at Bushland, Texas

<table>
<thead>
<tr>
<th>Mulch rate (mg ha(^{-1}))</th>
<th>Water storage(^a) (mm)</th>
<th>Storage efficiency(^a) (percent)</th>
<th>Grain yield (Mg ha(^{-1}))</th>
<th>Total water use (mm)</th>
<th>WUE(^b) (kg m(^{-3}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>72 c</td>
<td>22.6 c</td>
<td>1.78 c</td>
<td>320</td>
<td>0.56</td>
</tr>
<tr>
<td>1</td>
<td>99 b</td>
<td>31.1 b</td>
<td>2.41 b</td>
<td>330</td>
<td>0.73</td>
</tr>
<tr>
<td>2</td>
<td>100 b</td>
<td>31.4 b</td>
<td>2.60 b</td>
<td>353</td>
<td>0.74</td>
</tr>
<tr>
<td>4</td>
<td>116 b</td>
<td>36.5 b</td>
<td>2.98 b</td>
<td>357</td>
<td>0.84</td>
</tr>
<tr>
<td>8</td>
<td>139 a</td>
<td>43.7 a</td>
<td>3.68 a</td>
<td>365</td>
<td>1.01</td>
</tr>
<tr>
<td>12</td>
<td>147 a</td>
<td>46.2 a</td>
<td>3.99 a</td>
<td>347</td>
<td>1.15</td>
</tr>
</tbody>
</table>

\(^a\) Water storage determined to 1.8-meter depth. Precipitation averaged 318 millimeters.

\(^b\) Water use efficiency (WUE) based on grain produced, growing season precipitation, and soil water changes.

\(^c\) Column values followed by the same letter are not significantly different at the 5 percent level (Duncan's multiple range test).

Li Shengxiu and Xiao Ling (1992) summarized studies from China and results are similar to those reported above. Straw mulch significantly increased soil infiltration and reduced water loss by evaporation, thereby increasing water storage both in summer and winter (table 5). In addition to increasing soil water storage, the mulch decreased bulk density and increased the number of earthworms and soil organic matter content. Bulk density in the top zero to ten centimeters was 1.36 Mg m$^{-3}$ without a straw mulch compared with 1.29 and 1.23 with 4.5 and 6.0 Mg ha$^{-1}$ mulch, respectively. The earthworm number per square meter in the top fifteen centimeters was two without straw mulch, but twelve, thirty-two, and thirty-four with straw mulch of 3.0, 4.5, and 6.0 Mg ha$^{-1}$, respectively. Organic matter content in the top layer was 1.61 percent with no straw mulch, and 1.67 and 1.76 percent with 4.5 and 6.0 Mg ha$^{-1}$, respectively. Soil temperature was also affected, being cooler in the summer and warmer in the winter when there was a straw mulch on the soil surface.

### Table 5. Amount of Water Stored (millimeters) in Different Soil Layers with Different Amounts of Straw Mulch (kilogram/hectare)

<table>
<thead>
<tr>
<th>Depth (centimeters)</th>
<th>Without mulch</th>
<th>Mulch 3,000</th>
<th>Mulch 4,500</th>
<th>Mulch 6,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>66.1</td>
<td>71.2</td>
<td>74.4</td>
<td>76.2</td>
</tr>
<tr>
<td>30-100</td>
<td>191.5</td>
<td>194.5</td>
<td>198.3</td>
<td>201.1</td>
</tr>
<tr>
<td>100-200</td>
<td>248.9</td>
<td>252.5</td>
<td>259.9</td>
<td>271.1</td>
</tr>
<tr>
<td>0-200</td>
<td>506.5</td>
<td>518.2</td>
<td>532.6</td>
<td>548.4</td>
</tr>
</tbody>
</table>

*Note:* Two years' average values in two locations.

*Source:* Han Siming and others (1988).
Smika (1976) studied the specific effect of surface residues on soil water evaporation during a thirty-four-day period following 13.5 millimeters of rainfall in the central U.S. Great Plains. One day after the rain (figure 3), water contents to a fifteen-centimeter depth were similar with no tillage (herbicides only), minimum-tillage (combination of stubble mulch tillage and herbicides), and conventional-tillage (stubble mulch) treatments. After thirty-four days with no additional rain, water contents were greatest with no-tillage and least with conventional-tillage. Surface residue amounts during the study were 1.2, 2.2, and 2.7 Mg ha$^{-1}$ with conventional-tillage, minimum-tillage, and no-tillage treatments, respectively.

Shikula and others (1992) reported that mulches were very useful for increasing water storage in the semiarid steppe regions of the Ukraine. On no-plow plots, plant available soil water storage values were 170 millimeters to 186 millimeters in the 0 centimeter to 150-centimeter soil profile, compared to only 132 millimeters to 154 millimeters on the conventionally plowed plots. Wheat yields were also higher on the no-plow plots. Soil loss as a result of water erosion was eighteen to twenty-three times less than for conventional tillage. In addition expenditures for labor was reduced by 40 percent, fuel by 45 percent, and total expenditures by 48 percent for the no-tillage plots. They concluded that no-plow technologies should be adopted in the semiarid steppe zones of the Ukraine as soon as possible.

Although surface residues clearly reduce runoff and evaporation, it should be appreciated that these benefits diminish as the soil becomes wetter. Toward the end of a fallow, when the soil approaches maximum waterholding capacity, residues have little effect.

Figure 3. Soil Water Content to a 15-Centimeter Depth One Day (A) and Thirty-Four Days (B) after 13.5 Millimeters Rainfall as Influenced by Tillage Treatments (CONV-TILL, Conventional-Tillage; MIN-TILL, Minimum-Tillage; NO-TILL, No-Tillage) (from Smika 1976)
Tillage

The practice of tillage dates back to the beginning of history, and was well-established in Mesopotamia at least as early as about 2000 B.C. The first tillage tools were crude implements of stone, wood, and possibly bones and shells used by man to eliminate weeds and to chop or dig a few centimeters into the soil so seed could be planted. Later, animals were used to pull stick plows. Modern tillage systems had their origin in the 18th century when the moldboard plow was invented. A moldboard factory was opened in Scotland in 1760.

Until recently, frequent and thorough cultivation was considered the mark of good farming. The seal of the U.S. Department of Agriculture has a moldboard plow as the focal point. Because the more prosperous farmers cultivated their soils very often, it was generally assumed that this was of major importance. Tillage was important because it controlled weeds and, more importantly, it released nutrients from the soil, mostly from soil organic matter.

Conservation tillage systems, consisting of reduced tillage and no tillage, have received increasing attention in recent years because maintaining residues on the surface greatly reduces water and wind erosion. Conservation tillage is defined as any tillage or planting system that maintains at least 30 percent of the soil surface covered by residue after the crop has been seeded to reduce soil erosion by water. When wind erosion is the primary concern, residues or plants of other crops equivalent to at least 1.1 t ha\(^{-1}\) of flat, small grain residue must be maintained on the surface during the critical erosion period. These amounts of residue are generally sufficient to keep soil erosion at an acceptable level. Conservation tillage systems also require less fuel than more intensive tillage systems, and increasing fuel costs also have increased interest in these systems.

In semiarid regions, the emphasis on reduced and no-tillage systems has focused on water conservation. As already discussed, mulches increase infiltration and reduce evaporation, and the most practical way to create a mulch is to reduce tillage. Greb, Smika, and Welsh (1979) summarized more than sixty years of progress in wheat production in fallow systems in the central U.S. Great Plains (table 6). As the number of tillage operations decreased, marked increases in the amount of water stored during the fallow periods occurred with dramatic increases in yield. These positive effects tend to accumulate because higher yields result in more residue and increased residue results in more water storage, which translates into higher yields, creating an upward spiral. Soil physical properties also are improved.

Reduced tillage also is important in semiarid regions as a means of maintaining organic matter. As discussed earlier, cultivation increases biological activities in the soil. Cultivation also exposes fresh topsoil to rapid drying and, after each drying, a burst of biological activity occurs for a few days following rewetting. This is because the drying process releases organic compounds, probably from the breakdown of soil aggregates that are bound together by humic materials. Considerable organic nitrogen is mineralized as ammonia and later oxidized in large part to nitrates. Other nutrients also are made available from the decomposition of organic matter. This is particularly true for phosphorus because much of the phosphorus in soils is present in organic forms. The nutrients released as a result of tillage are readily available to growing plants and increased yields are generally obtained. Tillage also increases the infiltration rate of most soils and this reduces runoff and often increases storage of water in the soil profile so it can be used later for plant growth. However, unless the organic matter supply is replenished, the system is not sustainable. This is the situation for many soils of the world located in arid and semiarid regions and increased attention to the problem is critical.
Table 6. Progress in Fallow Systems with Respect to Water Storage and Wheat Yield at Akron, Colorado

<table>
<thead>
<tr>
<th>Years</th>
<th>Tillage during fallowa</th>
<th>Fallow water storage</th>
<th>Wheat yield (Mg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1916-30</td>
<td>Maximum tillage; plow, harrow (dust mulch)</td>
<td>102</td>
<td>19</td>
</tr>
<tr>
<td>1931-45</td>
<td>Conventional tillage; shallow disk, rod weeder</td>
<td>118</td>
<td>24</td>
</tr>
<tr>
<td>1946-60</td>
<td>Improved conventional tillage; began stubble mulch in 1957</td>
<td>137</td>
<td>27</td>
</tr>
<tr>
<td>1961-75</td>
<td>Stubble mulch; began minimum tillage with herbicides in 1969</td>
<td>157</td>
<td>33</td>
</tr>
<tr>
<td>1975-90</td>
<td>Projected estimate; minimum tillage; began no-tillage in 1983</td>
<td>183</td>
<td>40</td>
</tr>
</tbody>
</table>

Based on fourteen-month fallow, from mid-July to second mid-September

Source: Adapted from Greb, Smika, and Welsh (1979)

Runoff Control and Conservation

Although precipitation is lacking in semiarid regions, high intensity rainfall events are common and runoff can be significant. Runoff can be particularly high where fine-textured soils are dominant because of their low infiltration rates. As infiltration rates decrease, runoff increases, thus accelerating erosion. Terraces are often used to control runoff and reduce erosion, but they are expensive to construct and sometimes interfere with cultural practices, particularly in regions where large machinery is used.

Furrow diking, sometimes called tied-ridging, is also an effective cultural practice for retaining surface water until it can infiltrate. Furrow diking is even more effective if it is done on the contour, and it also lessens the erosion potential associated with a very large precipitation that could result in more surface water than can be retained in the basins. Seeding crop rows on the contour is a practice that is adaptive to all types of tillage, reduced tillage, and no-tillage systems and is highly recommended.

A major obstacle to farmer adoption of furrow-diking technology is that there are many years in which positive results are not obtained. Data from Bushland, Texas show that average runoff during the sorghum growing season was 25 millimeters, adequate to increase grain yields about 375 kg ha⁻¹ (Stewart and Steiner 1990). However, over half the years had little or no runoff, and often two or three of these years occurred in sequence. Farmers often discontinue the practice before enough favorable response is obtained to convince them that they must utilize the practice each year, knowing
very well that they will not get any benefit in half or more of the years. As already discussed the most effective tillage methods for increasing infiltration are those that maintain crop residues on the soil surface. In general furrow diking is not needed in those situations.

Effective erosion control and runoff conservation may involve a combination of practices. As mentioned earlier maintaining all or most residues on the surface can increase infiltration rates and reduce erosion if sufficient residues are present. However, for erosion control, terraces may also be recommended, depending on soil type, slope, and slope length. Fewer terraces may be required if conservation tillage systems are used.

Summary

Crop production in semiarid temperate zones requires specialized moisture management practices that impact one or more of the three components of successful dryland management systems identified in the introduction.

- Retaining precipitation on the land by using surface management techniques such as terracing, contouring, and furrow diking; by using tillage to break crusts or relieve compacted layers in the soil, thus improving infiltration; or by adopting reduced or no-tillage management systems to retain some or all crop residues on the surface.
- Reducing evaporation by using tillage systems that retain crop residues on the surface; by reducing tillage frequency and intensity; and by using more intensive cropping systems with less fallow.

By retaining rainfall and reducing evaporation, yields of currently grown adapted crops can be increased and it may be possible to grow alternative crops not previously grown in the region.

References


Soil Fertility Management for Intensive Agriculture in the Humid Tropics

Christian Pieri

Introduction

Soil fertility management is or may become a major consideration as it is expected that 75 percent of future increase in production (Crosson and Anderson 1992) will have to come from increased productivity of the 730 million hectares of these soils already cultivated. It is, of course, recognized that soil productivity is affected in many ways by the widely varying socioeconomic circumstances under which farming is practiced in the tropics. Rates of population growth and the associated pressure on the land, land titles, and difficult access to inputs may, in many cases, mean that sound practices of soil fertility management are simply not economical, at least given the resources to which the concerned farmers have access.

This paper focuses on technical and related matters concerning the contribution of soil fertility per se and its management in intensive agricultural production in the humid tropics.

The main aim of soil fertility management for intensive agriculture in the humid tropics from a technological perspective is the maintenance of the newly upgraded soil qualities to raise the inherent low soil productivity and to prevent more severe degradation symptoms such as erosion. Conservation tillage might well offer the best opportunity to reach that aim.

In the first section, through selected examples, the nature of the soil fertility problem in the humid tropics is identified, together with the major issues to be addressed in managing the soils under intensive, permanent methods of rainfed agriculture.

The second section analyzes the potential of some conservation tillage practices in soil fertility management and the maintenance of a high level of crop productivity. The case of Brazilian cerrados will be used as an example to analyze the constraints and potential of mulch farming in maintaining the soil fertility resource in a sustainable form for long-term productivity.

The last section summarizes the significance and application of the scientific findings for the World Bank in terms of actions and research agenda.

The Problem of Soil Fertility Management in the Humid Tropics

The humid tropics refer to areas where the average annual temperature is higher than 18°C and the length of the growing season exceeds 270 days in a year (Buringh and Dudal 1987) or according to Greenland and Lal (1977) where the rainfall exceeds evaporation for at least 7½ months in the year.

Oxisols and ultisols comprise two-thirds of the humid tropical land mass (Sanchez 1989). The primary constraints to plant production on these soils are low nutrient reserves and aluminum toxicity (table 1).

The following section discusses some of the challenges of managing soil fertility. The concept of soil fertility is discussed as well as building the fertility of acid soils and maintaining soil fertility in the humid tropics.
Table 1. Extent of Major Soil Constraints in the Humid Tropics

<table>
<thead>
<tr>
<th>Soil constraint</th>
<th>10^8 hectares</th>
<th>Percent of humid tropics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low nutrient reserves</td>
<td>980</td>
<td>66</td>
</tr>
<tr>
<td>Al toxicity</td>
<td>850</td>
<td>57</td>
</tr>
<tr>
<td>High P fixation</td>
<td>565</td>
<td>38</td>
</tr>
<tr>
<td>Acid, but not Al toxic</td>
<td>270</td>
<td>18</td>
</tr>
<tr>
<td>High erodibility</td>
<td>255</td>
<td>17</td>
</tr>
<tr>
<td>Poor drainage</td>
<td>195</td>
<td>13</td>
</tr>
<tr>
<td>Low CEC</td>
<td>165</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: Sanchez 1989.

Soil Fertility Concept

In agriculture, soil is best thought of as a renewable resource. As the soil resource is used over time, it may increase or diminish in its inherent productivity. Soil fertility is a concept for the evaluation of the inherent plant production capacity of the soil resource and its evolution under given climatic conditions and current farming practices.

The literature in soil science and related disciplines is rich in providing attributes of soil systems that are influential in controlling the soil fertility experienced by plants growing on such soils. In essence, these attributes are: (a) nutrient reserves and availability; (b) physical factors such as structure, porosity, and compaction that control the access of the plant roots to water, air and nutrients; and (c) the systems of physico-chemical regulation (that is acidity-alkalinity, redox potential) and the systems of biological regulation at rhizosphere and soil organic matter level (Swift 1987), which facilitate the synchronization of moisture and nutrients released from the soil to the plant (Ingram and Swift 1989).

Soil fertility is not a static concept; it is the dynamic interaction of these attributes, as influenced by climate and cultural practices. Thus, from an initial static concept of soil richness, referring principally to available nutrient reserves in soils, soil fertility is best described now as an evaluation of the status of the "replenishment system" (Tilton and Skinner 1987; Sebillotte 1989), which maintains the soil renewable resource in a sustainable form for long-term productivity.

In practice, the problem of soil fertility management for intensive agriculture in the humid tropics should be analyzed from two different and complementary aspects; (a) the initial detection and correction of the inherent soil constraints as listed in table 1, and (b) the maintenance of improved soil qualities for sustainable crop production.

Building the Fertility of Acid Soils

A vast amount of scientific and practical knowledge has been accumulated for 30 years on identification, distribution, and extent of the major constraints of acid and infertile oxisols and ultisols in the humid tropics. Appropriate technology to overcome soil chemical constraints is available and has been implemented (Sanchez 1976).

Practical recommendations for the determination of lime requirement and the control of aluminum toxicity based on soil analysis and crop tolerance (Kamprath 1972) have been defined and
adapted to local conditions. Scientists have demonstrated that aluminum activity in the soil solution is the best estimate of potential aluminum toxicity. It can be easily determined by measuring the ratio of exchangeable aluminum over the sum of exchangeable cations (Σ). One practical consequence is that aluminum toxicity can be decreased not only by the pH effect of liming products, but also by application of organic and inorganic fertilizers increasing the concentration of calcium (Ca), magnesium (Mg), and potassium (K) in soils, resulting in a decrease of Al/Σ ratio (Mengel and Kirby 1978).

Intensive work also has been carried out on phosphate availability and phosphorus (P) requirement in soils, particularly for oxisols and ultisols. These soils are rich in sesquioxides of iron or aluminum and have a high capacity for phosphate fixation, so that the availability to plants of phosphorus (native or applied) is usually very low (Fox and others 1974; Sanchez 1976). Thus, the P requirements have been assessed consequently in reference to P content in soil solution as influenced by crop, soil, and fertilizer management (Fox 1988). In addition, the potential use of different forms of P fertilizers has been studied, including the assessment of the agronomic value of unacidulated and partially acidulated indigenous rocks phosphate (Hammond, Chien, and Mokwunye 1986). Similarly, specific recommendations are available for the correction of other common nutrient deficiencies in cultivated oxisols, such as potassium (Cooke 1985), sulphur (Blair 1979), and zinc (Giordano and Morvedt 1972), the three most common other than phosphate.

From the perspective taken in this paper, I conclude that for a long time the attention of scientists and agronomists has been focused on the building of soil fertility and cannot be considered now as a major technical issue, even if local adaptation of the recommendations is sometimes required. The main problem for most farmers in the humid tropics, who want to improve the low inherent productivity of their fields, is clearly limited access to the required inputs attributable to unfavorable economic conditions and lack of infrastructure for efficient procurement (FAO 1987; Schultz and Parish 1989).

Strengthening the fertilizer sector in tropical countries, and particularly in Africa (Yates and Kiss 1993), is certainly an answer to this problem. It is beyond the scope of this short paper to address this issue, which has received full attention in many Asian countries with significant success (Soedjias 1991).

**Maintaining Soil Fertility in the Humid Tropics**

Once restored or rebuilt, favorable soil qualities should be maintained for sustainable intensive plant production. Three major causes influence the evolution of soil properties in humid tropical conditions.

**Water Balance**

The water balance is positive during most of the growing season, resulting in periodic excess of water in the soil surface, inducing runoff and drainage. The impact on the nutrient losses have been measured at field level under different cropping systems and reported by several authors (Sanchez 1976; Roose 1977). The loss of soluble nutrients by leaching has a significant impact on the nutrient balance of amended and fertilized fields, as illustrated by an example from Madagascar in table 2. Losses of nutrients by runoff and sheet erosion assessed during a fifteen-year period in Madagascar resulted mainly from the nearly 1 percent annual loss of soil organic matter from the soil surface (412 kilograms/hectare/year during 1958-83). Such soil organic matter loss may exceed 5 percent on recently cleared forested areas (Sanchez 1976).
Table 2. Nutrients Balance in Heavily Fertilized Maize Fields in Ampangabe (Madagascar) for a Three-Year Period (1975-78)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>K₂O</th>
<th>CaO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer application</td>
<td>+480.0</td>
<td>+180.0</td>
<td>+1,400.0</td>
</tr>
<tr>
<td>Crop residues rest.</td>
<td>+149.5</td>
<td>+109.1</td>
<td>+56.9</td>
</tr>
<tr>
<td>Crop uptake</td>
<td>-251.7</td>
<td>-142.0</td>
<td>-59.2</td>
</tr>
<tr>
<td>Leaching</td>
<td>-196.0</td>
<td>-40.4</td>
<td>-81.6</td>
</tr>
<tr>
<td>Balance (3 years)</td>
<td>+182.0</td>
<td>+107.0</td>
<td>+1,316.0</td>
</tr>
</tbody>
</table>


In oxisols and ultisols with limited nutrient reserves, the resulting negative nutrient balance is quickly reflected by soil chemical characteristics and by soil pH. Szott, Palm, and Sanchez (1991) observed that 40 percent of the available reserve of calcium and magnesium in the top layer (0-15 centimeters) was lost within 12 months under alley cropping systems introduced in the Yurimaguas region (Peru). They measured similar changes in the total nutrient stocks (living biomass, litter, and soil) under different fallow management systems, and then noted that the "lost calcium and magnesium may have accumulated below the 45 cm sample depth and may eventually be recycled by deep-rooted species...however, this would require a relatively long period time." Finally, the authors concluded that "such apparent losses seriously call into question the long term sustainability" of alley cropping and managed fallow systems, unless periodic applications of lime fertilizers are made as required by annual crops.

Thus, the maintenance of soil pH and soil nutrients reserve in the humid tropics has to be implemented through the periodic application of amendments, which is based not only on the calculation of nutrient uptake by crops but also on the assessment of mineral losses by leaching, principally for nitrates, calcium, and magnesium. Such an assessment requires more than the limited data now available, such as the estimates made recently by FAO on the nutrient balance in Sub-Saharan African countries. More basic data are required to assess, particularly in the humid tropics, the contribution of nutrients lost by leaching and erosion to the change of the nutrient balance, as measured by the model that has been set up (Stoorvogel and Smaling 1990).

Soil Organic Matter Oxidation

The increase of soil organic matter oxidation is well documented and annual decomposition rates in the humid tropics range from less than 1 percent to more than 10 percent according to some soil and crop management systems (Sanchez 1976). Very high "decomposition rates" (12.8 percent reported in Zaire by Sanchez) result from the combination of loss by erosion, decrease in annual addition of fresh organic matter, and oxidation of the soil organic matter (2 to 4 percent on average).

In contrast with traditional shifting cultivation with long periods of fallow (Greenland 1970), settled agriculture increases the rate of soil organic matter loss, not only on the surface but also in the deeper layer of the soil profile.

Annual cropping compared to perennial cropping systems, increases the rate of organic matter decomposition as illustrated by figure 1. This phenomenon is quite general: most of the soil organic matter is lost at the inception of cultivation cycles. This pattern is well illustrated by recent data from
the Yurimaguas experiments (figure 2). Moreover these data prove that soil fauna management, as experienced by earthworm inoculation, does not fundamentally change this pattern (Lavelle, Gilot, and Fragoso 1992).

In conclusion, if it is generally admitted that the maintenance of soil organic matter is of fundamental importance for no-fertilizer agriculture, it is also true that organic matter is a key soil attribute for the maintenance of soil fertility in low-cation exchange capacity (CEC) soils, such as oxisols and ultisols. Most of the negative charges (holding cations) are in the organic radicals. The soil structure and porosity of these soils are also largely dependent on the presence of organic binders, which bridge the aggregates and particles in soils dominated by low activity clays (Greenland and Lal 1977; Sanchez 1976).

Thus, for intensive agriculture under rainfed conditions and annual cropping, soil fertility management should be first targeted toward the maintenance of soil organic matter in such a way that the "replenishment system" of the soil resource is maintained for the long term.

Soil Tillage

Soil tillage is a major cause of changes in soil characteristic, because it influences directly the physical properties (structure, porosity, mechanical resistance) of the soil surface, and indirectly the whole hydric and temperature soil regimes controlling soil organic matter balance, root development, and nutrient availability.

A typical example is given in figure 3, which illustrates the impact of soil preparation methods on soil mechanical resistance to penetration in the context of the mechanized agriculture in the Brazilian cerrados region. The soil compaction induced in this case by continuous diskng has favored water runoff and erosion, which resulted in the loss of most of the initial costly corrective application of lime and phosphate, causing finally poor root development (table 3), and poor yields (Séguy, Bouzinac, and Matsubara 1992).

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Soil bulk density</th>
<th>Soybean root density*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disking (g/cc)</td>
<td>Plowing (g/dm³)</td>
</tr>
<tr>
<td>0-15</td>
<td>1.19</td>
<td>1.01</td>
</tr>
<tr>
<td>15-30</td>
<td>1.30</td>
<td>1.23</td>
</tr>
<tr>
<td>30-40</td>
<td>1.42</td>
<td>1.22</td>
</tr>
<tr>
<td>40-50</td>
<td>1.20</td>
<td>1.20</td>
</tr>
</tbody>
</table>

* Variety DOKO, 50 days after planting.
Figure 1. Change in Soil Carbon Content After a Fifteen-Year Period, Under Different Farming Systems, Akpanadoure, Benin

(Source = IRHO, 1992)

Figure 2. Effects of Earthworm Inoculation on Grain Production in a Continuous Maize Crop at Yurimaguas
In summary soil fertility management cannot be thought of only in terms of nutrient application in inorganic or organic forms to maintain the mineral and organic balance of cultivated soils. Tillage methods are of fundamental importance for the maintenance of good physical qualities of cultivated soils and the subsequent efficiency of the nutrients applied for improved plants. Tillage methods must be considered as indispensable to any soil fertility management, particularly in soils prone to compaction and erosion such as oxisols and ultisols.

What Is the Main Problem?

The major chemical soil constraints limiting plant growth are well known and the basic scientific and technical knowledge is available to overcome the soil acidity problem and the nutrient deficiencies, principally phosphorus. The implementation of this investment in soil fertility building is seriously limited by a broad web of socioeconomic factors, which are beyond the scope of this paper.

The main problem of soil fertility management for intensive agriculture in the humid tropics, from a technological point of view, is principally the maintenance of the newly induced favorable soil qualities that have to be created in oxisols and ultisols to raise their inherent low productivity.

This improved fertility must be maintained in spite of the difficulties of leaching induced by surplus rainfall, of the rapid turnover of soil organic matter, and of the poor buffering capacity of these soils -- significant decreases in pH and soil nutrient reserves are observed within months following lime and fertilizer applications.
From this technical perspective, it can then be noted that there is not a clear boundary between soil fertility decline and severe soil degradation symptoms such as erosion, which are both influenced by the same climatic and edaphologic conditions. The possible linkage between soil fertility decline and further soil erosion is supported by scientific analysis (Hudson and Jackson 1959; Lal 1990; Pieri 1992) in different agroecological circumstances.

It may also be consistent with the Bank's past experience. Among the 180 agriculture and forest projects analyzed by the Operations Evaluation Department (OED), entitled Renewable Resource Management in Agriculture (1989), it is very obvious that there are virtually no references to soil fertility. Dramatic symptoms of land degradation, such as erosion, deforestation, and weed infestation have been recognized as a major issue for only 8 percent of the projects. However, if soil fertility is never cited as an issue in this survey related to past Bank-financed projects, there is an implicit acknowledgment that it could be or become a potential problem. Such a concern is now clearly reflected in several of the Bank's more recent publications (Carr 1989; Meyers 1989; Anderson and Thampapillai 1990; World Development Report 1992; Yates and Kiss 1993).

**Improved Soil Fertility Management and Conservation Tillage**

In humid tropics, shifting agriculture based upon partial deforestation and complex mixed cropping has provided, and will continue to provide, a sustained soil productivity and a satisfactory maintenance of soil fertility, as long as low population density and available good farmland allows a long fallow period (Greenland 1970; Sanchez 1976).

Is there currently any sound alternative for intensive and settled agriculture? In the context of this paper, it has not been possible to address all the potential forms of intervening in soil fertility management in the humid tropics.

Among a broad range of techniques generally known as "conservation tillage" (Lal 1989), it has been suggested that direct planting in crop residues and/or permanent mulch cover with minimum or no-tillage and proper crop-rotation have the highest potential for sustainable soil fertility management under intensive agricultural conditions.

Attention was first directed to no-tillage in the late 1940s with the appearance of growth regulators, and more intensively in the 1960s with the commercial availability of contact herbicide (Paraquat), with no tillage planters, and fertilizer applicators (Phillips, Thomas, and Blevins 1980; Phillips and Phillips 1984). Several attempts to develop corresponding conservation tillage methods for the tropics have been reported in recent publications (Crovetto 1992), and especially for the humid tropics (Lal 1989; Sheng and Meiman 1991).

The case of Brazilian cerrados where such methods have been recently implemented by commercial soybean and grain producers on a significant scale (more than 20,000 hectares) is relevant. The following briefly reviews the major technical findings from this experience to demonstrate the potential of mulch farming as a soil fertility management system eventually suitable for intensive agriculture in the humid tropics. The information presented here has been principally drawn from Séguy, Bouzinac, and Pieri (1991) and Séguy, Bouzinac, and Matsubara (1992).

**Technical Constraints to Direct Planting Methods on Mulch Cover in the Brazilian Cerrados**

Three problems have to be solved for implementing no tillage methods in the humid tropics. First, one has to find a suitable mulch cover where warm and humid conditions favor the rate of decomposition of crop residues in the field, resulting in an insufficient protection of the soil top layer.
Thirty days after the onset of rain, the soil coverage measured on farmers’ fields (Fazenda Progresso, Mato Grosso State) was no more than, 54, 46, and 16 percent respectively for maize, rice, and soybean residues. Two months later the soil coverage was equal to 30, 38, and 7 percent, respectively.

Among a large set of technical experiments at field level, a mixed sowing of a commercial crop (40 to 50 kilograms/hectare of upland rice seeds) and a cover crop (4 to 6 kilograms/hectare of Calopogonium mucunoides) was found to be the best alternative. When planted, Calopogonium (a) has an initial slow growth rate without competitive effect for upland rice; (b) ensures a good soil coverage (more than 80 percent) over time; (c) has a high potential for recycling nutrients and for biological nitrogen fixation (Giller and Wilson 1991); and (d) has a strong allelopathic impact on weeds such as Digitaria horizontalis, Digitaria insularis, Eleusina indica, and Enchinochloa colonum. At harvest time, the calopogonium seeds can be easily separated from rice grain (mechanical and/or manual harvest) producing 500 to 900 kilograms/hectare of seeds. Other mulch covers can be used, such as Macroptilium atropurpureum, Stilozobium aterrinum, and Dolichos lab.

A new and promising development is now considered by using some native weeds such as Paspalum notatum for mulch cover (and/or fodder to feed animals in mixed farming). Incidentally it can be noted that "weed management," appears to be a new field of research for scientists who have observed and assessed that total weeding, which is always recommended in modern agriculture, may not be the best alternative for soil fertility maintenance in the humid tropics (Ramakrishnan 1992). Results suggest that weeds below a particular density level (up to 20 percent of the total weed biomass) have positive impact on soil fertility by lowering nutrient leaching and runoff erosion.

**Herbicide management** is another key problem in no tillage systems. In general terms, two successive herbicide applications are required, one for weed cleaning before sowing, and one to control eventual weed development before the full establishment of the planted crops. Herbicide technology is evolving rapidly and new chemical formulas are tested regularly.

The last potential problem is the availability of appropriate equipment for sowing and fertilizer application through a thick layer of mulch cover. Such equipment is now available in Brazil, adapted to all conditions. Hand tools, oxen drawn and motorized implements for direct seeding, and fertilizer and lime localization are locally produced (Santa Catarina and Parana States) and are commercially available.

**Impact on Soil Characteristics**

For the Brazilian cerrados, data on soil characteristics as influenced by direct planting methods on mulch cover compared to other tillage methods are limited and are still incomplete. Emphasis has been given to some soil physical parameters controlling root development, water movement, and biological activity. The soils analyzed are fertilized adequately and amended, which is usually done by commercial farmers in the cerrados zone. Table 4 shows some results from the Fazenda Progresso (Mato Grosso State) where different tillage methods have been compared since 1985-86, on a significant scale (130 hectares).
Table 4. Comparison of Average Infiltration Rate for Different Tillage Practices  
(Fazenda Progresso, Mato Grosso, Brazil, 1989)

<table>
<thead>
<tr>
<th>Tillage practices</th>
<th>Infiltration rate (centimeters/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous disking</td>
<td>28.4</td>
</tr>
<tr>
<td>No tillage without permanent mulch cover</td>
<td>29.6</td>
</tr>
<tr>
<td>Chiselling</td>
<td>34.0</td>
</tr>
<tr>
<td>Plowing (onset of the rainy season)</td>
<td>45.0</td>
</tr>
<tr>
<td>No tillage on <em>Calopogonium</em> + crop residues</td>
<td>48.2</td>
</tr>
<tr>
<td>Plowing (following harvest)</td>
<td>54.3</td>
</tr>
</tbody>
</table>


Direct planting on permanent plant cover provides satisfactory physical soil characteristics. Soil biological activity also is increased (table 5). The few chemical data available indicate that the pattern of nutrient distribution in the soil profile is modified more by conventional plowing than by direct planting methods or continuous disking (figure 4).

Economic and Technical Results

The Fazenda Progresso experience indicates that sustainable high yields are achievable as long as continuous disking and monocropping are replaced by deep plowing or no-tillage systems on permanent vegetative cover, such as *Calopogonium mucunoides*, associated with crop rotations (table 6).

Table 5. Measurements of Microbiological Activity for Two Types of Soil Preparation  
(Fazenda Progresso, Mato Grosso, Brazil, 1989)

<table>
<thead>
<tr>
<th>Tillage practices</th>
<th>Centimeters</th>
<th>Microorganisms per gram of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry season</td>
<td>Rainy season*</td>
</tr>
<tr>
<td>Plowing (after harvest)</td>
<td>0-10</td>
<td>1.2 x 10^5</td>
</tr>
<tr>
<td></td>
<td>10-20</td>
<td>1.2 x 10^5</td>
</tr>
<tr>
<td>No tillage on <em>Calopogonium</em> and crop residues</td>
<td>0-10</td>
<td>4.8 x 10^5</td>
</tr>
<tr>
<td></td>
<td>10-20</td>
<td>1.6 x 10^5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.7 x 10^5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.1 x 10^5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50.0 x 10^6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.4 x 10^5</td>
</tr>
</tbody>
</table>

* One month after the beginning of the rainy season (240 millimeters; 12 percent annual rainfall).  
Figure 4. Content of Soil Exchangeable Calcium and Magnesium for Different Tillage Practices, Compared to Initial Content in Native Cerrado Soil (Oxisol in Fazenda Progresso, Mato Grosso, Brazil, 1988)

On average, during the period 1986-92, these two systems provided similar yields of soybean (table 7) and maize. In contrast, upland rice is a crop not adapted to direct planting because it is very dependant on soil macroporosity and deep plowing (figure 5).

Costs of production have been calculated during the same period. No decisive advantage in favor of one or the other method of tillage has been observed. The average cost of land preparation (including the pre-emergence herbicide application) is approximately the same: US$45 per hectare, representing only 10 percent of the total cost of production.

An additional advantage cited by Brazilian farmers using these new techniques is the flexibility provided by direct planting methods. Field trafficability is increased on mulch cover and time of land preparation and seeding is substantially decreased per hectare -- direct planting - 1.4 hour; disking - 3.6 hour; and plowing - 4.3 hour -- as measured in Fazenda Progresso.

From this commercial experience in the Brazilian cerrados, it appears that no-tillage and permanent vegetative cover is an attractive alternative to the traditional disking and monocropping systems. The maintenance of favorable physical and biological soil properties is easier to maintain. More work certainly has to be done to monitor the chemical status resulting from direct planting methods under humid tropical conditions. High yields of soybean, upland rice, and maize can be achieved with both deep plowing systems, and no-tillage systems.

At this stage of experience it should be noted that both systems induce specific risks when the managerial and technical capacity of farmers are not sufficient. There is the risk of erosion induced by an inadequate plowing, the risk of pests (mulch cover is a niche for insects), and of weed infestation linked to improper use of pesticides.

Two surveys to assess the acceptability of the different components of conservation tillage initiated in Fazenda Progresso have been carried out in 1990 and in 1991. The first survey was run in the immediate surroundings of the Fazenda (total area surveyed 17,123 hectares; 57 farms); the second survey covered 2.6 million hectares (Mato Grosso State, center and southeast). Remote sensing analysis (Spot image) complemented a ground survey. Among the chief conclusions, it appears that from 1985 on (a) deep plowing progressively replaced disking (42 percent of soybean...

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop and soil management</td>
<td>Crops Yield (kg/ha⁻¹)</td>
<td>Crops Yield (kg/ha⁻¹)</td>
<td>Crops Yield (kg/ha⁻¹)</td>
<td>Crops Yield (kg/ha⁻¹)</td>
</tr>
<tr>
<td>Sowing of a mixture of rice and C. mucunoides. Rice yield = 3,225 kg ha⁻¹</td>
<td>Deep plowing</td>
<td>Fertilized with NPK⁺ at seeding</td>
<td>Soybean 1,215</td>
<td>Maize 4,700</td>
</tr>
<tr>
<td>Deep plowing</td>
<td>Thermo-phosphate Yoorin Bz 1500 kg ha⁻¹ b</td>
<td>Soybean 1,440</td>
<td>Maize 6,500</td>
<td>Soybean 900⁺</td>
</tr>
<tr>
<td>Soil cover at the end of the dry season (straws of rice + C. mucunoides) = 12.5 t ha⁻¹</td>
<td>Direct planting</td>
<td>Fertilized with NPK⁺ at seeding</td>
<td>Soybean 2,040</td>
<td>Maize 5,200</td>
</tr>
<tr>
<td>Direct planting</td>
<td>Thermo-phosphate Yoorin Bz 1500 kg ha⁻¹ b</td>
<td>Soybean 2,486</td>
<td>Maize 6,400</td>
<td>Soybean 2,947</td>
</tr>
<tr>
<td>There is natural dissemination of C. mucunoides the following years</td>
<td>Direct planting</td>
<td>Thermo-phosphate Yoorin Bz 1500 kg ha⁻¹ b</td>
<td>Soybean 2,486</td>
<td>Maize 6,400</td>
</tr>
</tbody>
</table>

⁻ NPK fertilizer placed at seeding
⁺ soybean: 350 kg ha⁻¹ 0-25-25
⁺⁺ maize: 350 kg ha⁻¹ 5-30-15- + 100 kg ha⁻¹ urea
b Fertilizer thermophosphate
  - 1,500 kg ha⁻¹ of Yoorin Bz applied in 1987 for three years complimented with N and K to achieve same level as⁺
⁺⁺ Plots dominated partly or totally by Calopogonium sp
Table 7. Impact of Different Tillage Practices and Crop Rotation on Soybean Production (Fazenda Progresso, Mato Grosso, Brazil 1992)

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>Disking</th>
<th>Plowing</th>
<th>No tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocropping</td>
<td>1,675</td>
<td>2,120</td>
<td>1,990</td>
</tr>
<tr>
<td></td>
<td>(100)</td>
<td>(127)</td>
<td>(119)</td>
</tr>
<tr>
<td>Soybean + rice</td>
<td>2,564</td>
<td>3,092</td>
<td>3,041</td>
</tr>
<tr>
<td></td>
<td>(153)</td>
<td>(185)</td>
<td>(182)</td>
</tr>
<tr>
<td>Soybean + maize</td>
<td>2,850</td>
<td>3,010</td>
<td>3,057</td>
</tr>
<tr>
<td></td>
<td>(170)</td>
<td>(180)</td>
<td>(183)</td>
</tr>
</tbody>
</table>

Source: Séguy, Bouzinac, and Matsubara 1992

seedbeds are plowed); (b) crop rotations replaced monocropping particularly in maize growing farms; and (c) direct planting methods were used only on 4 percent of the total area, but many farmers (65 percent) are trying them. These first surveys suggest that direct planting methods are raising expectations among farmers.

More and more scientists (Kang, Wilson, and Lawson 1984; El Swaify, Singh, and Pathak 1987; Lal 1987; Sanchez, Palm, and Smyth 1990; Crovetto 1992) also have come to the conclusion that direct planting methods on mulch cover are cost effective in containing soil degradation, maintaining soil fertility level, and sustaining soil productivity in the humid tropics. However, much of this work has not gone beyond scientific investigation and predevelopment. It must be concluded that more experience is required and should be encouraged to implement and assess such methods in both commercial and, even more so, in present smallholder agriculture.

Conclusions

What then can we learn from a more focused attention on the question of soil fertility management in World Bank agricultural project work? The socioeconomic circumstances of particular farming systems are so diverse that there can be few general conclusions and what makes most sense in any particular circumstance must be adapted to the local situation (Tourte 1984; Binswanger 1980).

It is thus a complex policy issue to look at systems of effective soil fertility intervention to maintain the soil resource in a sustainable form for long-term productivity, particularly, in the context of intensive settled agriculture under rainfed conditions (IBSRAM 1991).

However, from the scientific findings and practical experiences presented in this paper, it is necessary to stress three implications for the Bank's actions and research agenda. First, a few principles should guide our thinking about the soil fertility dimension in project work. The documented experience is substantial in indicating that, in many tropical situations, it is most cost-effective to intervene early in terms of maintaining soil "chemical fertility" and related structural
elements, such as organic matter content, because the longer such intervention is delayed, the more expensive, and thus sometimes impossible, any such replenishment of the system becomes.

Figure 5a. Effects of Tillage Practices on Maize Yields (Average Six Years, 1986-92), Fazenda Progresso, Brazil (Seguy, Bouzinac, and Matsubara 1992)

Figure 5b. Effects of Tillage Practices on Upland Rice Yields (Average Five Years, in 1986-91), Fazenda Progresso, Brazil (Seguy, Bouzinac, and Matsubara 1992)
With this guiding principle, the possibility should be considered during project design that the soil fertility resource is declining early in the project cycle and even before the symptoms of extreme degradation, for example, erosion becomes highly evident, as suggested by the Brazilian cerrados experience.

This is presented here as hypothesis and it would be instructive if more Bank projects could be examined carefully to explore its validity, under differing farming conditions of the humid tropical agroecological world to begin with.

Second, a related question is, do we know how to measure change in soil fertility? As already noted, the literature of soil science and related disciplines is rich in defining the attributes of soil systems that influence soil fertility as measured by plants growing on such soils on experimental plots or sites. The problem is that there is as yet no successful integration of these diverse measurable aspects that leads to effective low cost implementation over large project areas where soil fertility interventions may well be contemplated.

Recently, Australian scientists (Hamblin 1992) have addressed this issue on an agroecological basis "to improve the ability of providing land holders and managers with early warnings of ecological deterioration and productivity loss." For each region, they strive (a) to select only three indicators on which the others depend; (b) to develop the reasons (hierarchy) for the selection; and (c) to identify the process or methodology for obtaining and using the information.

Table 8 illustrates the selection made for a region dominated by mixed cropping under rainfed conditions. The first two indicators are related to the productivity of soils as influenced by climatic and edaphic factors. Certainly nutrient balances calculated at regional levels can be a relevant indicator of possible change in soil fertility (Stoorvogel and Smaling 1990; Andre 1990). Experience in Burkina Faso is certainly noncontroversial in this regard (table 9) but just how relevant that set of findings is to other agroecological zones must, for the moment, remain an open question.

**Table 8. Three Most Important Primary Indicators of Sustainable Agriculture in Rainfed Crop and Animal Production Region**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Why</th>
<th>Process/Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water use efficiency</td>
<td>Easy to relate production to rainfall; useable for both crops and pastures</td>
<td>Yield (kilograms/rainfall; useable for both millimeters/hectares); at scales of farm, shire, and region to detect trends in time and between areas</td>
</tr>
<tr>
<td>2. Soil health</td>
<td>A direct expression of sustainability of system</td>
<td>Soil analysis of pH (trends) nutrient balance; direct measurement of worm counts, surveys of microflora</td>
</tr>
<tr>
<td>3. Farm management skills</td>
<td>Understanding needed before change occurs; good level required for financial survival</td>
<td>Farm records and farm surveys; units of cash flow, debt equity, whole-farm planning</td>
</tr>
</tbody>
</table>

*Source: Hamblin 1992*
Thus, there seems to be a major gap in the knowledge of soil fertility management systems pertaining to workable indicators for guiding interventions at the project level. Hence, there is at first sight a case for a research program dedicated to identifying such pragmatic indicators and testing them in project implementation.

I suggest that we organize a working group to clearly identify the specific needs related to soil fertility management and soil fertility monitoring in the Bank’s current lending program, to summarize the scientific state of knowledge in these matters, and to identify ways of bridging the gap between what is known and what is needed at operation level.

Third, in the last *World Development Report 1992*, it is clearly indicated that preserving soil fertility cannot be envisaged in isolation from the management of other natural resources: water, natural vegetative covers, and fauna, which are jointly exploited on the same surface area.

In order to progress beyond the relatively simple step of building up soil fertility, and to foster intensive agriculture in the humid tropics it will be necessary to develop transitional cropping and farming systems for each specific condition. Conservation farming might well offer the best opportunity to reach that aim.

The technical dimensions of conservation farming run the full gamut of mechanical innovations and hence, mechanization policy in general, to biological control systems, including a more effective use of herbicides and farmers’ access to them, and finally to advances in biotechnology (such as the development of herbicide-resistant crop cultivars). The most promising of these new technologies is direct planting in permanent vegetative cover. This has been substantiated by research and is being adopted by increasing numbers of farmers around the world. More experience has to be gained and analyzed at an operational scale to identify the technical and socioeconomic constraints to the practical implementation of conservation tillage methods. This experience surely will be influential in determining more effective intervention for maintaining soil fertility and a high level of soil productivity in the humid tropics.

### Table 9. Course of Yields with Fertilizer Treatment and Fertilizer Efficiency at Six Young Farmer Centers in Burkina Faso

<table>
<thead>
<tr>
<th>Rotation no. (Course no.)</th>
<th>Yield (kilograms/hectares)</th>
<th>Fertilizer rate (kilograms/hectares)</th>
<th>Efficiency (yield/N + P₂O₅ + K₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P₂O₅</td>
<td>K₂O</td>
</tr>
<tr>
<td>1 (1st)</td>
<td>2,060</td>
<td>20</td>
<td>31</td>
</tr>
<tr>
<td>2 (4th)</td>
<td>1,546</td>
<td>20</td>
<td>31</td>
</tr>
<tr>
<td>3 (7th)</td>
<td>1,437</td>
<td>69</td>
<td>82</td>
</tr>
<tr>
<td>4 (10th)</td>
<td>1,514</td>
<td>107</td>
<td>116</td>
</tr>
<tr>
<td>5 (13th)</td>
<td>1,445</td>
<td>107</td>
<td>116</td>
</tr>
</tbody>
</table>

*Source: According to Hien in Pieri 1992.*

### References


Preserving the Options
International Research for Sustainable Agriculture

Hubert G. Zandstra*

Somehow the global food production system must keep pace with the demand that 90 million new mouths place on it every year. In addition the natural resource base -- land, water, and plant and animal species -- must be preserved, and eventually upgraded to satisfy food needs 100 years from now.

Increased productivity in agriculture is central to reducing damage to the resource base. The technologies required to raise productivity while conserving natural resources will come from agricultural research, the domain of national research systems and the CGIAR centers.

The CGIAR centers have formulated their response to Agenda 21 of the United Nations Conference on Environment and Development (UNCED). They will increase emphasis on ecologies that are particularly threatened. Improved germplasm and management techniques will, however, remain the source for technologies to improve land-use systems. The author expects that commodity, factor, land use, and policy research for increased productivity will become more participatory and will include measures for conservation and rehabilitation of biotic, land, and water resources for specific watershed or farm conditions.

The CGIAR is developing an ecoregional approach for this purpose. It will facilitate the combination of capabilities of several CGIAR centers to address problems in threatened ecologies. It will also evolve the CGIAR’s modus operandi toward one of increased participation of national research and development organizations with a wide range of capabilities including ecology, farmer organizations, natural resource policy, and nature conservation.

The FAO estimates that the land’s carrying capacity is severely challenged in many of the more marginal ecologies of the world, such as parts of the humid tropics and the tropical mountain regions of the Andes, the Himalayas, and the Eastern African highlands. In much of the industrialized world, artificially high prices have led to excessive use of agricultural chemicals causing environmental pollution. In developing countries the lack of fertilizer of any kind is reducing crop yields, ground cover, and the rate of regrowth of native vegetation during fallow periods. This increases soil loss and people migrate to new, marginal, highly erodible land in much of the developing countries. And as the natural resource base deteriorates, it becomes ever more difficult to provide for an increased population.

The impact of greater demand for food and fuel for the rapidly growing number of poor is not confined to land and water resources. It also threatens the diversity of plant and animal life. Genetic diversity of crops has been the main source for progress in agriculture over the last seventy-five years, and holds the promise for reducing future dependency of agriculture on toxic chemicals for pest control.

* Hubert Zandstra is Director General of the International Potato Center in Lima, Peru and presently chairman of the Consultative Group on International Agricultural Research’s (CGIAR) committee on sustainability and environment.
Interconnected Challenges

Three of the major problems confronting humankind -- poverty, the environment, and population growth -- are closely interrelated (Murqueito 1992). Poverty is demonstrably toxic to the environment, for example, as the poor press on forest margins and fragile lands in pursuit of food. And while there are programs focused on health and education for women, which have reduced population growth rates, clearly population growth is slowed most effectively by higher incomes. Also higher incomes provide the resources for health and education programs. Finally, in the longer run, environmental degradation will limit income growth through its impact on the resource base. The three problems, then, form a complex nexus with poverty as the pivotal dimension.

Agricultural research can play a central role in resolving these problems through its impact on agricultural productivity and on the environment. Solutions to the poverty--environment--population nexus of problems in developing countries require economic growth. Growth alone may not be sufficient but it will be necessary. Growth, the direct answer to the poverty problem, is favored tremendously by declining real prices for foodstuffs as these lubricate the complex interactions that lead to economic growth. Indeed there are very few examples where growth has occurred without such price decline. Increased productivity in agriculture is central to lowering food prices. As well, increased productivity brings higher incomes to the sector, propelling ever widening demands and income streams. The resulting higher incomes will both slow degradation of the environment and population growth. Moreover, reduced population growth will itself favor the environment. Finally, improved management of agricultural activities, through the use of resource-conserving technologies, will directly reduce the impact of agriculture on the local, nearby, and global environments.

Sustainable Agriculture and Productivity

Of the many definitions of sustainable agriculture I would like to share the one the CGIAR has defined in 1987 as: "The successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources."

More recently the CGIAR committee on Sustainability and Environment has adopted the following definition of sustainable agriculture: "A sustainable agriculture is one that over the long term enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fibre needs, is economically viable and enhances the quality of life for farmers and society as a whole."

This definition stresses the changing human needs. It implies that the choices we make today about using resources will not be permanently maintained. Sustainable agriculture, however, will allow us to meet our present needs while maintaining or increasing our future options.

Between 1950 and the end of the century the average area of cropland per person is expected to drop from 0.24 to 0.13 hectares. Maintaining per capita food production at the present level will therefore require increases in yields. In addition the productivity of arable land is deteriorating through desertification, waterlogging and salinity, loss of topsoil, compaction, and accumulation of toxins.

Scientists also are predicting significant climate changes. It is well established that 25 percent of the world's population in the industrialized world generates nearly 75 percent of total carbon dioxide emissions thus contributing to eventual global warming. Rising temperatures due to atmospheric buildup of carbon dioxide and other greenhouse gasses have serious implications for
agriculture. Furthermore, a thinning of the earth’s protective ozone layer is allowing harmful ultraviolet radiation to strike the earth’s surface.

The result is that farmers must do more with less, not simply increase food production but also assure that the resource base is upgraded. Somehow the global food production system must keep pace with the demand that 90 million new mouths place on it every year. Second, the natural resource base — land, water, and plant species — must be preserved, and eventually upgraded, to fuel the agricultural giant that will have to satisfy the food demands of the future.

Agriculture therefore faces a double challenge — not only to increase productivity to meet food needs, but to assure that the resource base is preserved for the future.

World population has more than doubled since 1950 to reach about 5.4 billion. Growth is expected to continue until the end of the next century, when world population could reach from 10.2 to 14 billion. Nearly all this growth will take place in the developing countries.

The technologies required to raise productivity while conserving natural resources will come from agricultural research. It follows then that those who would reduce poverty, conserve natural resources, and slow population growth should see a well-functioning global agricultural research system as an effective vehicle for achieving their aims.

But increases in food production cannot be achieved by research alone. Economic and social conditions, and especially government policies, are limiting factors. Many governments now recognize that the present cost of protecting resources to conserve soil, water, and forests is lower than the cost of trying to restore them later after much environmental damage is done.

The CGIAR centers have put a heavy emphasis on research designed to help poor farmers, despite the evidence that returns in production are greater from research done on prime farmland. This is because the introduction of agriculture in less favorable areas has frequently resulted in environmental damage. Subsistence farmers cannot afford conservation programs. For them the greatest concern is survival. Yet increased demand for food will have to be met where the demand exists: not by developing the most favorable environment at the expense of the less favorable, but by helping the poorest become more productive.

Methodological Consequences of Natural Resource Management Research for Sustainable Increases in Agricultural Production

The increased attention for sustainability issues largely stems from the need to avoid degradation of the resource base on which agriculture depends and the deterioration of the quality of the environment, while assuring a continued increase in agricultural production to meet the demands of the growing world population on.

From its definition follows that sustainability is a comprehensive quality of a complex system. It, therefore, is not a simple parameter that can be directly measured. However, one could quantify the physical and biological processes occurring in a particular agroecosystem and quantify interactions between processes and components of the system. Researchers could then relate these processes and interactions to environmental and social conditions, and try to predict the behavior of such a system over time. Such approaches will require the use of comprehensive simulation models, at specified levels of input and based on certain assumptions with respect to social and environmental conditions, crop varieties, the incidence of pests and diseases, and so forth.

All physical and biological processes occurring in agroecosystems are functions of time and space. Therefore, time and space scales have to be defined before systems can be described and the sustainability of such systems can be assessed. It is important to note that the mathematical equations
or analytical models and measurement approaches used to describe physical and biological processes in agroecosystems may be fundamentally different between different time or space scales. This implies that information obtained from a specific set of time and space scales (for example, minutes and millimeters, or days and meters) is not necessarily relevant for another set of scales (for example, years and kilometers). For this reason, the assessment of sustainability for different scales would have to be distinguished. For example, if nutrients are transferred from surrounding grazing lands to agricultural lands in the form of animal manures, this may not be a sustainable system, as far as the grazing lands are concerned. However, this imbalance would not be noticed if one would only consider the farmer's field as the relevant unit. Similarly, on the scale of the region or country one could easily miss this nonsustainable practice.

In addition to the time and space scales, one has to define the agricultural systems in terms of inputs, outputs, soil, crop, environmental, and social conditions. If the initial and boundary conditions of a system are not specified, the behavior of that system over time cannot be described. For example, one has to indicate whether carbon dioxide contents, mean atmospheric temperatures, and crop genetic potentials can be taken as constant, and so on. Of course predictions can be made for different scenarios, but these examples illustrate that long-term predictions on the behavior of agricultural systems may be of limited value.

The long-term impact on the natural resources of a region from changes in agricultural practices or land-use systems is therefore difficult to ascertain. Nonetheless, there are obvious improvements that can be made to avoid deterioration of land qualities and biological diversity, without major challenges of measurement. These include among others, reduction of soil loss, prevention of toxins in the environment, improved nutrient use and cycling, and the use of multiple genetic backgrounds in cultivars.

For many of these practical interventions directed at the correction of obvious resource use problems, measurement can be relatively simple in terms of specific resource productivity such as yield or net returns per unit of soil phosphorus or millimeters of water (Zandstra and others 1986).

These concepts have been extended to those of total factor productivity (TFP) which when appropriate care is taken in capturing and costing all resources should reflect the comparative sustainability of land use alternatives. Pricing of resources and products would have to compensate for distortions such as subsidies, and demand induced changes in product prices. In most situations the best objective measure is therefore not a monetized value of production, but rather a physical one, such as yield, calories, protein, or grain.

The new approach to resource management research is based on four major considerations: (a) the need to integrate resource management research with research on crop and tree improvement and livestock husbandry, (b) the need to address human and technical dimensions in an integrated way, (c) the need to adopt a systems level approach and to plan and evaluate the component research from this viewpoint, and (d) the strategic need to link policy formulation to technology development and diffusion. This systems approach requires multidisciplinary teams of scientists in several disciplines of social, biological, physical, and/or engineering sciences, as well as capabilities: (a) soil sciences, including soil physics, chemistry and biology, and soil conservation and land management, (b) economics and social sciences, including human nutrition, (c) crop sciences, including agronomy, physiology, and plant nutrition, (d) plant pathology and entomology, (e) hydrology and water management, (f) forestry, including agroforestry and social forestry, (g) aquatic biology, (h) crop, tree, and livestock improvement, and in addition, (i) in mathematics, statistics and biometrics, simulation modeling, meteorology, and climatology. The research methodology can be described under three headings: (a) diagnostic research, (b) building inventories of component technologies, and (c) policy management for technology diffusion.
The starting point for resource management research is the diagnosis of the position of existing farming systems on the transition path from extensive to intensive agriculture. This diagnostic process includes the following steps:

- The characterization of the ecoregion by both physical and socioeconomic parameters to create a sampling framework to know where and to whom results are relevant and to where they can be extrapolated.
- The utilization of the diagnostic research in priority setting, including the selection of research thrusts based on urgency and generality of problems.
- The design of strategic experimental and laboratory research.

Building an inventory of resource management components requires a farming systems perspective in both formal agricultural experimentation and for the evaluation of indigenous technologies identified by farmers themselves. Formal experimental work as well as sources of indigenous technical knowledge will feed into inventories of resource management components, each with descriptors on the circumstances of farming systems conducive to its adoption and use by farmers in their systems. While some of the component technology research can be conducted on station, much of it will require community level participation in a well-defined location. Such "Heritage Research Sites" for natural resources management research have been prepared by CIP.

For the policy management for technology diffusion it is important to spell out the factors conditioning the behavior of small, resource poor farmers. All farmers, including resource poor ones, operate in a production environment in which policy is a key component in shaping their decisions. When policy changes create appropriate conditions to intensify, farmers shift their production strategy. Policy instruments of all types, but particularly market prices, input prices and subsidies, and credit access and subsidy, are useful to draw new technology into local farming systems to preempt falls in labor productivity. In most cases advances will be made in a stepwise fashion by the introduction of a sequence of new components that accumulate into sustainable and productive resource management systems.

**Institutional Consequences of Natural Resources Management Research for Sustainable Agriculture**

The research will have to be highly multidisciplinary and should therefore combine a range of institutions at the national, regional, and international level.

**Spatial Coverage**

The activity is generally focused on a major ecological condition, but it may cover ecological systems (recurrent combinations of ecologies that are strongly interdependent in their use of, and impact on natural resource systems). It may also focus on a predominant land-use system (for example, livestock production in the savannahs on acid weathered soils in South America).

The activity is developed within a region, or a contiguous area covering parts of more than one region. While this is so, consideration should be given to spill over effects to similar ecologies in different regions (for example, from the Andes to other areas of the cool mountainous tropics).
Commodity, Enterprise, and Factor coverage

The approach is designed to address major constraints to increasing sustainable production. It includes work on priority commodities, livestock, agroforestry, nutrient and soil management, and water management as part of research on improving land use systems, actual or potential. The work also includes a strong emphasis on policy and institutional aspects that affect the sustainability of land use.

Institutional Construct

The activity will be as structured as an interinstitutional initiative involving several international centers and a wide range of national research organizations selected for their capacity, commodity coverage, and location. The activity can be hosted by any international center that has advantage because of location, commodity, or other expertise.

The consortium will seek substantial involvement of national systems, their government, nongovernment, academic, and, where appropriate, commercial institutions. This involvement will result in a considerable devolution of research activities to institutions with advantage over others in terms of capability, location, or access. Participation will be open and based on merit.

The coverage, priorities, outputs, and institutional participation will be defined in a research planning process that involves all participating IARCs and NARS. The funding of agreed upon activities will predominantly be from existing sources, but will be supplemented from international and national sources as contract research or grants-in-aid to participants for collaborative (shared) work. Research will be planned in a way so that to the extent possible existing physical and human capabilities will be used.

The activity will have a governance that complements that of the participating institutions. It will normally have a steering committee, which is small, but represents members of all important participating groups. The steering committee assists the host institution in decisions involving the allocation of research tasks and funds. It approves a program of work and budget on a yearly basis and helps develop procedures for monitoring, internal and external reviews, and reporting.

Ecological Suicide

Traditional farming systems designed to feed small populations are failing to meet the needs of increasing populations. Unable to increase food output from limited resources, the poor are driven to farming practices that amount to ecological suicide: shortening bush fallows, extending cultivation to forest areas, and grazing more animals than the land can support. The intensification of agricultural production to meet growing needs can have undesirable environmental or ecological consequences and is contributing to the deterioration of natural resources and living conditions in the developing world.

There are two sides to the issue. First, we need to develop technologies that give farmers higher income and minimize environmental damage. Second, we need to produce as much food as possible on the most stable land so that people will not be literally driven into the hills because of lack of food. Experience has shown that it is possible to develop responsible agriculture.

Though worries about the environment have brought about changes in the world’s research agenda, reports of declining rice and cereal yields may eventually create a backlash. It is still uncertain whether a leveling off of yields is a short-term aberration due to unfavorable weather
conditions, or whether it is the beginning of a long-term trend that could have disastrous consequences. The loss of production momentum in Asia and the failure under stress of traditional systems of land use, combined with the depletion of nonrenewable natural resources, pose tremendous problems.

If the production lid is not lifted, the implications for the future are horrendous given the problem of feeding twice as many people just a few years from now. At the same time, if we don’t invest in our natural resources, we may one day lift the lid to find that the world’s food basket is nearly empty.

References


Endnotes


2. Some believe it cannot even be achieved (Figueroa 1991).

3. This analysis and much of this section is based on unpublished materials of Karl Harmsen, Head Natural Resources Management, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India and Louise Fresco, Professor of Tropical Agriculture, University of Wageningen, The Netherlands.

4. The most common mechanism suggested is that of a research consortium. This provides for a flexible, open, and participatory process that allows a wide range of IARCs and NARS to participate and benefit. It allows for a sharing of tasks of problem identification, priority setting, task allocation, implementation of research monitoring, and governance.
Biological Nitrogen Fertilization: 
Present and Future Applications 

Ralph W.F. Hardy*

Introduction

I'm pleased to share with you a very timely opportunity in component technology -- biological nitrogen-fertilization systems. This component technology is relevant to crop production and productivity, to food, to economics, to environment, and to sustainable agriculture, which was discussed by the previous speaker.

I plan to provide an overview of the status and identify possibilities for investment at this time. It's timely for an expanded, focused effort on applications of biological nitrogen fertilization. Some of you may refer to this area as biological nitrogen fixation, but I will use fertilization rather than fixation in parallel with synthetic nitrogen fertilization. During the last thirty years an outstanding scientific and technological base has been developed from biological nitrogen research. Probably there are in excess of a thousand scientists worldwide that work in this area. I estimate that we're spending worldwide between US$50 and 100 million a year to support this research activity. We're spending most of this money on the front end of the process -- science and early technology development. Little emphasis is placed on the conversion of this substantial science base to useful products and processes. The major opportunity at this time is a focused, high-quality application effort to produce products and processes.

My recommendation to the World Bank and other governmental and nongovernmental organizations (NGOs) is to invest in an integrated focused program to develop the most promising near-, mid-, and long-term applications of biological nitrogen-fertilizing systems. To be successful in this area it's going to take a substantial investment -- US$10 million in year one, $20 million in year two, $30 million in year three, $40 million in year four, and $50 million in year five (in 1992 dollars) continuing for about fifteen years. I believe it will need a consortium of organizations to support the proposed activity. Investors should expect an appropriate return on their investment. It's too long term for the private industrial sector (based on my twenty-two years in the DuPont Company). This area was too long term in the 1980s for the private sector and is even less acceptable in the 1990s where the private sector has an even shorter time horizon in research. I project that products and processes can be expected to be commercialized from as early as three years up to fifteen years. The major returns are expected from the high-reward products that tend to be the longer-term opportunities. This proposed development should not be centered in universities; nor should it be done in government laboratories. The private sector has the experience to focus, integrate, and manage this application type of program. The private sector is not a leader in front-end research, but the private sector is effective in converting science to useful products and processes. Some of the work may be contracted to academic and government laboratories.

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Opportunities

Biological nitrogen-fertilizing systems (BNFS) are a huge economic opportunity. The annual cost of fertilizer nitrogen is US$20 to $60 billion worldwide. It is equal to or greater than the US$25 billion agrochemical industry. In addition, there are productivity improvements in legumes, tree crops, and possibly cereal grains. BNFS will enable decentralized manufacturing as opposed to highly centralized huge nitrogen-fertilizer plants. Decentralization would be advantageous to rural communities. BNFS are an integral component of sustainable agriculture and forestry. It enables improved environmental compatibility with decreased groundwater pollution and greenhouse gas production.

Synthetic nitrogen fertilization is one of the key components of crop yield improvement during the last thirty to forty years (figure 1). Several years ago I plotted crop yield versus nitrogen-fertilizer application per area. From the 1950s through the 1970s there was a strong correlation. World fertilizer consumption has gone up almost linearly from 1950 to 1990 (figure 2). We were using about 3 million tons of synthetic nitrogen fertilizer in 1950 and increased this twenty-seven fold over the forty-year period so that 80 million tons were used by 1990. Annual global fertilizer nitrogen addition now represents about 50 percent of the nitrogen fixed by natural biological and physical processes. Pest perturbation of a major global cycle by 50 percent is substantial and may be of concern although no specific problem has been identified.

Figure 1. Total Nitrogen Fertilizer (Kilograms)/Area under Cereal Cultivation
Figure 2. World Fertilizer Consumption Nitrogen Totals, 1950-1989

A strong case can be made for the need for alternatives to synthetic nitrogen fertilizers (table 1). Fossil energy and economic costs were a major concern in the 1970s. There is a large capital cost required to build the big thousand-plus ton-per-day nitrogen-fertilizer-manufacturing facilities. About a third of the fossil energy cost for corn production up to the farm gate in the United States is used for the production of synthetic fertilizer nitrogen. In addition, there are transportation, storage, and application costs as well as purchase costs. The about 50 percent inefficiency of fertilizer-nitrogen use is a major limitation. There are environmental concerns. Probably the most significant environmental problem in high productivity agriculture is not agrochemical or pesticide contamination of groundwater and soils, but nitrate contamination of groundwater from inefficiently used fertilizer nitrogen. Conversion of nitrate to nitrous oxide results in one of the most potent greenhouse gases; nitrous oxide is 180 times as potent a greenhouse gas per molecule as is carbon dioxide. The increase in tropospheric gaseous nitrogen is correlated more with the increase in fertilizer nitrogen use in the 1980s than it is with the amount of fossil fuel combustion. Then there is the sustainability issue. Synthetic nitrogen fertilizer is not a sustainable practice while BNFS are more sustainable.

There are biological nitrogen-fertilizing or nitrogen-fixing alternatives; nature has provided them (table 2). In general, there are two types. In one type a microorganism and a plant form a symbiotic or associative relationship with various degrees of intimacy to produce a system that is able to take the abundant but unusable molecular nitrogen from the air and provide useable nitrogen directly to the plant with 100 percent efficiency of transfer, not the 50 percent efficiency of fertilizer nitrogen. In the best known example there is a class of microbes called rhizobia that form nodules on roots or occasionally on stems of well-known legume plants such as peanuts, soybeans, peas, beans, and alfalfa and some less well-known legumes -- *Sesbania* and *Aeschynomene*. There also are legume trees. About 30 to 70 percent of tropical forests are legume trees.
Table 1. Need for Biological Alternatives to Synthetic Nitrogen Fertilizer

- Fossil Energy and Economic Cost
  -- Capital Cost for Thousand + Tons/Day Nitrogen-Fertilizer Plants
  -- Fossil Fuel (35-40,000 feet$^3$ of Natural Gas/Ton Nitrogen Fertilizer)
    Major Fossil Energy -- Derived Input for Grain Corn
    Production up to Farm Gate
  -- Transportation/Storage/Application
  -- 80 MM Tons - $20-$60MMM Cost

- Inefficiency of Fertilizer Nitrogen Use by Crops
  -- About 50 Percent

- Environmental Concerns
  -- Nitrate Contamination of Ground Water
  -- N$_2$O from NO$_3^-$ Denitrification Is Potent (180 x CO$_2$)
    Greenhouse Gas (Troposphere Gaseous Nitrogen Increase
    Correlated with Fertilizer Nitrogen Increase in the 1980s)

- Agricultural Sustainability
  -- Biological Nitrogen Fertilization More Sustainable
  -- Synthetic Nitrogen Fertilization Less Sustainable

Table 2. Biological Nitrogen-Fertilizing Systems

Symbiotic Relationships (Many with Agricultural/Forestry Significance)

<table>
<thead>
<tr>
<th>Microbe</th>
<th>Relationship</th>
<th>Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Rhizobium</em></td>
<td>Legume Root/Stem Nodules</td>
<td>Legumes, for example, <em>Glycine, Arachis, Pisum, Phaseolus, Medicago, Sesbania, Aeschynomene</em>, and so forth. 30 to 70 percent of Tropical Forests are Legume Trees</td>
</tr>
<tr>
<td><em>Frankia</em></td>
<td>Nonlegume Angiosperm Root Nodules</td>
<td>Nonlegume Angiosperms, for example, <em>Alnus</em> (Alder), <em>Casuarina, Ceanothus, Elaeagnus, Hippophae, Myrica, Shepherdia</em></td>
</tr>
<tr>
<td><em>Azospirillum</em></td>
<td>Other Associations</td>
<td>Grasses, Sugarcane</td>
</tr>
<tr>
<td><em>Anabaena</em></td>
<td>Intracellular Associations</td>
<td><em>Azolla</em> in Paddy Rice</td>
</tr>
</tbody>
</table>

Free-Living (Limited Agricultural/Forestry Significance)

*Anabaena, Nostoc, Azotobacter, Bacillus, Clostridium, Rhodospirillum*, and so forth
In another type, a microorganism called *Frankia* forms a symbiotic relationship with nonlegume plants such as alder and other nonlegume angiosperms. There are other, less intimate associations where organisms such as *Azospirillum* associate with the roots of certain grasses such as sugarcane. There are relationships where certain algae associate with a fern called *Azolla* in paddy rice. The top of table 2 is more important for agriculture and forestry and the bottom is less important. Microbes living by themselves fix or fertilize such small amounts of nitrogen that they're really not worth considering for agricultural or forestry purposes. The top part of the chart is the important area, and we need to expand that capability beyond those limited crop and tree plants that now form symbiotic or associative relationships to fix nitrogen.

The biological system also has limitations (table 3), but we're living in the era of biology, not the era of the physical sciences which ended ten to twenty years ago. There are few major fundamental discoveries occurring in the physical sciences. Biology is where the action is, and there are major new tools for biology. We have the ability to do things that were previously impossible in biology, and we're very, very early in the learning curve of new biological capabilities. Some early benefits of the new-biology era will be used in the agricultural area in the next few years, and the agricultural base is building. There are real technological opportunities today to address these limitations in BNFS that previously were difficult to impossible.

**Table 3. Limitations/Technology Opportunities for Biological Nitrogen-Fertilization Systems**

- Limited Crops and Trees/No Cereal Crops
- High Specificity of Plant Host Range of Rhizobia with Legumes, for example, *Bradyrhizobium japonicum/fredii* - Soybeans Only
- Poor Competitiveness of Added Rhizobia with Endogenous Soil Rhizobia
- Inadequate Formulation/Stabilization
- Limited Rate of Nitrogen Fertilization, for example, 100 kilograms of Nitrogen/hectare
- Inhibited by Fertilizer Nitrogen
- Chemical/Physical Stress Sensitivities
- High Energy Requirement -- 12 lb CH₂O/lb Nitrogen
- Oxygen Sensitivity of Biological Nitrogen-Fertilizing Catalyst
- Complexity of Biological Catalyst

The limitations are the following:

- Limited Crops -- For example, BNFS can be used with legumes and some tree crops but not with cereal grains.
- Specificity -- There is high specificity, a microbe is specific for a given plant, so you have to have different microbes for different plants.
• Poor Competitiveness -- The microbes that are already in the soil tend to compete very strongly with improved microbes that are added to the soil. We need to find ways to improve the competitiveness of added microbes.
• Stabilization -- We aren't able to formulate these microbes for stability throughout production, storage, and field use.
• Limited Rate -- The bean is an example where there is a very limited rate of nitrogen-fertilizing capability for most of the microbes that are used. Beans probably fix only a few kilograms of nitrogen per hectare in most cases.
• Inhibition -- These biological nitrogen-fertilizing systems are inhibited by fertilizer nitrogen. We'd like to be able to combine the use of fertilizer nitrogen with BNFS, for example, integrated nitrogen management analogous to integrated pest management.
• Stress -- These organisms are very sensitive to chemical and biological stresses.
• Energy Requirement -- BNFS require a high amount of energy to operate; 12 pounds of carbohydrate per pound of nitrogen provided.
• Oxygen Sensitivity -- They are extremely sensitive to oxygen.
• Catalyst Complexity -- The enzyme nitrogenase is a very complex catalyst.

The above limitations, in fact, are best viewed today as opportunities; our knowledge base and biological tools make it possible now to do several key things that were impossible heretofore.

Assessment of Possibilities

Nine possible product/process applications for BNFS are shown in Figure 3. They are positioned on the basis of low-to-high reward and low-to-high risk with respect to projected success. For example, improved microbes for beans are fairly low risk with modest return opportunity. Other examples include expanding production of microorganisms in areas where they don't have quality production at this time; alternatives to green manuring in rice; improving the characteristics of macrobes; improving the formulation of microbes; giving the capabilities that legumes have for BNF to grain cereals -- one of the major opportunities at this particular time; inventing catalysts that work at room temperature instead of high pressures and high temperatures, and developing associative systems that provide useful amounts of nitrogen fertilization. The ultimate solution is transgenic self-nitrogen-fertilizing plants so that only the plant, not the plant and microbe, are needed. The farmer would only have to use the seed. However, at this stage an effort to produce transgenic self-nitrogen-fertilizing crops is very high risk. There are too many barriers to be overcome. Fifteen to twenty-five years of additional knowledge may enable us to overcome these barriers.

I will make a few comments on each objective. The first concerns improved rhizobia for beans. Low rates of biological nitrogen fertilization occur at this time. Some recent data from Mexico and Canada suggest that rhizobias can be found with improved rates of nitrogen fertilization for beans; the amount of nitrogen fixation is actually substantial. This is a fairly low-risk situation with a low plus reward. The major benefit would be for South American food protein production. Another near-term application is the establishment of production facilities for rhizobia and Frankia in developing countries. Inoculation with effective microbes usually produces 20 to 30 percent yield increases. NIFTAL has developed such technology. Stem-nodulated crops may be developed as green-manure crops. The International Rice Research Institute (IRRI) has shown that stem-nodulated crops accumulate 100 kilograms of nitrogen per hectare in a forty to sixty day period.
Reincorporation of the vegetation may need to be solved. Overall, the above are low risk and low reward.

Figure 3. Biological Nitrogen-Fertilizing Applications

In the intermediate risk area there are intermediate reward opportunities. These are mid term, which is five to ten years to obtain products. Through selection and genetic engineering approaches rhizobia could be improved with respect to competitiveness, amount of nitrogen fixation, expanded host range, and decreased sensitivity to fertilizer nitrogen. Some of the scientific discoveries are in hand. Improved formulations are needed to stabilize rhizobia. The objective is desiccation tolerance, storage stability, and stability as preinoculated seeds. The opportunities would involve material for formulation, coupled with microbial selection. Ability to formulate is critical for any biological organism and is as important to biological pest control agents as it is for biological nitrogen-fertilizing agents.

There are long-term -- fifteen plus year -- applications. Probably the most attractive, based on its projected medium risk and high reward, is the extension of the rhizobial nitrogen-fertilizing system to major cereal grains such as corn, wheat, rice, barley, sorghum, oats, and so on. The approach is to transfer the necessary genes that enable a legume plant to form a nitrogen-fertilizing symbiosis with rhizobia to cereal grain plants. One might describe the approach as teaching the cereal grain what the legume has learned about forming a nitrogen-fertilizing symbiosis. To do this we need to discover what the legume plant has learned or what genes the legume plant has that enables it to form the symbiosis. We call these legume genes necessary for the symbiosis the \textit{sym} genes. Thomas A. LaRue at Boyce Thompson Institute has, over more than ten years, produced pea mutants and from them identified thirty \textit{sym} genes. The next steps are to microlocate these \textit{sym} genes on the pea chromosomes, clone the \textit{sym} genes, and then make transgenic cereal grains with the
sym genes and agronomically develop these sym transgenic cereal grains for self nitrogen fertilization through a rhizobial symbiosis and also, of course, for high yield. The successful outcome would be self nitrogen-fertilizing grains where the need for synthetic nitrogen fertilizer would be eliminated. The key fundamental scientific answer -- the pea plant mutants for the sym genes -- is in hand. A major development effort is needed for the cloning and subsequent steps and is projected to require up to fifteen years with a focused, intensive effort to produce seed that could be introduced into farmers' fields. The opportunity is large and will require substantial investment and continuity. There is a reasonably high probability of success. The reward for success is very large for plant productivity, the environment, and sustainability. Investors should obtain a favorable return.

Another longer-term application is to seek useful associative symbioses for nonlegume crops. The recent observation of nitrogen-fixing endophytic microbes in sugarcane by Johanna Dobereiner in Brazil may be such an opportunity. Additional quantitative data are needed to assess the potential of these organisms. Earlier examples of associative symbioses, such as that of Azospirillum and grass sugarcane discovered in the 1970s, have limited utility because of their low rates of biological nitrogen fertilization. The approach here would be to survey and collect organisms with greatest potential and modify or select these organisms for improved characteristics. At this time, the risk is high because of the experience to date. The return could be significant if successful.

Undiscovered organisms in nature could be very useful. For example, Allan R. J. Eaglesham at Boyce Thompson Institute discovered in the 1980s a novel rhizobia from potting material obtained from Potomac sand. This novel rhizobia is able to both photosynthesize and fix nitrogen. It forms nodules on stems of a legume called Aeschynomene and has the potential to be energy self-sufficient in biological nitrogen fixation. Furthermore, it is genetically similar to the rhizobia that nodulates soybeans. This nitrogen-fixing photosynthetic rhizobia may be the answer to concerns about the energy cost to the plant of symbiotic nitrogen-fertilizing systems.

Transgenic self nitrogen-fertilizing plants, containing the nif genes for biological nitrogen fixation, are a very high-reward opportunity, but the knowledge base makes the risk so great at this time that developmental focus on this objective is not justified. Barriers, such as the need for compartmentalization or protection of the highly oxygen-sensitive nitrogenase enzyme, will be needed.

Another opportunity is the design of new catalysts to enable nitrogen-fertilizer-production plants to operate at low temperatures and pressures and to be small in size. Major scientific advances during the last year have provided an atom-by-atom structure of the biological catalyst that fixes nitrogen. It is a complex molecule. I do not see this information enabling the design of a low-cost process. The biological catalyst requires large amounts of a sophisticated molecular form of energy called ATP. It is too high risk to pursue for nitrogen-fertilizer production. It's a very exciting area if you are a chemist trying to figure out how to do new things with nitrogen, a very abundant raw material.

Recommendations

A summary of my recommendations are presented in table 4. There is a major opportunity for a focused, high-quality effort in application to develop products and processes for biological nitrogen-fertilizing systems for agriculture and forestry. The outstanding scientific and technological base established during the last thirty years in this field and the new tools of biology make this opportunity timely.
**Table 4. Recommendations**

- Integrated Focused Program on Developing the Most Promising Near-, Mid-, and Long-Term Applications of Biological Nitrogen-Fertilizing System

- Investment of US$10, $20, $30, $40, and $50MM/Year for years one, two, three, four, and five and $50MM thereafter in 1992 US$ for fifteen years. Support by Consortium of Government/Private Organization Supporters. Investors Should Expect an Appropriate Return on Investment

- Products/Processes Expected to be Commercialized from as soon as Three Years up to Fifteen Years

- Major Return from High Plus Reward Products

- Application Program Directed by a Board Comprised of Private Sector Entrepreneurs. Should not be Managed by Government or Academe but by the Private Sector

- Economic Opportunity -- Reduced Capital and Operating Costs of Alternative Products/Processes for US$20-$60MMM Fertilizer Nitrogen Market. Productivity Improvements for Legume and Tree Crops and Cereal Grains

- Decentralized Manufacturing

- Integral Component of Sustainable Agriculture and Forestry

- Improved Environmental Compatibility -- Ground Water, Greenhouse Gases
Making IPM Work: 
Developing Country Experience and Prospects

Jeff Waage*

Introduction

Agricultural production in developing countries is significantly affected by the action of pest insects, nematodes, plant diseases, and weeds. Together these pests cause losses to crop production of the order of US$300 billion annually, about 30 percent of potential global food, fiber, and feed production.

Preharvest and postharvest losses to pests have been higher than average in many developing countries. Broadly speaking this can be associated with a tropical or subtropical climate favorable to pest increase and an under-resourced national crop protection capability. But it is possible to be more specific. Pest problems in developing countries today are substantially associated with deliberate efforts to intensify agricultural productivity in order to meet a growing demand for food and for revenue from the export of agricultural products.

Agricultural intensification aggravates pest problems through the creation of large monocultures, the introduction of genetically uniform plant varieties, the reduction of intervals between cropping, and the use of agrochemicals.

Any crop grown in greater abundance and over larger areas appears to accumulate pest species (Strong, Lawton, and Southwood 1984), and often greater populations of these pests. Programs to intensify crop production in developing countries have often extended areas under cultivation and encouraged large monocrops, because this is more efficient. In many cases these large areas are planted to genetically uniform crop varieties which are easily exploited by adapted pests.

Intensification also has involved the reduction of intervals between the planting of the same crop. Around the developing world, periods of fallow, or periodic removal of crop residues or even crops (for example, rampasan) have long been effective means of interrupting the buildup of pest populations. Intensification often leads to overlapping of crops and more continuous resources for pests. Even where a range of crops are grown in sequence this can be a problem, because some of the worst pest species are polyphagous (Moran 1983). Thus, the well-known pest control crisis in the Gezira cotton scheme in Sudan was fueled by the introduction of vegetable crops in the intercrop period between cotton, which allowed the polyphagous cotton bollworm, Helicoverpa armigera, to maintain numbers between cotton crops (Griffiths 1984; Kiss and Meerman 1991). Subsequent intensification of pesticide use greatly aggravated this problem.

Finally, an unfortunate side effect of agricultural intensification in developing countries has been the introduction of new exotic pests. Increasing world trade, the movement of plant genetic material by development programs, and even the movement of food aid has brought to the tropics many species from other regions. In favorable new habitats, free of their specific natural enemies, these species often become serious pests.

Recent and notable introductions of exotic pests in developing countries include the golden snail on rice (from Latin America to Southeast Asia), the larger grain borer on maize (from Central

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America to Africa), the mango mealybug (from South Asia to West Africa), the cassava mealybug and mite (from South America to Africa), itch grass, a weed of tropical cereals (from South Asia to Central America), the cypress aphid (from Europe to Africa), and the coffee berry borer (from Africa to South America). In passing it is worth noting that many of these exotic pest problems are amenable to biological control, and most are the subject of successful or ongoing programs of the International Institute of Biological Control (IIBC) and its collaborators.

For all of the above reasons, we can expect agricultural intensification to create new and greater pest problems. Therefore, development programs should provide in their design for a specific effort in pest management. To the limited extent that countries and development assistance agencies have made this provision in the past, they have done so largely by making chemical pesticides cheaply or freely available to farmers. Recent experience has shown that this approach can sometimes lead to more problems than it solves.

The Pesticide Experience

When introduced into pest control programs in the 1950s, synthetic organic pesticides had some remarkably desirable properties. They were extremely toxic to pest insects, weeds, and diseases, not very toxic to man, effective against a range of pests, and relatively cheap. Since then chemical pesticides have encountered a number of problems.

Intensive pesticide use has led to the selection of pesticide-resistant strains of many pest species. This has necessitated the introduction of new pesticides, some of which have been more toxic to humans. Cross resistance between old and new products have shortened the life of the latter. Today over 500 species of insects and mites are reported to be resistant to one or more pesticides, and a few are resistant to all major pesticide groups (Georghiou 1990). Herbicide and fungicide resistance is less prevalent but growing (Davies 1992).

Pesticides have had undesirable side effects on the environment and on human health in developing countries (Rengam 1992). Early forms, particularly organochlorine insecticides, accumulated in food chains. Newer insecticides have been developed to be less persistent in the environment, but sometimes this has only resulted in their more frequent application.

But perhaps the most striking consequence of continued pesticide use has been its capacity to create rather than control problems with serious insect pests. For a number of reasons the natural enemies of insect pests, that is the predators, parasites, and pathogens that limit their numbers naturally, are often more susceptible to pesticides than the pests themselves. Thus, it is possible that an application of pesticide may confer a degree of control by killing pests, but remove a degree of future control, by killing natural enemies (Waage 1989).

In some cases this can lead to wasted effort and expense, replacing a free, natural control with an expensive chemical one. In others, where natural enemies are particularly important, it can cause pest problems to get worse. Not only can the target pest resurge, but other crop-feeding species, which have posed no problem before, suddenly become pests because the insecticides have eliminated their natural enemies too.

In varying degrees, resistance of insect pests to insecticides and the quite separate effect of insecticides on natural enemies combine to create a phenomenon called the "pesticide treadmill," which goes something like this. Pest resurgence following pesticide applications poses farmers with a dilemma. Having little or no experience with nonchemical approaches to pest control, they have little option but to respond to new or greater pest problems with the application of more pesticides. This further aggravates the problem by making pests more resistant to chemicals and killing even more of
their natural enemies that would limit their numbers. Insecticide use increases further. Characteristically farmer's costs increase, as insecticide use goes up, and income declines, as uncontrollable pests reduce yield. Ultimately the cropping system may be abandoned.

The pesticide treadmill represents an extreme situation, but one which has been experienced again and again around the world with a range of insect pests in a number of key crop systems including fruit trees, vegetables, cotton, and rice.

**IPM -- An Alternative Approach**

Economic problems and crop failures associated with the pesticide treadmill attracted widespread attention and led to research into a new approach to pest control, which earned the name integrated pest management or IPM. Integrated pest management is an alternative to reliance on pesticides, which draws from a range of pest control methods to achieve the most effective, economical, and sustainable combination for a particular local situation.

While scientists speak broadly of IPM, it has been largely a response to insect pest problems. In principle, IPM is relevant to weeds and plant diseases, and indeed should integrate management of all crop pests. In reality, pesticide use on weeds and plant pathogens has caused fewer problems, alternatives are less thoroughly explored, and insect IPM proceeds as a model with the potential of future, broader relevance.

Among the various methods employed in IPM for insect pests, the most important is biological control (Lim 1990), and particularly the natural control, which already exists in the crop system, conferred by the many predators, parasites, and diseases of insect pests, weeds, and other species. It is this self-renewing, baseline of control, which the farmer can conserve and enhance, and to which he/she can add other IPM components, always mindful of the need not to interfere with the natural enemies that provide it, lest he/she creates problems with pest resurgence, as illustrated above.

Cropping practices can be modified to discourage pests or encourage natural enemies, and thereby counteract some of the problems created by large-scale monocultures. Resistant plant varieties can be used. Natural enemies can be augmented at critical periods, so that they build up to controlling levels when pests are abundant. Attractants and repellents, often natural products from insect pests or plants, can be used to influence pest behavior, to trap pests in order to kill them, or to monitor their numbers as a basis for decisions about other control methods.

With varied and vested interest in pest management, the precise role of pesticides in IPM has had a number of interpretations. Thus, the argument that IPM should minimize (that is, rather than rationalize) pesticide usage is more easily accepted by environmentalists than by the agrochemical industry. However, for developing countries, a history of pesticide misuse and resulting pest, human, and environmental problems, together with the relatively high cost of chemicals, make minimizing pesticide use a sensible objective of IPM in many cases.

Pesticide use in IPM can be reduced by observing changes in pest numbers and using chemicals only when pests reach economically damaging levels, when the consequence will not be more pest problems, and when no other economical control alternatives exist. At the same time, alternatives to so-called broad-spectrum chemicals, which can kill pests and natural enemies alike, are encouraged, including biological pesticides, which are formulations based on specific pathogens of the pest, and more selective chemicals.

The assembly of pest control methods into an IPM strategy is best illustrated by example. I will take an example from work done by IIBC at its Station in Pakistan, where we operate as part of
the Pakistan Agricultural Research Council (PARC) to help develop IPM on a range of crops including sugarcane, vegetables, cotton, apples, and mangoes. The following study is not yet published.

**Case Study: Development of IPM Methods for Insect Pests of Mangoes in Pakistan**

Mangoes are grown in a number of regions of Pakistan, largely for local consumption. Insect pests are a major problem, and of these there are four kinds that have become the targets of pesticide application: mealybugs, fruit flies, scale insects, and leafhoppers. Farmers apply insecticides about five times per year, but still suffer problems with these species. During the 1980s, staff of PARC-IIBC worked with cooperating mango growers in the Punjab to develop IPM methods which would give good, cost-effective pest control. This required developing IPM methods for each pest, while ensuring that these were compatible with methods developed for other pests.

**Mealybugs** (*Drosicha stebbingi*) feed on the growing shoots and flowers of mangoes and thereby limit fruit production. Studies on their ecology revealed that females lay their eggs in the soil around trees and young larvae move up to the leaves in the spring. As the season progresses, a number of predators, particularly a ladybird (*Sumnius renardi*), reduce numbers of mealybugs dramatically. On the basis of this understanding, farmers were encouraged to hoe around the base of trees in the winter, to expose and kill eggs.

Further studies on ladybirds revealed that they spend the winter in shelters such as rough tree bark. The smooth trunks of mango did not provide this kind of refuge, and hence they have to emigrate from the crop at the end of the season. To see if this was responsible for their late appearance, artificial shelters, simple bands of rough sacking fastened around mango trunks, were put in the orchard. As anticipated, ladybirds used these shelters for overwintering and thus became active in the mango crop earlier in the season, giving better control of mealybugs. The biology of the predators was explained to farmers, and the shelter bands adopted.

**Fruit flies** (*Bactrocera dorsalis* species complex) received the majority of insecticidal sprays to mango because their maggots, laid in the mango fruit, can greatly reduce the market value of the crop. As an alternative to chemicals, attractant traps were made from cheap local materials and baited with an imported fruit fly attractant, methyl eugenol. These traps proved highly effective, reducing infestations from 35 percent of fruit to 3 percent.

**Scale insects** (primarily *Aspidiotus destructor*) caused problems in sprayed orchards, where they covered leaves and produced a honeydew that attracted mold. However, experimental studies revealed that they were a secondary pest, brought about by the use of insecticides against fruit flies and mango hoppers, which eliminated their effective natural enemies. Hence, with the use of traps for fruit fly control, the scale insect problem decreased.

**Mango hoppers** (*Amritodus* and *Idioscopus* spp) remained the only pest requiring insecticide applications. Ecological studies revealed that the several species involved had a range of different natural enemies, but despite these damaging levels were still reached. This made it difficult to abandon insecticide applications, but careful study of hopper distribution on plants revealed that insecticides only had to be applied to the lower part of the trees, up to 5 meters, to get effective control. This reduced the amount of chemical applied, and also the risk of upsetting biological control of mealybugs and scales. Farmers were encouraged to modify their spraying accordingly.

As a result of this program of research in farmers orchards, experimentation, and integration of methods for the four insect pests, annual sprays were reduced from five to one, with a
fourteen-fold reduction in cost to the farmer, which more than compensated for the costs of IPM methods. Roughly 25 percent of the 13,000 hectares of mango in the Punjab presently use this IPM method.

This case study identifies some typical and important properties associated with development of effective IPM systems:

- Research was done on-farm, where farmers' practices and the nature of pest problems could be understood.
- A good understanding of the local ecology of the pests and natural enemies, their populations, distribution, and movements was essential to developing IPM methods.
- IPM methods involved a mix of technologies, some imported, like pesticides and attractants, but some local as well, like hoeing and shelter bands for ladybirds.
- Farmers were closely involved in the process of IPM development, and trained to understand the pests, their natural enemies, and the IPM methods for their control.
- The IPM methods returned a net benefit to the farmer.

Constraints to IPM Development and Implementation

Despite 20 years of research into IPM methods and examples such as the one just described, which show the economic benefits of IPM, IPM is not widely practiced today in developing countries. Pesticide use in developing countries is rising rapidly, and now accounts for about 20 percent of global pesticide sales. Insecticides remain the major kind of pesticide used in developing countries. Some countries like India and China, despite a long tradition in biological control and IPM research, have recently developed national insecticide production industries, concentrating on production of broad-spectrum pesticides particularly harmful to IPM.

In recent years considerable effort has been made to analyze the record of IPM in order to identify constraints on its wider application. To chronicle all of these efforts would take pages, and therefore I will cite only two recent ones.

In 1989 a group of donor agencies and international organizations concerned about IPM established an IPM Task Force to evaluate IPM development and constraints on its implementation on a global basis. This group prepared a report on IPM in developing countries, with the aid of expert consultants (NRI 1992) and has subsequently organized a series of regional workshops to identify constraints and opportunities for IPM, which are still ongoing.

Building on the results of the first such regional workshop in Malaysia, the Asian Development Bank (ADB) and CAB International organized in 1991 a Conference on IPM in the Asia-Pacific Region, to which ministerial-level delegations from twenty-one developing countries in the region were invited. The objectives of the conference were to share experience in pest management and IPM, to develop policy guidelines for IPM implementation by governments, and to develop regional action plans for IPM in key crop systems (Ooi and others 1992).

These initiatives, involving scientists, donor representatives, and national policymakers, have considered constraints and opportunities for IPM in considerably more detail than I can here. Instead, I will highlight a few conclusions common to these efforts.

The Need for Greater Awareness and Training

While the problems associated with pesticide misuse are attracting increasing attention worldwide, the nature and benefits of an IPM approach remain poorly understood outside the scientific community. IPM successes developed in one part of the world are little known elsewhere. Policymakers, crop
protection specialists, farmers, and the general public all need to be the subjects of an awareness-raising exercise, presented in an appropriate form for each constituency. The message needs to identify clearly for particular crops the problems with present pest control methods, some simple IPM options, and the economic and social benefits of this approach.

Those directly involved in the development of IPM methods; the researcher, extension specialist, and farmer, have a forty year tradition of nearly exclusive reliance on chemical pesticides. Raising their awareness of IPM alone is insufficient to empower them to develop IPM. They need training in understanding pest ecology, monitoring pests numbers, recognition and evaluation of natural enemies, and the use of various IPM techniques (for example, resistant plant varieties, attractants, and need-based pesticide application). Training methods and materials must be designed to be appropriate to these different groups.

**Better Integration of Researcher, Extension Specialist, and Farmer**

By its very nature, IPM development and implementation defies the conventional process by which technology-driven research is carried out on the experimental plots of a research institution, packaged, and passed through extension specialists to farmers. This model was developed in pest management for the extension of pesticide technologies. At the outset, at least, it worked fairly well because these products appeared relatively simple to use and highly effective in a range of situations requiring little local adaptation. Furthermore, in the process of research and extension of pesticide technologies, under-resourced national services were augmented by the more substantial advisory services of agrochemical companies.

IPM, by contrast, is highly specific to crop, pest, and location. Thus, in the case study on mango pests in Pakistan, a number of IPM methods were closely linked to the local ecology of the pest. The need to provide shelters for ladybirds reflected the composition and design of the particular orchards, as did the designation of 5 meters as the height limit for insecticide application against hoppers.

A direct consequence of the site-specificity of IPM is the need to develop IPM methods on-farm. IPM research in centralized research institutions too frequently fragments into single-technology efforts, selects pests that are convenient to study rather than important to the farmer, and develops inappropriate, relatively high technology, and expensive methods.

On-farm research not only compels the researcher to consider all pests and their local ecology together, but makes possible as well the involvement of farmers, and the inclusion of their knowledge, perception, and practical economic constraints in the design of IPM methods. Once trained to recognize pests and natural enemies, farmers have a unique capability to be research partners and innovators because of their knowledge of the crop environment. A paper given by Andrews in this symposium presents one of the most exciting examples of farmer involvement and innovation in pest management. Needless to say, the involvement of extension specialists and farmers in IPM development also facilitates subsequent adoption of IPM practices, a point at which many top-down, science-driven IPM efforts fail.

**The Need for Government Support at the Policy Level**

Much of the difficulty in developing and implementing IPM stems from a lack of support at the policy level. Certain government policies can be directly antagonistic to IPM, such as government pesticide subsidies that reduce the cost of pesticides to the farmer and distort true economic comparisons with
alternative approaches like IPM. In developing countries, government pesticide subsidies, often supported by donor agencies, have been extensive and substantial (Repetto 1985).

Like scientists and farmers, many governments have a long experience of strict reliance on pesticides for supporting programs aimed at food security and agricultural export. Hence, many government crop protection recommendations are concerned exclusively with chemical pesticides. Regulation of pesticide use, which could benefit IPM, is frequently ineffective or absent.

It would be fair to say that IPM on a national scale is only possible in countries where the government adopts IPM as a central component of agricultural projects. In so doing governments must be prepared to structure their research and extension system to facilitate IPM development and implementation (see above), and to provide the training and resources to support this effort. It will often be necessary to establish interministerial committees to guide IPM implementation and, particularly to coordinate research and extension activities, which are presently poorly linked in many developing countries.

Having laid out a daunting set of challenges and prerequisites for development and implementation of IPM, it is time for another case study to demonstrate that this can, indeed, be done! This study concerns the implementation of IPM against insect pests of rice in Indonesia. Much of the value of this study is to be found in its history, which is drawn mostly from Kenmore (1991). Other relevant references, besides those given in the text below, include Whitten and others (1990), Barfield and others (1991), and Fox (1991).

Case Study: IPM of Insect Pests on Rice in Indonesia

In the 1970s, the Indonesian government, supported by development assistance agencies, embarked on a rice intensification program which involved the widespread use of insecticides and the introduction of high-yielding rice varieties. Production increased, but with it increased a new insect pest, the brown planthopper, *Nilaparvata lugens*. This tiny insect lives at the base of rice plants and sucks their sap. The planthopper is capable of rapid reproduction and, unchecked by its natural enemies, it can reach numbers that cause rice plants to brown and wither.

By 1977, 700,000 hectares of rice production were infested by brown planthopper. In response pesticide application intensified -- by now pesticide use was directly subsidized by the government. In retrospect we know that pesticides removed the important natural enemies of the brown planthopper, such as spiders, and that this loss of natural control outweighed any controlling effect of the pesticides. Not surprisingly, therefore, intensified pesticide application increased the pest problem further.

In 1980 rice varieties bearing new planthopper-resistant genes developed at IRRI were widely planted. Following this and a large increase in fertilizer use in irrigated areas, the planthopper problem diminished for four years, although pesticide use was still high. Indonesia reached self-sufficiency in rice. But this achievement was short-lived. Soon, planthopper outbreaks began again in areas planted to new varieties and damage rose to levels reported in the 1970s.

It was at this crisis point, with the apparent failure of a program based on existing pest control technologies, that the government of Indonesia bravely chose the alternative path of IPM. The convincing argument for IPM was based on the results of international and national research, which demonstrated that commonly used insecticides induced planthopper outbreaks by eliminating their natural enemies, and that reducing pesticide application, in field trials, led to no loss in yield.

This timely understanding and its promotion at a policy level was facilitated by the FAO Intercountry Rice Integrated Pest Control Project and started in 1980. This FAO project supported communication and research by Asian scientists on the role of pesticides and natural enemies in
brown planthopper control, and thereby facilitated and accelerated IPM promotion and uptake with national programs. It also played a major supporting role in the IPM success, which was to follow in Indonesia.

The Indonesian National IPM Policy was announced in November 1986 as a Presidential Instruction, which banned fifty-seven trade formulations of insecticides from use on rice, ordered that resistant varieties be grown in affected areas, more than doubled the number of government field pest observers assigned to rural extension centers and ordered that observers, extension staff, and farmers be trained in IPM.

Banning pesticides, and the consequent removal of pesticide subsidies on rice, were a prerequisite for IPM implementation, but alone insufficient. It was the program of training that succeeded in empowering farmers to be practitioners of IPM.

Because IPM of brown planthopper relies largely on a knowledge of the local ecology of the pest and its natural enemies, training was focused less on technology transfer than on gaining a personal understanding of the rice ecosystem and how to grow a healthy crop. The traditional extension model of training farmers to use new equipment or pesticides was traded for a more fundamental educational approach, where farmers were encouraged to discover the role of natural enemies, to learn by doing, and to ultimately become IPM experts (Gallagher 1992).

The program works through applying these training methods first to pest observers, who are employees of the Ministry of Agriculture. Pest observers receive more than 500 hours of training, over two rice seasons, which includes all aspects of rice production and alternating crops. These trainees then become trainers themselves, and use their skills to train farmers and extension specialists, two for twenty-five trainees. Farmers receive more than 50 hours of training over one rice season, based entirely in the field, and involving the growing of a rice crop using the IPM method. Trained farmers then take this knowledge to their villages and train other farmers. Training methods require little equipment: containers to collect natural enemies and paper and crayons to draw and redraw the rice ecosystem, as knowledge grows.

By mid-1992 the numbers of people trained in this method were estimated at 1,000 observers, 3,000 extension specialists, and 150,000 farmers. An additional 300,000 farmers are thought to have been trained subsequently by IPM farmers returning to their villages. By this method, it is planned to extend this training to 2.5 million farmers by 1995 (Wardhani 1992).

Today in Indonesia, IPM on rice is a cross-sectoral policy implemented under a steering committee consisting of representatives of the Ministries of agriculture, population and environment, health, education, local government, finance, economic coordination and the Central Bureau of Statistics, all coordinated by the development planning agency, BAPPENAS.

The benefits of IPM implementation can be expressed in a range of ways, but the focus of the program has been on increasing profit to the farmer. During the period 1987-90, total application of formulated pesticide on rice has fallen over 50 percent while rice yield and production has risen. Yields of IPM-trained farmers are usually the same or higher than those of untrained farmers. The primary benefits come from reduced pesticide use and its associated costs. At the farm level, the program has so far reduced average insecticide applications per season from over 4 (1986) to 2.1 (1989) to 0.8 for IPM farmers in 1991.

As a result, farmers’ net profits increase by about US$18 per IPM-trained farmer per season. Dollar for dollar, the increase in farmers’ profits is estimated to give a return on training investment of 4.6 to 8.6. (Kenmore 1991).

Other benefits of IPM have been the effect of training on improved crop production, as farmers become more observant of changes in their crops, and improvements to occupational health and the local environment from reduced use of pesticides. Also, IPM protects and makes more sustainable those inputs that do contribute substantially to yield, in this case fertilizers and improved crop varieties. Without IPM, and with consequently higher pest populations, the benefits of these inputs would be short-lived, as experience has shown.
Perhaps the most convincing measure of success has been the continuing and increasing commitment to the effort at all levels in Indonesia. The federal government, which benefitted substantially from a reduction of 85 percent in pesticide subsidies, has begun to realign the research agenda to support IPM training and field implementation (Wardhani 1992). District administrators are diverting funds to accelerate farmer training, and at the farm level, villages are raising funds to pay for their own training programs (Kenmore 1991).

The commitment of the Indonesian government to IPM has been paramount to its success. Development assistance has played a role, initially through support to the FAO Intercountry Rice IPM Project from AIDAB (Australia) and DGIS (Netherlands). In 1989, USAID made a policy development grant of US$10.5 million to Indonesia for the IPM program, and further funding for implementation is anticipated from the World Bank in 1993.

By far the largest component of Indonesian and donor investment has gone to farmer training. The scale of this exercise is unprecedented in pest management extension – in the last two years alone, 2 million person-days of high-quality IPM training have been given to Indonesian rice farmers. The management challenge to national programs of a project of this scale is considerable (Useem, Setti, and Pincus, forthcoming), and will usually require donor support.

The Indonesian rice IPM program has proven responsive to change, which is perhaps the greatest evidence of its sustainability. In 1990 a long-standing, but usually minor pest of rice, the white stem borer, *Scirpophaga innotata*, reached outbreak levels in Java. Calls to relax restriction on pesticide use were resisted by the federal government, and national funds were allocated to training farmers in pest recognition, which permitted manual control by removing the pests’ egg masses. Pesticides suspected of actually contributing to the problem were avoided and losses in the following year were much reduced. Research was initiated, parallel to training, through the existing IPM program. Rather than weakening the commitment to IPM, this new pest problem has strengthened it, and demonstrated the power associated with broadening the IPM constituency from crop protection specialists to policymakers, extension specialists, and farmers.

**Getting IPM Going**

The history of the Indonesian rice IPM program illustrates the need for policy support and change, training and awareness raising, and the reorganization of the research-to-extension-to-farmer model. It also provides some insight into how IPM programs can be initiated.

**Making the Most of IPM Entry Points**

Crises in pest management, such as the pesticide treadmill experienced in Indonesia, provide entry points for IPM. In such situations it is often possible to quickly improve the situation of farmers simply by pesticide reduction, thereby gaining support at the farm and government level for further development of IPM.

The identification and exploitation of IPM entry points is the most effective way to initiate the adoption of IPM. Once developed for a particular pest, IPM tends to spread to cover other pests in the crop system, as we have seen for white stem borer in rice. This is due in part to the fact that farmers now have an incentive to avoid pesticide use that might disrupt existing IPM. More importantly, however, an IPM approach and associated training makes farmers, researchers, and extension specialists more aware of opportunities to develop IPM for other pests.
The self-spreading effect of IPM can also be seen to operate between crops. In Indonesia, where farmers alternate rice with other crops (palawija), including vegetables and soybean, a training/research program has begun on IPM against pests of these crops, which after all support many of the natural enemies that will be important in next seasons’ rice production. As already observed, however, little spread of IPM is likely unless it is adopted as a national crop protection policy.

The recent Conference on IPM in the Asia-Pacific Region identified particular entry points for IPM in rice, cotton, vegetables (particularly brassicas), sugar cane, fruits, and plantation crops. All of these crops experience excessive pesticide use in some areas, which could be rapidly reduced at a saving to the farmer. For all of them, experience of successful IPM exists for key insect pests in certain areas that could form the basis for developing IPM in new areas, through adaptive, local research.

The Value of Intercountry IPM Networking

The FAO Intercountry Rice IPM Project was an essential catalyst to the Indonesian program, as it continues to be to equally promising national rice IPM programs in other Asian countries. As a regional, donor-funded effort, it fostered research and information sharing in the region, generating a considerable knowledge base from relatively modest efforts of national and international research institutions. It was this activity and the participation of Indonesian scientists in it, that provided at the critical time, convincing evidence from the field that IPM would work, and that farmers could be trained to use it.

A similar, regional activity is necessary to backstop efforts in other commodities that can serve as IPM entry points. Such an effort should involve a large component of the technical cooperation between developing countries (TCDC), because there already exist successful or at least promising IPM programs somewhere in the world for most developing country crop systems.

Over the past year, efforts of this kind to stimulate uptake of IPM in developing countries have begun. As a direct result of the Conference on IPM in the Asia-Pacific Region, the Asian Development Bank will support CAB International to manage an Asian regional cotton IPM program, to involve India, Pakistan, and China. This will be coordinated with a larger regional initiative by FAO on cotton in Asia, which will include a greater range of countries. In addition to this, and to the continuing Asian rice IPM program, FAO is also planning regional vegetable IPM initiatives in Asia and Africa.

Distinctly missing from these initiatives is regional support for IPM in plantation crops, like sugar cane, coffee, coconut, citrus, cocoa, oil palm, and so forth. This undoubtedly reflects a view that private industry can support IPM development, and there is some precedent for this -- indeed some of the first IPM programs were developed for plantation tree crops in Asia (Liau 1992).

However, many plantation crops are grown by smallholders who have poor access to the IPM experience through government or company-based extension. Furthermore, the commercial nature of these commodity industries has itself limited the exchange of information between countries. If anything, the relatively organized nature of the plantation sector, and the ease of implementing pest management decisions in it, would ensure a high return on the relatively small investment necessary to raise awareness and exchange information on the IPM experience.

Regional programs of technical networking and support logically focus on particular commodities. However, governments can develop pest management policy, such as that regulating pesticide use, to cover all crop systems. It is important, therefore, that support to developing and
implementing IPM in particular commodities take into account the need to provide governments with the information and stimulation to extend IPM over all crops.

Extending IPM Further -- Being Proactive

In the arguments and case studies presented so far, the emphasis has been on crop systems where chemical control of insect pests is presently causing problems, thereby creating opportunities for IPM. But many crops in developing countries are grown at a subsistence level, and receive little pesticide application. What is the role for IPM here?

A number of experts have considered this question and arrived at similar conclusions (Teng 1989, Lim, 1990; Kiss and Meerman 1991). For subsistence crops IPM should aim to optimize the resources inherent within the system to improve yield, identifying and making use of natural biological control, cultural controls, improved crop varieties and other methods that involve low, realistic inputs. IPM should be developed as part of a general approach to healthy crop production as in the Indonesian case.

Many farming systems sit today poised between subsistence and intensification. Returning to the argument with which I began this paper; if we have as a priority the intensification of agricultural production in developing countries, then we can expect, for good ecological reasons, an intensification of pest problems. If we are to propose a more sustainable alternative to complete reliance on chemical pesticides, we should be developing an IPM approach in these crops now in advance of problems which demand this.

As Kiss and Meerman (1991) point out for the situation in Africa, where intensification is anticipated in a range of crops, farmers not yet used to chemical control may be more responsive to alternatives. Perhaps the challenge will be more one of convincing governments and donors to invest in the development of an IPM approach in an intensification program in advance of perceived pest problems.

A particularly good example of a crop system suitable for the proactive development of IPM is the rapidly expanding horticultural and fruit export industry of developing countries. In South America, Africa, and Asia, this industry is rapidly outstripping conventional agricultural exports as a major generator of foreign exchange income. The crops are frequently new -- exotic fruits, vegetables, spices and flowers -- as are many of the pests. Indeed many if not most of the insect pests are exotic, brought in through incautious movement of planting material. Without their indigenous natural enemies, and with a poor national capability in diagnosing or managing these new problems, pesticide use can be expected to be high. The need to provide unblemished produce for many of these commodities will further aggravate this situation.

Opposing this tendency, however, will be the increasingly stringent minimum residue levels for pesticides imposed by North America, Europe, Japan, and other importers. Developing country producers are, in effect, stuck. Without the rapid development of an IPM approach, it is difficult to see how a crisis in pest management in this important new agricultural sector can be avoided.

Virtually all of the insect pests associated with tropical high value horticulture are well known to field or protected cultivation in industrialized countries. Virtually all are prone to resurgence after pesticide application, and virtually all can be effectively controlled using nonchemical methods. With this experience, and the organized nature of the horticultural industry, prospects for preventing another, costly pesticide treadmill are good. An appropriate first step would be a modest regional IPM program, of a form similar to that described above, aimed at supporting and communicating on farm research into IPM methods.
Implications for Development Assistance Agencies

Of the many implications that IPM holds for development assistance, and particularly for its support to agricultural intensification to support food security and wealth creation in the developing world, I would like to close by drawing out three.

Environment, Agriculture, and IPM

Donor agencies are increasingly aware of the problems of pesticide use and the opportunities presented by IPM to reduce these. To a large extent, this awareness comes from their national constituencies, in the form of concern for the environmental implications of pesticide use. In the North, the movement toward IPM is driven largely by conservation and health issues. In the South, as we have seen, it is presently driven largely by economics, although environmental and health concerns are rapidly gaining ground. Thus, while developing country representatives prioritize for pesticide reduction and IPM for those crops where it will improve farm economies (Ooi and others 1992), developed countries like Denmark and the Netherlands can comfortably make decisions to reduce pesticide use by 50 percent over all crops!

The Northern, environmental slant on IPM has had implications for the way IPM is viewed in development assistance programs. Presently, for instance, guidelines for pesticide use in donor agencies stress human and environmental safety. The emphasis is on identification of acceptable and unacceptable chemicals and safe use and disposal of pesticides. While guidelines of this kind pose extremely important constraints on the provision of pesticides to agricultural intensification programs, they often fall short of specifying an IPM approach, that is, the development of the most economical and sustainable pest management strategy, without the presumption of a reliance on chemical pesticides.

There is much scope for reconsidering donor guidelines for pesticide use in the context of recent experience of IPM in agriculture in developing countries. Not only can a stronger case be made now for IPM, but experiences like that in Indonesia have revealed the extent to which IPM is not simply a technical intervention in a crop production program, but an exercise in human resource development intimately linked with other such activities in the agricultural sector of developing countries.

IPM stands out as both economically sensible and environmentally sound, and therefore can draw strength from a wide constituency in donor agencies and developing countries. As an environmental initiative, it is one of the more easily realized challenges. In Agenda 21, for instance, it is proposed that substantial uptake of IPM at the farming community level can be achieved before the end of this century, and indeed this is possible.

Research to Develop IPM

Traditionally, donor support to IPM development has passed through national and international agricultural research institutions. The growing consensus that technology-driven, top-down research does not lead quickly to successful IPM should therefore give donors pause to think. Success appears to be more closely associated with a more decentralized, on-farm research and training effort involving scientists and farming communities.
While the farm-level focus of IPM research, and the necessary restructuring of the research-extension-farmer model might be seen to threaten established research institutions, nothing could be further from the truth. Rather, the development of IPM will help to give these institutions a more meaningful agenda in the context of national agricultural development.

By investing more in IPM research and development at the farm level, and encouraging the participation of local governments, community organizations, and other nongovernmental organizations (NGOs), donors can ensure that the problems addressed by national and international research institutions will, in future, be more demand-driven and less technology-driven, which can only make these institutions more sustainable.

**IPM Implementation and Its Need for Donor Support**

As the Indonesian rice IPM case has indicated, the scale of IPM implementation at the farm level involves substantial commitment from governments and donors, particularly to training, and it takes time, even at the remarkable rate that has been achieved in Indonesia. Furthermore, at the level of implementation, IPM becomes a program of human resource development, intimately linked to other aspects of crop production.

In developing programs of agricultural intensification, donors and governments should therefore view IPM not as a technical component for expert consultation, but as a broad educational program to involve farmers and other groups, backed up with resources for local research. As such, IPM will not only be most successful, but it may come to serve as a model for bringing together farmers, government, scientists, and others to effect positive change in agricultural development.

**References**


Changing Perceptions and Practices of Central American Smallholders

Keith L. Andrews, Jeffery W. Bentley, Rafael Díaz D., Elfas Sánchez and Fransisco Salinas*

Jeff Waage (1993) has given us a comprehensive and insightful look at what integrated pest management (IPM) is, and he provided us with interesting examples from Asia. Several other important successes in Latin America should be mentioned (Andrews and Quezada 1989). Among the most notable cases are bananas in Central America, sugar cane and coffee in many of the countries, soybeans in Brazil, and melons in Honduras. As with the Asian rice example which Jeff Waage presented, the Latin American successes are with intensively produced cash crops.

Before discussing our smallholder or hillside farmer IPM program in Central America (especially Honduras) we need to look at the recent history of the soil conservation and regenerative agriculture movement in the region. For nearly twenty years, Asociación Coordinadora de Recursos para el Desarrollo (ACORDE) headed by Elfas Sánchez, Finca Loma Linda, has taught thousands of Honduran smallholders about organic gardening and soil management and conservation. In 1982 ACORDE helped a small group of Guatemalan extension agents find asylum in Honduras. This was the core of people that started the World Neighbors program in Honduras. World Neighbors, the Peace Corps, Partners of the Americas, Catholic Relief Services, and dozens of other private and public sector extension agencies eventually began extending appropriate technologies of organic fertilizers and soil management as elements of community and human development projects. Despite their low budgets, these agencies have enjoyed high adoption rates of their technologies, because of their participatory, grassroots approach, which is ably summarized by Bunch (1982). These nongovernmental organizations (NGOs) have been effective in the challenging context of marginal, hillside farm communities. A tribute to their success is that the Honduran public sector extension programs began emphasizing similar soil conservation technologies.

In 1983 Zamorano (Escuela Agrícola Panamericana) started the Integrated Pest Management Project in Honduras (MIPH) with the U.S. Agency for International Development (USAID) funding. The project evolved into the Crop Protection Department (DPV). From the beginning, Zamorano’s IPM program collaborated with farmers. Together they developed a menu of different pest control practices for most pest complexes. The technologies were transferred to farmers during extension trials on their farms (Goodell, Andrews, and López 1990; Bentley and Andrews 1991). Later Zamorano developed a biological control center to enhance natural control of the major pests in Central America (Cave 1992). Zamorano now has a massive educational program for rational pest and pesticide management to reduce health and environmental hazards from pesticide abuse; this program has been active in all Central American countries as well as in the Dominican Republic and Bolivia. Zamorano’s maize, bean, and sorghum IPM program has demonstrated the ability to develop nonchemical solutions to most of the common problems that rural families try to solve with pesticides.

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Zamorano's IPM program worked with consulting anthropologists from the beginning and hired one full-time (Bentley) in 1987 to study linguistic and cultural aspects of smallholder pest control. The anthropologists have developed culturally sensitive research and training techniques with a group of agronomists at the DPV (Bentley 1989, 1990, 1991a, Bentley and Melara 1991).

These three threads of soil management/conservation, IPM, and anthropology came together in 1990 when World Neighbors personnel in Honduras asked Zamorano to help train their staff. The combination of Zamorano and World Neighbors was natural and complementary. Zamorano had technical skills in pest management and the ability to discuss and modify them with small farmers, but did not have a large cadre of effective, low-cost extension agents. World Neighbors had many extension agents from rural villages, good communication skills with farmers, and the winning technologies of soil conservation and organic fertilizers, but not the ability to develop alternatives to inappropriate pesticide use and increasing pest problems associated with cropping system intensification. Because the extension agents are from the people themselves, unless they are given new skills and training, the extension agents have little or nothing new to teach the farmers. Without the extension capabilities of the NGOs, Zamorano's research and development capabilities can't reach the real world.

In late 1991, Zamorano, World Neighbors, ACORDE, and Catholic Relief Services formed the national IPM consortium and in mid-1992 started an extension program with their own resources. Despite having "bootlegged" all support up to now, the results are so encouraging that we have begun to enlarge the Honduran program and expand it to other Central American countries. We expect to obtain support from the United Nations Development Programme (UNDP) in the very near future. The project, which is explained in this paper allows the cooperating organizations to develop a synergistic approach to a complex set of problems.

Our technical collaboration with smallholder farmers is based on learning what the people know and what they don't know, figuring out what they need to know, teaching it to them in a way that is consistent with what they know, and then learning from them as they synthesize new information with old knowledge. Our program includes a series of short courses that emphasize hands-on learning and introduction of new concepts and information that increase farmers' abilities to innovate. The first course has been given to 500 change agents in three countries, and focuses on insect reproduction and biological control (Bentley 1992a, b). Future courses already being developed will cover applied plant pathology, soil pest and disease control, and pesticide safety.

Our pest management goal is not to simply eliminate pesticides from the farms. We must help farmers to develop alternative pest control, and to increase and stabilize food production. This is especially important in those cases where farmers face new pest problems as a result of having adopted soil management practices like cover crops, reduced tillage, and not burning crop residues. To use Jeff Waage's terminology, the "entry point" for this IPM project is the NGOs' desire to protect and enhance the gains they have made in soil management. IPM specialists have a responsibility to keep soil management programs from losing momentum because of new pest problems with which they are associated. In other words, from the start this effort places IPM within a more holistic, regenerative agriculture initiative with poor, hillside farmers as the primary clients.

From the beginning of this program we assumed that a participatory research and extension methodology was essential. Marginalized Central American smallholders are keen observers and experimenters who know a great deal and constantly innovate. They should be good research collaborators. However, in practice their contributions have been limited because they have little notion of some key elements in the bioecology of pests, biological causes of disease, biological pest control, and other important aspects of sustainable pest control (Bentley 1989). The gaps in their knowledge contribute to a feeling of helplessness in the face of pest problems and in the past helped create dependency on synthetic pesticides. Earlier extension efforts often met with polite puzzlement and empty promises to implement technologies that the farmers simply did not understand. When
asked to suggest priorities for cooperative research, most farmers proposed studies of pesticide efficacy (Bentley and Andrews 1991).

We now believe that farmers will be best able to innovate and adapt the practices they need for each of their many natural and economic environments if they are previously trained in the key concepts that they have lacked (for example, biological control, insect life cycles, germ theory of disease). In order to understand our training program, we need to look at the results of the anthropological studies carried out by Bentley and his cooperators to document the nature of campesino or peasant knowledge.

On some topics this knowledge is encyclopedic, but in other areas it can be distressingly incomplete, and from the point of view of a positivist scientist, even wrong. For example, farmers are often experts at handling crops and livestock, but do not understand what causes disease, and think that insects are spontaneously generated. While farmer participation is now widely promoted, most descriptions of "participation" are more rhetoric and wishful thinking than substance. They appear to be based too much on a naive desire to work together than on a businesslike understanding of the complimentary strengths of the partners. In order to make farmer-scientist interactions more fruitful, we need to honestly confront the limitations as well as appreciate the strengths of indigenous technical knowledge -- just as we need to be realistic about what researchers understand and can do.

Bentley (1991b) presented a simple scheme (figure 1) to help us understand why peasant ethnoscience is so variable. This model can be applied to explain the knowledge of Bombay bus drivers, Bank bureaucrats or any other group of people, but in this paper we will concentrate our discussion on its application to Central American smallholders' pest management understanding. The level of understanding of any subject is a function of two factors: the perceived importance of a thing or phenomenon and the ease with which it can be observed. Importance is defined as meaning of perceived value or harm to the local people; the concept includes economic utility and potential to cause physical pain. For example, humans perceive bees as important because they produce food and their stings hurt and occasionally kill people. Whether or not a creature is conspicuous or easily observed depends on its size, color, movements, time of activity, and perceived risk to the observer, and is also influenced by cultural attitudes (such as, "spontaneous generation is common," or "all insects are bad"). We assume that there is a strong relation between knowledge and behavior and that by acquiring knowledge the learner may adopt more effective behaviors.

Figure 1. Four Classes of Farmer Knowledge

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</tbody>
</table>
Importance and ease of observation can be diagrammed as two axes that divide folk knowledge into four cells (figure 1), with different taxonomic structures and unique classes of knowledge. In the upper right-hand cell of the figure are the important, easily observed topics like social insects, weeds, farm tools, and plant growth stages. These domains are rigorously classified and well understood. The upper left-hand cell includes easily observed but unimportant entities like large, nonstinging arthropods. Earwigs, spiders and mud dauber wasps are good examples; these animals are named but are neither highly differentiated taxonomically nor connected with much cultural lore. The lower right-hand cell includes important but difficult-to-observe topics such as many plant diseases and most aspects of insect reproduction. These are named and, although not split into many folk categories, are the focus of cultural beliefs that may be at odds with western science. The lower left-hand cell holds those topics that peasants consider to be both unimportant and difficult-to-observe. Topics like parasitic wasps, which campesinos are generally unaware of, are not even named.

Although many of the prime examples presented here come from insect taxonomy, this philosophical scheme can account for much indigenous technical knowledge about the natural environment. This scheme is about ideas rather than biological organisms per se. Some organisms are easy to classify according to one of the four classes of knowledge, while others must be teased apart. Honduran folk knowledge of ants, for example, falls in at least two classes: stinging behavior and seed eating are in the "important, easy to observe" class, while ant reproduction and predation fall in the "unimportant but easy to observe" cell.

Classes of Knowledge

The various kinds of knowledge have very different formal characteristics and, as we will see, present vastly different opportunities for participatory research and extension work.

Conspicuous and Important: "Thick Taxonomies"

Phenomena that are conspicuous and considered to be important tend to be organized into many folk categories in a taxonomy five or six layers deep. Conspicuous and important organisms are often labeled at the biological species level. Explanations of these phenomena -- the quality of honey, the painfulness of wasp stings -- are often couched in "positivist" terms, that is, the explanations are consistent with scientific knowledge and acceptable to scientists.

With the help of our colleague, entomologist Ronald Cave, we have found that Honduran campesinos generally categorize social bees and certain wasps to the species level. Campesinos must gauge bee defence strategies and honey quality to decide whether to chop a tree down and split it open for honey. Campesinos describe various kinds of honey as medicinal, good to eat, nasty, and potentially poisonous.

Conspicuous but Unimportant: Strings of Folk Genera

Conspicuous but unimportant phenomena are often classified in a taxonomic structure with many categories, but few levels -- shallow strings of dozens of names with no subordinate and few superordinate categories. Conspicuous but unimportant organisms are often labeled at the biological
family or order level. There is little attempt at explanation, positivist or otherwise, for phenomena in this group.

As much as anthropologists like to portray traditional rural people as able taxonomists, exhaustive studies of folk taxonomies often reveal many animal names with little paradigmatic structure. Hunn (1977) found that for Tzeltal speakers of Mexico, 106 of 335 individual names for animals were classed as birds, another 45 as mammals, while 184 names, many of which were insects, were not included in higher taxonomic levels (except for that of animal) and most of the 335 names include no subdivisions.

Honduran campesinos do not think of any "bugs" (terrestrial arthropods) other than honey producers as beneficial, so most insects are classified in a shallow taxonomy and are given folk genus names with no species subdivisions. Campesinos lump the entire order of Dermaptera (earwigs) together as tijerillas (little scissors), just as most spiders are undifferentiated arañas and all dragonflies (order Odonata) are merely caballitos del diablo, "the devil's little horses." Being conspicuous is no guarantee of even a unique name for animals with no perceived economic importance. The mud dauber wasps (family Sphecidae) are highly conspicuous, building nests shaped like organ pipes, footballs, and mud clods on houses and other buildings. Campesinos see the wasps hauling spiders or grasshoppers into the nests and know that they rear their young there, but because sphecids are considered to be useless and harmless they are merely lumped into the residual category "just wasps," sharing the name avispa with the vespid and other wasps. Many campesinos claim that sphecids have no name, or that they do not know it.

**Important but Difficult-to-Observe: the Enigmas**

Nothing is more maddening than a real problem with no obvious solution, like many insect pests and crop diseases. The voracious worms that seem to appear fully grown from nowhere, others that descend on a field by the thousands overnight and diseases that suddenly wipe out whole fields rank high on the importance scale, but are hard to observe. Magic-religious explanations or other 'odd' unscientific sounding beliefs about insects and other organisms are likely to occur in the important but difficult-to-observe cell.

Important but difficult-to-observe phenomena may or may not have complex taxonomies, depending on biological factors. For example, bean diseases in Honduras are poorly classified, with viral, bacterial, and fungal disease, nutritional deficiencies, certain insect damage, and other ailments all grouped together. Some insect pests are classified at the biological species level, although knowledge of their behavior, especially of their reproduction, may be poorly understood. 'Folkloric' explanations (for example, spontaneous generation), often at odds with positivist science, are much more common than they are for other kinds of knowledge.

Multiple diseases are more difficult to observe and differentiate than one disease. Campesinos confuse many bean diseases (Bentley 1991a) but because there is only one major maize disease in Honduras, maize ear rot, farmers are able to focus on the disease and acquire a body of knowledge comparable in some aspects to that of plant pathologists. Honduran campesinos have formed many of the same hypotheses as specialists for solving this disease problem, including increased soil fertility, quicker drying of the grain, burning crop residues, and bending the maize plant over (Bentley 1990).

Although insect pests are some of the few insects other than bees and wasps, which campesinos classify at the biological species level, farmers have a poor understanding of caterpillar reproduction. The cogollero or whorlworm, Spodoptera frugiperda, is an endemic maize pest which campesinos perceive as chronically lowering crop yields. Because it is very tiny when it first hatches
and glides through the air on a silk thread, landing inconspicuously on the earth and making its way to maize plants, campesinos do not notice the cogollero in its early instars. They notice the little windows the tiny larvae carve in maize leaves, eating off the green tissue and leaving a transparent film in the center, but many fail to distinguish those windows from the damage of leaf miners, a host of small insects of different orders that work in the completely opposite way, by eating out the interior of the leaf. Campesinos notice whorlworms when they are large caterpillars eating the tender new tissue of the maize whorl, and burying themselves in their own feces. Farmers believe that the worms are generated spontaneously by the corn plant itself, citing as evidence the fact that smashed whorlworms are green, like maize plants (Bentley and Andrews 1991).

Not only material factors (size, mobility, and so on) influence how easily organisms can be observed. Cultural attitudes also affect how people see the world around them, even though those attitudes may have been shaped in part by the biological structure of that world. For example, Hondurans, both campesinos and most of the middle class, believe that all insects are bad except bees. Virtually all insects are thought to be herbivorous. While this belief may have a basis in the observation of abundant plant eating insects in the tropics, it also affects campesinos' vision of their fields as being virtually under siege to insect pests; plant protectionists know that many of the pesticide applications made are not justified economically (Shaxson and Bentley 1991). After learning to recognize the beneficial aphid lion, Chrysoperla spp., one farmer said "and I used to apply pesticides when I saw those in my field!" We have known university trained producers who have applied pesticide in eighty hectares of maize to control earwigs that are effective whorlworm predators.

Difficult-to-Observe and Unimportant: the Empty Quarter

Because difficult-to-observe and unimportant phenomena are not usually categorized, they fit into no folk taxonomies and are not labeled at any levels of biological classification. They are accompanied by no folk explanations. Many organisms are neither named nor paid any attention to, because they are both difficult to observe and not perceived as important. Because they are so small, none of the wasps in the four major families of parasitic Hymenoptera in Honduras is even recognized by farmers, let alone seen as pest controllers. Each herbivorous insect has at least one parasitoid wasp, and sometimes dozens, as well as nematodes, flies, and other tiny organisms whose lives are intertwined with the host they feed on and kill. If not for these little creatures, Central American farmers would starve; yet the wasps are neither named nor known.

Some additional examples of farmers' knowledge of pesticides provides a review and helps illustrate the value of this scheme.

- **Important and easy to observe.** Acute pesticide poisoning and the quick die off of pests following an application are important and easy to observe, and farmers understand them.

- **Easy to observe but unimportant.** Farmers could easily see that earwigs, spiders, wasps and other beneficial insects are killed by pesticides, but as long as the biocontrol role of these animals is not appreciated, their deaths are considered unimportant.

- **Important but hard to observe.** Many farmers and NGOs are starting to think of botanical insecticides as important and desirable. Many odd, almost mythical, beliefs about the characteristics and efficacy of botanical insecticides are spreading rapidly. But the many plants with their complicated and ephemeral chemical structures are hard to study. We are far from filling the research demand for this topic.
• **Hard to observe and unimportant.** Although chronic pesticide poisoning is important, it is so difficult to observe that for many years farmers didn't notice it, and didn't realize its importance.

**Implications for Technology Generation and Transfer**

The anthropological model presented above is useful for describing how farmers perceive some of IPM specialists’ most important ideas and concepts. This scheme of Central American peasants’ knowledge is also valuable in orienting outreach and participatory research and development efforts (figure 2).

**Figure 2. Style of Participation According to Class of Knowledge**

```
IMPORTANCE

-   +

E O
A B
S S
E E
O V
F A
T I
O N

Scientists teach new ideas to
farmers, then learn from farmers
who synthesize new information
with old

Scientists learn from farmers

Farmers learn from scientists

Scientists expand existing folk
taxonomies, enhance farmer
observations, challenge existing
beliefs

**Important and Easy-to-Observe**

As this class includes farmers’ most familiar topics, this is where scientists can learn the most from them. Rhoades' (1989) familiar example of diffused light potato storage falls into this class. Scientists learned about the technology from farmers in Kenya and successfully spread it to farmers around the world.

Just a few of the other topics where plant protection specialists can learn much from traditional peoples include:
• Intercropping, crop rotation schemes and other cropping practices
• Behavior of other large social insects
• Natural history, pharmaceutical, and nutritional value of "weeds" and other wild plants
• Control of vertebrate pests.

Farmers' knowledge should especially be relied on to set research agendas instead of allowing scientists’ often esoteric disciplinary interests and unrealistic expectations to drive research. Unused maize-drying buildings in Honduras, abandoned water harvesters in Arizona's Papaguerfa (Bentley 1987) and failed, large-scale, capital-intensive irrigated rice schemes in West Africa are just some of the monuments to planners' and scientists' arrogance.
Not Important but Easy-to-Observe

There are great opportunities for collaborative research on topics in this class that the scientist considers to be of importance. By teaching farmers things they do not know about certain easily observed organisms, farmers may gain an enhanced perception of some of the species and processes around them, and then learn more about them by continued observation. By changing peasants’ attitudes regarding the importance of some easily observed phenomenon an important chain of creative innovations may be unleashed.

Scientists can help shift farmers’ notions of insect predation from the unimportant to the important side of the chart, by teaching them about it. Because earwigs, social wasps, ants, certain true bugs (Hemiptera), and praying mantises are easy to observe, if we let farmers know that these creatures help control crop pests, they can teach themselves how to conserve and manipulate these natural enemies. Farmers often gratuitously destroy wasps and ants to avoid being stung. The unimportant but easily observed class of knowledge is especially suited for extending precepts. Teaching farmers that ants eat insects gives people a reason to see ants in a new light, re-evaluate them as natural enemies, and then learn how to manipulate them. This appears to be the approach taken by the Asian rice IPM outreach program that highlights the role of spiders and other easily observed natural enemies as biocontrol agents.

In Honduras we use bee, wasp, and ant reproduction as a starting place for discussing insect metamorphosis with farmers: explaining fly reproduction (which they partially understand) and moth and beetle reproduction (which they do not understand) in terms of hymenopteran reproduction (which they do understand).

As farmers blend new information with old knowledge and new observations, they may create new, synthetic ideas and technologies, which scientists would not have invented. We experienced one such case in Honduras. One of us (Andrews) experimented with the predatory wasp, Polybia spp., moving hives onto maize fields, but was frequently stung and most of the wasp colonies soon absconded. We abandoned the idea in the early 1980s. Not long afterward Andrews explained wasp predation to a group of farmers, and one of the farmers, Wilfredo Flores, began moving nests. In 1989 we discovered that Flores was successfully moving nests on his own. Campesinos traditionally move nests from brush to avoid being stung while clearing land. They start learning about wasp relocation as children, bringing hives into rural schoolrooms and releasing them, hoping to terrorize the teacher and other students. This experience helped Flores overcome some of the problems that had discouraged our early attempts.

Farmers who have become aware of insect predation through our biological control course have invented many new methods for stimulating the activity of predators in their fields. One farmer placed boxes of worm-infested potatoes on top of a fire ant (Solenopsis geminata) colony, removing the box just as the ants finished removing the insects but before they began to feed on the tubers. Another farmer set out raw sugar to attract ants and other predators into his field. One herded chickens through his cornfield to eat caterpillar pests. Others have hand collected ladybird beetles to release them in their fields.

It appears in retrospect that the soil conservation and management programs carried out by our NGO colleagues fit initially in this cell. Soil erosion and depletion are easily observed. By helping farmers to see the importance of these phenomena, and by giving them a few prototype technologies, farmers move the subject to the conspicuous and important cell; they then concentrate their efforts to learn more on this subject.
Important but Difficult-to-Observe

This class represents the greatest challenge to scientists because it sometimes implies changing beliefs rather than simply adding new information. It is a heterogeneous class that permits at least three styles of intervention (expanding existing taxonomies, enhancing farmer observation, and challenging existing beliefs).

Expanding Existing Taxonomies

Some agronomists have ridiculed the campesinos' use of the word "ice" (hielo) for plant disease (Bentley 1991a). The agronomists mistakenly thought that farmers believed that their crop froze. However, ice labels most plant diseases much like the English term "cold" labels a set of human ailments. Farmers do not believe that the plants actually freeze. Now many of our extensionists use the term. They explain to farmers "as you know, there are many kinds of ice" and then explain the different symptoms and causes of various diseases, essentially filling in a broad traditional category, ice, with a series of new subordinate categories: fungus, virus, bacteria, and so on. Associated with the new terms are many useful etiological and management concepts.

Enhancing Farmer Observation

If farmers are interested in a topic and lack the tools of observation to fully appreciate it, one tactic is to share novel methods of observation with them. In a study of maize ear rots, the major disease of maize in Honduras, we found that campesinos know virtually all that phytopathologists know, except for the causal agent (Bentley 1990; del Rio 1990), so in over a dozen villages in the remote interior we set up a microscope and showed the fungus to campesinos, and we explained how this kind of fungus was like mushrooms that they were familiar with, but smaller. We then invited the campesinos to suggest possible control tactics. They proposed dozens of ideas, of which we eventually tested three for control of the disease: burning crop residues, bending the maize plant or removing leaves or tassel at physiological maturity, and trials of (native) maize varieties. As a result of the extension effort they carried out a series of novel epidemiological and control experiments.

Challenging Existing Beliefs

This may be more difficult and is risky. It requires great sensitivity. For example, many Honduran campesinos believe that agrochemicals spontaneously generate insect pests. They say that the first pests were seeded in chemical fertilizer so the people would be forced to buy insecticide, but each one they bought contained the seeds of yet another pest, trapping the farmers on a conspiratorial chemical treadmill. It is our belief that when farmers realize the true relations between pesticide and pest populations, they will be better able to wean themselves off agrochemical dependency. Farmers understand very well that physiological traits are inherited by the offspring of people, livestock, and crops -- and they readily grasp the idea of insects being selected for genetic resistance to pesticides. Farmers also accept the idea that natural enemies are killed by insecticides. They are fascinated by insect reproduction and can be helped to jettison the concept of spontaneous generation. We spend days carefully building a logical framework for changing the idea of spontaneous generation that is
nevertheless consistent in most respects with the local culture. At the beginning of our short courses, less than one-third (32 percent) of the participants understand that insects come from eggs while 81 percent know this at the end. We rely heavily on experiential learning. We show farmers caterpillars hatching from eggs. We watch mature caterpillars pupate and emerge as moths. Farmers learn that they can capture caterpillars and care for them in bottles until the adult emerges. By giving people tools for learning they continue to teach themselves after the course.

**Unimportant and Difficult-to-Observe**

On the other hand, adding completely new concepts is easier. Although initially campesinos do not know about parasitic wasps, they enjoy the topic. (Only 7 percent of the farmers know of parasitoids at the outset of our biocontrol course, while 93 percent of them understand the concept and can identify these natural enemies at the end.) We use photographs and live parasites in bottles to expose campesinos to the subject. We also find it easy to introduce farmers to the notion of entomopathogens by analogy with humans: just as people get sick and sometimes die because of disease, so do insects. We show farmers cadavers of insects killed by disease. Farmers’ knowledge of entomopathogens goes up to 79 percent from a mere 9 percent at the beginning of the course. This subject offers promise because of the growing importance of biological insecticides as alternatives to chemicals. Basic knowledge about disease may help farmers accept the biological control agents, even though they take days instead of minutes to kill pests.

**Concluding Remarks**

Human resource development is the key to the success of IPM; education, empowerment, and effective implementation go together. Our technical collaboration with smallholder farmers is based on learning what the people know and what they don’t know, figuring out what they need to know, teaching it to them in a way that is consistent with what they know, and then learning from them as they synthesize new information with old knowledge. Our program includes a series of short courses that emphasize hands-on learning and introduction of new concepts and information that increase farmers’ ability to innovate. The notion that natural enemies can be manipulated and conserved improves from 29 to 77 percent during our short course. Approximately 80 percent of the farmers who have participated in the courses have adopted or adapted at least one of the technologies included in the course. Fifty percent report that they no longer use insecticides. This acceptance of the biological control message is encouraging for its own sake and suggests that "farmer participation" can be more than rhetoric. We expect that further experience will help farmers to go beyond any all-or-nothing attitude toward pesticides to one that is more in line with the IPM idea that all tactics, if used correctly, can be important elements in a balanced program. Scientists can help farmers increase the rate of endogenous innovation.

Training, if it is to be effective, should be based on focused, sophisticated social science. Anthropologists’ involvement cannot be limited to post mortems or token visits. Pest management has to be recognized as a human enterprise. Men and women have to be seen as the complex centerpiece of all pest management activities. The entomologists, plant pathologists, ecologists, and their biological and agronomic scientist colleagues should play more supportive and less directive roles.
Extension must put as much emphasis on concepts as on facts and concrete technologies. The model for understanding the strengths and weaknesses of local knowledge presented here helps demonstrate the value of this approach. Almost half the participants interviewed four to six months after completing the biocontrol course have invented a new technique based on the new concepts presented in the course.

IPM research should be site specific, responsive, and strongly influenced by the farmers. Given the severe human and financial limitations facing IPM today and the site specificity of pest problems, outreach takes at least temporary precedence over research. While research and extension are best viewed as concurrent and complementary activities, we feel strongly that there is a serious misallocation of resources in Central America today that results in unused research findings and farmers unable to enjoy the benefits afforded by the application of scientific ideas.

Pesticide problems are only one of many motivations for carrying out an IPM program. Addressing pesticide abuse should be a component of almost any IPM program. However to treat IPM as a tool to correct pesticide abuse while ignoring rural families’ production needs is inappropriate.

A consortium approach that builds on the strengths of several very different private organizations creates valuable synergisms. Effective, focused public sector organizations can play important roles too. IPM is such a multifaceted undertaking and developing world institutions are so small and specialized that the union of their capacities is essential to the progress needed in IPM.

Not all of our ideas could be developed in the space available, but are discussed in detail in the references given elsewhere in the text. We would enjoy corresponding with interested parties at any time.

References


WOMEN IN AGRICULTURAL RESOURCE MANAGEMENT
Raising the Productivity of Women Farmers in Sub-Saharan Africa

Katrine A. Saito*

Introduction

Women farmers in Sub-Saharan Africa (SSA) now dominate the smallholder sector and account for more than three-quarters of the food produced in the region. Yet the economic, social, and cultural environment in which they work, rear their children, and manage their households is not supportive and, in some respects, actually hostile. Given the widespread food insecurity in SSA, this inhospitable environment results in large private and social costs.

Governments and donors alike are increasingly realizing that one of the critical factors in revitalizing agriculture in Africa is to raise the productivity of women farmers. Increasing the productivity of women farmers will contribute directly to higher output and improved household food security. It is likely that the greatest gain from raising women farmers' productivity would come in the form of improved child nutrition, increased capacity for education and more generally, an enhancement of the welfare of rural households, an increasing number of which are female-headed.

This paper summarizes the findings of a study, funded by the United Nations Development Programme (UNDP), of women farmers in SSA and the problems they face in raising their productivity. It is based primarily on four country studies -- Burkina Faso, Kenya, Nigeria, and Zambia -- which document women’s roles in agriculture, identify and evaluate the key constraints they face in attempting to raise their productivity, and recommend measures to relieve these constraints. All four country studies draw on fieldwork, specialized studies undertaken by local researchers, direct experience in World Bank agricultural operations, and extensive household surveys in Kenya and Nigeria, with 720 and 750 randomly selected rural households surveyed in each country, respectively. An important feature of these surveys was the collection of data on a plot-specific basis. Data was collected in this way because of the common practice in Africa of men and women managing their own plots. Based on the plot-specific information, farmer level observations were constructed by aggregating outputs and corresponding farm inputs on all his/her plots. Enumerators living in the villages undertook the fieldwork over the cropping season and sections of the questionnaire were administered four times corresponding to the main phases of agricultural activity. The country studies have also benefitted from discussion within the countries concerned. In Burkina Faso, for example, the draft report was reviewed and revised during a month-long process of discussion at the village level among farmers and government officials, culminating in a workshop with senior government officials.

The Key Findings of the Study

The African rural household is changing and traditional farming systems are breaking down. In response to evolving social and economic circumstances, particularly growing population pressure on an increasingly degraded land, men are migrating off the farm in search of more remunerative activities elsewhere. As a result, the traditional pattern of intrahousehold rights and obligations is

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changing. The gender-specific nature of African farming is disappearing as women are growing crops (such as coffee and other cash crops) and taking on tasks (such as land clearing) traditionally the responsibility of men, and making decisions on the daily management of the farm and household. Although men are generally still more involved than women in cash crop production, the Kenya and Nigeria surveys show that all crops are grown by men and women. In Kenya, for example, 33 percent of the women surveyed grew coffee compared to 26 percent of the men, and in Muranga District more female than male respondents had a plot of coffee and more women than men decided on the inputs and controlled the proceeds from coffee plots.

These evolving circumstances have changed the role of women in African agriculture. In all four countries studied, smallholders are the core of the agricultural sector, and women now comprise the majority of smallholder farmers. In Kenya, for example, 61 percent of women surveyed cited farming as their main occupation compared to only 24 percent of men. In Nigeria, farming was the main occupation of 88 percent of female and 58 percent of male household heads. The survey data also show the preponderance of female labor input in farming; women are engaged on a more regular basis than men in all farming activities and phases of the production cycle.

Both men and women in the rural household make decisions on what to farm, how to farm it, and how to dispose of the proceeds, but these decisions are usually specific to the plot they manage and the revenue it yields. While some men and women do make certain decisions on each others' plots, essentially they manage their own separate plots (table 1).

Table 1. Decisionmaking Responsibilities by Gender in Kenya and Nigeria
(as percentage of decisions made)

<table>
<thead>
<tr>
<th>Head of Household(^1)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farmer using plot</strong></td>
<td>Head</td>
<td>Wife</td>
</tr>
<tr>
<td>Kenya</td>
<td>Nigeria</td>
<td>Kenya</td>
</tr>
<tr>
<td>Who decides what to plant?</td>
<td>(703)</td>
<td>(2213)</td>
</tr>
<tr>
<td>- Husband</td>
<td>88</td>
<td>73</td>
</tr>
<tr>
<td>- Wife/Woman</td>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td>- Other</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Who decides to use fertilizer?</td>
<td>(252)</td>
<td>(1080)</td>
</tr>
<tr>
<td>- Husband</td>
<td>86</td>
<td>94</td>
</tr>
<tr>
<td>- Wife/Woman</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>- Other</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Who decides to use improved seeds?</td>
<td>(270)</td>
<td>(456)</td>
</tr>
<tr>
<td>- Husband</td>
<td>87</td>
<td>79</td>
</tr>
<tr>
<td>- Wife/Woman</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>- Other</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Who decides to sell the crop?</td>
<td>(202)</td>
<td>(1536)</td>
</tr>
<tr>
<td>- Husband</td>
<td>93</td>
<td>68</td>
</tr>
<tr>
<td>- Wife/Woman</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>- Other</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>

Note: Actual sample sizes given in parentheses. They show responses for those plots where the decisions applied and were made.

\(^1\) Defined as households headed by single, divorced, or widowed women, and households where the spouse has been absent for six months or more.

*Source:* WAPIA survey.
Female-headed households (FHH) are becoming increasingly common in SSA. In Zambia, for example, they comprise about one-third of all rural households and up to 51 percent in the Northern Province. FHH are far from homogeneous, and include both autonomous households recognized and accepted as headed by women (mostly widows or single women), and households headed *de facto* by wives during the male head’s absence. Although the practice of male outmigration is common, in some societies the wife who remains behind may not head the household. Despite heavy male outmigration in Burkina Faso, for example, FHH are uncommon because Burkina Faso’s polygamous society absorbs these "lone" wives into the extended family. Within the family compound, however, wives manage their farming activities on their own plots.

**Female-headed households tend to be particularly disadvantaged as farmers (table 2).**

**Land** -- Landholdings of households headed by women are much smaller than those headed by men. In Nigeria, for example, the mean size of land farmed by FHH was one-third that of male-headed households (MHH).

**Labor** -- FHH also tend to be smaller in size and have fewer farming adults than MHH. In the Northern Province of Zambia, for example, FHH had an average of 3.4 persons compared to 6.5 persons in MHH. The smaller number of farming adults in FHH point to a lower family labor supply than for MHH. In Oyo State in Nigeria, for example, the supply of family labor was much more restricted than in MHH, and women’s use of hired labor, often paid for with remittance income, was insufficient to compensate.

**Table 2. Characteristics of Male- and Female-Headed Households in Kenya and Nigeria**

<table>
<thead>
<tr>
<th></th>
<th>Kenya</th>
<th>Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td><strong>(Sample size)</strong></td>
<td>(508)</td>
<td>(199)</td>
</tr>
<tr>
<td>Gender of head as % of all HH</td>
<td>72</td>
<td>28</td>
</tr>
<tr>
<td>Religion of HH head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Christian</td>
<td>72</td>
<td>84</td>
</tr>
<tr>
<td>% Muslim</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Marital Status of HH head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% married</td>
<td>95</td>
<td>67</td>
</tr>
<tr>
<td>% widowed, divorced</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>% single</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HH heads</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>All family members</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>% HH heads &gt; 60 years</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Education (no. of years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HH head</td>
<td>3.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Children in HH</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>No. of individuals/HH</td>
<td>8.6</td>
<td>8.0</td>
</tr>
<tr>
<td>No. of individual farming/HH</td>
<td>2.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Dependency ratio*</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Note: Dependency ratio is the number of individuals aged under fourteen and over sixty divided by the total number of adults in the household.

Source: WAPIA Survey.
Capital -- FHH are relatively undercapitalized. The survey data show that, in Kenya, for example, the total value of farming tools and equipment in FHH is less than half that in MHH, and 92 percent of female farmers used only hand tools compared to 72 percent of male farmers.

Extension contact -- Women heading households also had much less contact with extension agents (only 4 percent of FHH were in contact with extension compared to 14 percent of MHH).

Education -- Women heading households also had lower levels of education than men heading households, and in both Kenya and Nigeria, children of FHH had more years of schooling than those of MHH.

Women work considerably longer hours than men on both agricultural and other tasks (table 3). The range of tasks on and off the farm that SSA women farmers, especially those heading households, are required to perform is very broad, and calls for an application of time and energy that tests human endurance. The four country studies show rural women working, on average, 50 percent more hours per day than men. There is a marked seasonal pattern in the type of work performed, with women's labor input exceeding men's in both the rainy and dry seasons.

Table 3. Average Daily Hours in Agricultural and Nonagricultural Economic Activities by Gender

<table>
<thead>
<tr>
<th></th>
<th>Burkina Faso</th>
<th>Kenya</th>
<th>Nigeria</th>
<th>Zambia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>Agriculture</td>
<td>7.0</td>
<td>8.3</td>
<td>4.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Nonagriculture</td>
<td>1.7</td>
<td>6.0</td>
<td>3.8</td>
<td>6.1</td>
</tr>
<tr>
<td>Total</td>
<td>8.7</td>
<td>14.3</td>
<td>8.1</td>
<td>12.3</td>
</tr>
</tbody>
</table>

Source: Volume II Country Studies.

Clearly, there is a finite limit to the time and energy that women farmers can apply. Given the already large and growing contribution women farmers are making to agricultural production in general, and to feeding their households in particular, policymakers must recognize that any strategy to improve agricultural productivity that increases the demand for labor, especially female labor, must take the consequent opportunity costs fully into account.

Gender Differences in Agricultural Productivity

Within a given agroecological environment, agricultural productivity is determined by the amounts of land, labor, capital, and other inputs that are used, and by the quality of these factors. Providing technologies and managerial skills are the same, farmers who have identical access to identical factors will produce identical outputs of a given crop. That is, their productivity will be identical. If they use different technologies or different quantities of these factors, their productivity will differ. Differences in the productivity of men and women farmers are likely. As noted above, men and
women in the African rural household pursue their own-account activities both on and off the farm and they also have different endowments (such as land rights and education), and different access to technologies, to factors of production (such as labor and capital), and to support services (such as extension and credit).

Using data from the rural household surveys of Kenya and Nigeria, men’s and women’s productivity in agriculture and the relative contributions of different inputs and factors of production were examined. A Cobb-Douglas production function was used. The dependent variable was the gross value of output because intercropping is a common farming practice in both Kenya and Nigeria; both conventional and nonconventional inputs were used as explanatory variables. The main conventional inputs were land cultivated, family labor and hired labor disaggregated by gender, and capital stock; the main nonconventional inputs (represented by dummy variables) were an index of tenurial status (constructed by considering the extent of control a farmer has over a plot in terms of the ability to improve, sell, rent, mortgage, and lend the plot), use of insecticide, tractor use, gender of farmer, extension contact, and soil fertility. District dummies were also included to reflect different agroecological conditions. Education and age variables were represented in years.

The results highlight the importance of female family labor for both male and female farmers: on male-managed plots in Kenya, for example, female family labor is the most important factor of production, with an elasticity of more than twice that for male family labor (table 4). Similarly on female-managed plots, female family labor is positive and significant with a relatively high elasticity. Another noticeable result is that hired female labor significantly and positively affects output on male-managed plots while male-hired labor significantly and positively affects output on female-managed plots. This cross-gender effect of hired labor may be explained by the difference in task -- hired male labor tends to be used mostly for land clearing while hired female labor is used mostly for weeding and harvesting. In other words unlike family labor, which shows little gender-specialization by task, hired labor tends to be used for the traditional tasks of men and women.

Table 4. Land Holdings of Farmers Surveyed in Kenya and Nigeria by Gender (hectares)

<table>
<thead>
<tr>
<th></th>
<th>Kenya (hectares)</th>
<th>Nigeria (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td><strong>Households</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By gender of household head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean total size of household holding</td>
<td>2.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Total number of people per household</td>
<td>8.6</td>
<td>8.0</td>
</tr>
<tr>
<td>Hectares per person</td>
<td>0.3</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>Holdings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By gender of land user</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean holding size of household head</td>
<td>3.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Mean holding of household members</td>
<td>1.9</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Source: WAPIA survey.

Another important finding is that contact with extension did not increase the output of female farmers as it did for male farmers. Possible reasons for this difference include a lack of
complementary inputs, incomplete adoption, poor explanation, and hence understanding of technologies (women complained in both Nigeria and Kenya that the technology was "too technical"). The male-dominated research and extension staff frequently lack understanding of women's roles and constraints, and cultural norms hinder effective communication between male extension agents and female farmers. Furthermore, agricultural technical messages concentrate on the resources, commodities and tasks of more interest to men than women, while extension to women often revolves around home economics subjects. Finally, women's attendance at extension activities is constrained by their lack of time and mobility. In other words although the provision of extension services to women farmers has improved in recent years, women's contact with extension does not have the same impact on output as men's contact with extension.

Women's disadvantaged access to factors of production and support services results in considerable loss in productivity. Simple comparative evidence from the Kenya survey found that men's gross value of output per hectare is 8 percent higher than woman's. However, from the econometric analysis it was found that if women had the same human capital endowments and used the same amounts of factors and inputs as men, the value of their output would increase by some 22 percent. Thus women are quite possibly better, more efficient, farm managers than men and their productivity is well below its potential. Capturing this potential productivity gain by improving the circumstances of women farmers would substantially increase food production in SSA thereby significantly reducing the level of food insecurity on the region. If these results from Kenya were to hold in SSA as a whole, and recalling that women produce an estimated 75 percent of the region's food, simply raising the productivity of women to the same level as men could increase total production by 10 to 15 percent.

In addition to the production function analysis, influences on the adoption by men and women of selected agricultural technologies, such as the use of fertilizer and agrochemicals, were analyzed. These results highlighted the importance of extension contact in raising the probability of both men and women adopting such technologies, and also the positive effect of education, especially for women. For example, it was found that one year of education raised the probability of women using agrochemicals by 4 percent and of men by only 1 percent. The factors affecting the use of credit were also analyzed, and one especially interesting result was that women's use of credit was negatively affected by the distance to the financial institution, a highly plausible finding given the severe constraints on women's time and mobility.

What This Means for Policymakers

Governments are beginning to realize that raising agricultural output and productivity means a greater focus on women farmers. However, the pace of implementing the requisite supportive measures has been all too slow, resulting in considerable loss in potential output. As discussed above, potential agricultural output is reduced by as much as 22 percent because of women's disadvantaged access to inputs and support services. This potential productivity gain can only be realized by substantially improving women's access to inputs and support services such as land, labor, technology, extension, and credit. Some of the key measures can be summarized as follows:

- **Land Rights**: Since the 1960s, some attempts have been made to improve women's rights to land, but in practical terms, the situation has frequently worsened: growing population pressure on increasingly depleted land has further weakened women's land rights, and as good agricultural land has become more scarce, women are managing even smaller plots. As pressure on the land increases and efforts to improve agricultural productivity intensify, it will be even more important to ensure
that women have access to and control over adequate land. Women's legal rights to land throughout Sub-Saharan Africa must be expanded and secured so that they can be implemented in practice.

- **Farm Size:** Within the context of a growing shortage of good quality farming land in SSA, women are particularly disadvantaged compared to men in the size of plots they farm (table 5). However, given existing farming technologies, smallholders are faced with a situation where available family labor and insufficient income to hire labor constrains the productive use of additional land. Because smallholder technology is labor intensive, and because of acute seasonal labor shortages, more land, even if available, would not be a solution. Hence, smallholders, especially female, must gain access to more inputs and better technology so that the returns to the land they have is increased, in short, their productivity is raised.

**Table 5. Summary of Labor Use Per Hectare on Male- and Female-Managed Plots: Kenya and Nigeria**

<table>
<thead>
<tr>
<th>Source of Labor</th>
<th>Kenya</th>
<th></th>
<th>Nigeria</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male plots</td>
<td>Female plots</td>
<td>Male plots</td>
<td>Female plots</td>
</tr>
<tr>
<td>No. of hours</td>
<td>% of total</td>
<td>No. of hours</td>
<td>% of total</td>
<td>No. of hours</td>
</tr>
<tr>
<td><strong>Family labor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>524</td>
<td>32.7</td>
<td>486</td>
<td>23.2</td>
</tr>
<tr>
<td>Female</td>
<td>722</td>
<td>43.1</td>
<td>1,135</td>
<td>54.2</td>
</tr>
<tr>
<td>Child</td>
<td>82</td>
<td>5.1</td>
<td>114</td>
<td>5.4</td>
</tr>
<tr>
<td><strong>Hired labor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>128</td>
<td>8.0</td>
<td>160</td>
<td>7.6</td>
</tr>
<tr>
<td>Female</td>
<td>136</td>
<td>8.5</td>
<td>176</td>
<td>8.4</td>
</tr>
<tr>
<td>Child</td>
<td>8</td>
<td>0.6</td>
<td>24</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,600</td>
<td>100.0</td>
<td>2,095</td>
<td>100.0</td>
</tr>
<tr>
<td>Hired as % of total</td>
<td>17.0</td>
<td>17.0</td>
<td>13.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

*Source: WAPIA Survey.*

- **Labor:** The survey findings clearly show that women are the "work horses" of SSA agriculture. In both Kenya and Nigeria, women provide most of the family labor on plots they manage as well as on plots managed by men. Averaged over all plots, Kenyan women provide 84 percent more family labor than Kenyan men, while Nigerian women provide 33 percent more than Nigerian men. On a per hectare basis, the use of labor on women's plots is higher than on men's plots (31 percent more in Kenya and 37 percent more in Nigeria).

All four countries face the paradoxical situation of a rural labor shortage within a labor-surplus economy with high population growth rates and high rates of unemployment. This has to do with the generally low level of labor productivity, reflecting smallholders, especially female smallholders, limited access to information and resources that would enable them to adopt different technologies, and increase labor productivity. With low average and marginal returns to labor, male family members in particular seek employment possibilities off the farm. That a high proportion of male heads and members of rural households are not engaged in farming is reflected in the findings of the
surveys. This reduces family labor supply and highlights the lack of cash or credit with which to hire labor. As a result, households adjust cropping patterns and farming systems to fit labor availability. They do this by limiting the area cultivated and planted, the amount of weeding or fertilizer applied, or by growing less labor-intensive crops such as cassava, and thus reducing labor value added. The solution lies in raising output by generating and employing superior technology.

- **Technology**: Labor- and energy-saving technologies are women farmers' greatest needs. In addition they require production technologies for their commodities, constraints, and objectives, which are not always exactly the same as those of male farmers. No matter how technically feasible recommendations may be, they cannot increase productivity unless they are implemented. Certain technologies may be less easily adoptable by female than male farmers because, as the four country studies demonstrate, male and female farmers do not operate under the same conditions. If gender-related problems are allowed to constrain adoption, women farmers will be further disadvantaged and efforts to increase national agricultural output and productivity will be compromised.

- **Agricultural Research**: To address these technology needs, agricultural research must focus more on the needs of the majority of farmers -- women -- by concentrating on the farming and household system, by increasing participatory research with male and particularly female farmers, and by improving feedback from gender sensitive extension agents and systems. Gender sensitive technology generation and promotion is possible. An understanding of women’s farming roles and constraints, including cultural constraints, is a prerequisite to devising suitable strategies. Evidence from the country studies suggests that appropriate technology equipment for women farmers should be economically accessible and viable. In addition the necessary infrastructure and facilities should be available. Women should be included in the planning and trained in the operation of the technology, and the technology must be targeted at the person who will use it.

- **Extension**: The production function analysis showed that contact with extension significantly and positively affects the output of male farmers, but not of female farmers. To address this problem, three strategies need to be pursued simultaneously.
  - More female farmers need to be contacted by agricultural extension agents. Female heads of households are most in need of extension contact because relatively few are in contact with extension agents and are less likely to receive information from close relatives. They also have considerable decisionmaking authority on whether or not to implement the advice.
  - The quality of communication must be improved: male agents must be sensitive to the needs of women farmers, and efforts should be made to increase the number of female agents (for example, by integrating retrained home economics agents into the extension service, as has been done in Nigeria).
  - The messages must be suitable for the objectives and constraints of women farmers. To do this requires better diagnosis of gender differences in agricultural activities and constraints.
  - Monitoring and evaluation should routinely be on a gender-disaggregated basis.

The country studies show that there are many useful and practical examples of how to improve extension for women farmers in Africa², but a more intensified effort is needed.

- **Credit**: Women’s access to formal credit must be increased. Cost-effective and sustainable financial services are critically needed by African smallholder farmers, both men and women. As the country studies show, they are presently quite inadequate, especially for women. In Nigeria, for example, only 5 and 11 percent of women surveyed had obtained credit from a bank and a cooperative, respectively, compared to 14 and 24 percent of men. Availability of inputs and technologies is to no avail unless farmers have the means to obtain or use them, and the seasonal surpluses of agricultural income may not be invested to full advantage. Financial innovations aimed
at providing such services in a sustainable way should be identified, particularly a greater effort is needed to explore and identify the informal savings and credit systems that are working for smallholders in Africa, together with ways of linking them to formal financial systems. Specific examples of such innovations are drawn from the Kenya and Burkina Faso studies.

Conclusion

Women are so important to African agriculture that initiatives to raise the sector's productivity cannot afford to ignore them. As this study shows, women do most of the work on the farm and increasingly have become the key decisionmakers. Despite this additional responsibility, however, women's access to agricultural inputs and support services has not improved commensurately. This results in a considerable loss in agricultural productivity and output, more than 20 percent according to the Kenyan analysis. The recommendations set out in this study are consistent with well-established tenets of agricultural development. Tenurial rights to land, land and labor productivity, cost-effective extension advice, appropriate technologies, and viable financial services are all important for effective agricultural development strategies. However, what this report emphasizes is that agricultural development strategies have not adequately focused on the clients, and in Sub-Saharan Africa at least, the clients increasingly are women. If SSA is to revitalize the agricultural sector and improve household food security -- goals assigned high priority by all countries in the region -- raising the productivity of women farmers must be made the centerpiece of agricultural strategy.

Endnotes

1. For a more extensive presentation of this study, see "Raising the Productivity of Women Farmers in Sub-Saharan Africa," by Katrine A. Saito (with contributions by Hailu Mekonnen and Daphne Spurling), World Bank Discussion Paper (forthcoming).

Agricultural Extension for Women - Experience from Nigeria

Ndanusa B. Mijindadi

Introduction

Agricultural extension aims at providing farmers the necessary education, skills, and technologies to enable them to make effective farm management decisions. However, in Nigeria and indeed in other African countries, the primary focus of agricultural extension efforts with respect to farm production traditionally has been on men. This is not surprising as African conventional wisdom is that men make the key farm production decisions - not women. As a result of the above reasoning, there had been a tendency to neglect women in the delivery of extension messages in the area of farm production. Instead, extension advise directed at women traditionally had concentrated entirely on home economics related topics -- home management, child care, family nutrition -- all those aspects that have to do with the domestic roles of women.

In recent years, however, the dominant role of women as farmers who make key farm management decisions has become increasingly clearer. That women play a dominant role in agricultural production is valid not only for those African countries where there have been an out-migration of men to other countries to seek employment (Lesotho, Malawi, Botswana); it is also valid for those countries where political unrests and civil wars have resulted in a large number of deaths of males (Ethiopia, Uganda). More importantly, it is equally true for several African countries in normal times.

In Nigeria, for example, women involvement in farming ranges from situations where they assist in certain operations such as planting, weeding, harvesting (as in parts of the northern states) to situations in which certain crops are designated as "women-crops" -- especially food crops such as cocoyams and cassava -- for which women have exclusive production responsibilities (as in parts of the southeastern states). There are also areas in Nigeria where women farmers own and manage farms without any restriction on the crops they cultivate (as in the middle belt states).

It needs to be mentioned that the recognition of the dominant role of Nigerian women in farm production and the need to modify the extension system to address the issue was brought effectively to the attention of Nigeria's agricultural authorities after a series of World Bank Study Missions to a number of loan-assisted projects in various parts of the country. These studies indicated that women were indeed responsible for as high as 70 percent of actual farm work, and in some cases constituted up to 60 percent of the farmers; while they receive little or no information from extension agents. This has led to the redesign of all World Bank loan-assisted Agricultural Development Projects to accommodate a Women In Agriculture (WIA) Program, which should ensure extension service support to women farmers.

Thus, the aim of this presentation is first to highlight the objectives of the WIA program; second, describe its organizational structure and the implementation strategies employed; and third, summarize its major achievements as well as constraints. It is hoped that the lessons from Nigeria's experience in her efforts to provide extension services for women farmers could be of some use to other countries who may be in similar situations.

* Head, Federal Agricultural Coordinating Unit, Ibadan, Nigeria.
The Agricultural Development Projects and Objectives of Women in Agriculture Program

Before discussing the objectives of Nigeria’s Women In Agriculture Program, it would be in order to briefly discuss the extension service system in Nigeria, otherwise called the Agricultural Development Projects (ADPs).

The ADPs were started in the mid-1970s as enclave integrated agricultural development projects with funding assistance from the World Bank. The broad objective is to increase the production of both food and industrial crops. The core elements include a systematic extension program, adaptive research, input delivery system, a rural infrastructural program (rural feeder road, rural water supply), and an autonomous project management unit. The relative success of the first enclave projects encouraged the Nigerian Government to accept the ADP system as the main strategy for encouraging agricultural production at the small farmer level. Thus, the projects have been established on a statewide basis in all the thirty states of the country including the Federal Capital Territory of Abuja.

At present the Training and Visit (T&V) system of extension is the strategy for providing extension service support to farmers within the ADPs. The main features of the T&V system are the fact that the number of operating farm families that can be effectively covered by a village extension agent is so assigned to him/her; the entire state is divided into zones, blocks, and cells for field level operation; and effective supervision is ensured. There are field visits and trainings conducted by Subject Matter Specialists (SMS) and other officials for extension staff and farmers. Extension officials are constantly kept up to date with research innovations through adaptive research activities and monthly technology review meetings (involving researchers from research institutes and universities). The training sessions provide opportunities for field extension staff to acquire knowledge on technologies required to meet identified field problems while at the same time providing researchers with a better grasp of field problems. Other features of the T&V extension approaches include farm trials on farmers’ fields (which act as demonstrations to farmers); regular and fixed schedule of farm visits; and the use of the print and electronic media to enhance dissemination of farm innovations.

The operations of the ADPs are undertaken through activities of the core subprograms of (a) technical services (covering adaptive research on crops, livestock, fisheries, and agroforestry); (b) extension services; (c) engineering services - feeder roads, rural water supplies; and (d) commercial services -- input supply, marketing, and credit. There are also support units -- administration, finance/accounts; planning, monitoring, and evaluation; personnel development and training.

The WIA program, which may be part of the extension services or technical services subprogram, has the primary objective of increasing the productivity and incomes of women farmers. Specifically the program objectives include the following: (a) identify the constraints faced by women farmers; (b) source and where necessary collaborate with research institutions to develop suitable technologies to meet identified constraints and needs; (c) ensure timely extension support to women farmers in the area of agricultural production, processing and utilization (with greater emphasis on production); (d) provide advice to women on the formation of groups so that they can gain access to farm inputs and credit; (e) encourage diversification of women farming activities to small-scale production enterprises such as small ruminants, poultry, fisheries, and piggeries; and (f) introduce labor saving technologies in the activities of women farmers.
Organization and Operational Procedures

The extension services in every state in Nigeria now has women extension workers at all levels of its operation, from the headquarters at the state capital city to the villages. Thus at the headquarters there is the Head of the Women In Agriculture Program who has the rank of Deputy Director and works under the Director Extension Services or Director Technical Services. Head WIA has a university degree in agriculture, extension, or other related discipline with at least five years relevant working experience. She has overall responsibility for the planning and implementation of the program. She is assisted at the headquarters by a Subject Matter Specialist who may also act as Deputy Head of the program.

At the zonal level, there are SMS (WIA) who supervise and monitor the implementation of the WIA programs in the zone. More specifically they liaise with research institutions to source relevant technologies, develop production messages, participate in field problem identification surveys and trainings, and provide overall support to Block Extension Agents (BEAs).

At the Block level, there are WIA Block Extension Agents who are essentially Village Extension Agents and work mostly with women farmers. They are advised to spend about 70 percent of their time on agricultural production related matters and 30 percent on post harvest technology related problems. BEAs (WIA) have specific responsibilities to identify and organize women into groups in the eight cells in the block, and to liaise with cooperative society inspectors to register women groups into cooperative societies. The BEAs, however, report to the Block Extension Supervisors.

At the circle or village level, there are no separate Extension Agents (EAs) for WIA. However, an understanding has been reached that at least 30 percent of all EAs in an ADP are expected to be female. In addition all female EAs are to ensure that at least 60 percent of their contact farmers are women farmers. Furthermore, all EAs (men and women) are to disseminate information to all farmers where no religious or customary barriers prevent such contacts.

Implementation Procedures

The operational procedures of the Training and Visit system of extension, which is currently in use in the ADPs, also provide the basic strategies for extension support to women farmers. The strategies include the use of the following:

- **Surveys or studies** -- the objective here is to assess women farmers' priority needs, the constraints they face, and potential development opportunities in the area. Such studies are undertaken by resource persons from research institutes and universities working in collaboration with subject matter specialists in WIA. From the results of the surveys, needed technologies can be identified and problems requiring solutions passed to the appropriate agency.

- **Adaptive research** -- while a number of agricultural technologies are gender neutral, it is important that technologies identified to meet women's needs are relevant to their circumstances. Thus, this strategy ensures that technologies directed at women are, where necessary, adapted specifically for use by women and made to suit the environment in which they operate.

- **Training** -- this is undertaken at various levels. For example, at the monthly technology review meetings, resource persons from research institutions and universities in collaboration with Head WIA select and treat topics on technologies for
which the skills of subject matter specialists and BEA supervisors need updating. The topics and technologies treated are based on problems identified during studies and on results arising from adaptive research; other relevant technologies may also be treated. In addition, fortnightly trainings based on recommendations and technical messages ready to be passed on to farmers are organized for Extension Agents. Such recommendations are presented in simple to understand language using learning aids as necessary.

The ADPs are also encouraged to establish skill development centers in various parts of the zones for the direct training of both field extension staff and women farmers on improved production technologies. At such trainings, practical demonstrations of the technologies are given.

Finally, in passing messages to women farmers, Extension Agents may pay visits to individuals farmers, that is, direct face-to-face contact, or work through women’s groups.

Field visits are undertaken regularly by SMS (WIA) sometimes in the company of officials from the research institutes, Federal Agricultural Coordinating Unit, and the World Bank to supervise implementation of the program.

Performance of the Program

In the last three years emphasis has been placed on four activity areas (a) ensuring that the organizational structure for providing needed extension services to women farmers is in place; (b) getting block and village level extension workers to establish necessary contacts and rapport with women farmers; (c) sourcing and demonstrating improved technologies that attempt to solve the identified constraints faced by women farmers; and (d) establishing appropriate linkages between WIA program of the agricultural development projects and other women’s programs being undertaken by other agencies.

Viewed against the above areas of emphasis, some modest achievements have been recorded.

Staffing

With regards to staffing, table 1 indicates the following. All states’ ADPs except one now have in place qualified Heads of WIA program. Subject Matter Specialists are also operating at the headquarter level for all but six of the thirty states. The requirement for Zonal Subject Matter Specialists has been met to some degree by all but four states where none was in place as of October 1992.

At the critical block level only three states, Rivers, Taraba and Yobe, have less than 25 percent of the required BEAs. However, in the Rivers State the shortage of BEAs (WIA) should not be a matter of concern as there are no customary nor religious barriers preventing male extension workers from passing technical messages to women farmers. In the other two states, the staff shortage problem has arisen as a result of the recent creation of states. Taraba and Yobe States were carved out of the older states of Adamawa and Borno, both of which have acceptable degrees of staffing at the block level.
Table 1. Women in Agriculture Program in Nigeria: Staffing Situation in Agricultural Development Projects (1992)

<table>
<thead>
<tr>
<th>ADP</th>
<th>Head WIA HQ SMS</th>
<th>Zonal SMS</th>
<th>BEAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Rq Post S</td>
<td>In Rq Post S</td>
<td>In Rq Post S</td>
</tr>
<tr>
<td>Lagos</td>
<td>1 1 -</td>
<td>1 - 1</td>
<td>4 - 4</td>
</tr>
<tr>
<td>Ogun</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 - 4</td>
</tr>
<tr>
<td>Oyo</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 - 4</td>
</tr>
<tr>
<td>Osun</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 3</td>
</tr>
<tr>
<td>Ondo</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>5 5</td>
</tr>
<tr>
<td>Edo</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>2 2</td>
</tr>
<tr>
<td>Delta</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 3</td>
</tr>
<tr>
<td>Kwara</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 4</td>
</tr>
<tr>
<td>Kogi</td>
<td>1 1 -</td>
<td>1 1 -</td>
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<td>Abia</td>
<td>1 - 1</td>
<td>1 1 -</td>
<td>3 3</td>
</tr>
<tr>
<td>Akwa Ibom</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>6 6</td>
</tr>
<tr>
<td>Anambra</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>5 2</td>
</tr>
<tr>
<td>C/River</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 2</td>
</tr>
<tr>
<td>Enugu</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 1</td>
</tr>
<tr>
<td>Imo</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 3</td>
</tr>
<tr>
<td>Rivers</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 2</td>
</tr>
<tr>
<td>Benue</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 3</td>
</tr>
<tr>
<td>Plateau</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 4</td>
</tr>
<tr>
<td>Taraba</td>
<td>1 1 -</td>
<td>1 - 1</td>
<td>4 4</td>
</tr>
<tr>
<td>Adamawa</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 3</td>
</tr>
<tr>
<td>Bauchi</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>4 4</td>
</tr>
<tr>
<td>Yobe</td>
<td>1 1 -</td>
<td>1 - 1</td>
<td>4 4</td>
</tr>
<tr>
<td>Borno</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>5 5</td>
</tr>
<tr>
<td>Abuja</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>2 2</td>
</tr>
<tr>
<td>Niger</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 3</td>
</tr>
<tr>
<td>Kaduna</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 3</td>
</tr>
<tr>
<td>Kebbi</td>
<td>1 1 -</td>
<td>1 1 -</td>
<td>3 3</td>
</tr>
<tr>
<td>Kano</td>
<td>1 1 -</td>
<td>1 - 1</td>
<td>2 1</td>
</tr>
<tr>
<td>Jigawa</td>
<td>1 1 -</td>
<td>1 - 1</td>
<td>2 2</td>
</tr>
<tr>
<td>Katsina</td>
<td>1 1 -</td>
<td>N/A</td>
<td>3 2</td>
</tr>
<tr>
<td>Sokoto</td>
<td>1 1 -</td>
<td>2 - 1</td>
<td>2 2</td>
</tr>
</tbody>
</table>

Note: Rq = Required; S = shortfall; N/A = not available.
Table 2. Summary of Selected WIA Activities in Nigeria (1991-92)

<table>
<thead>
<tr>
<th>ADP</th>
<th>No of Women Groups</th>
<th>No. of Women Contact Farmers</th>
<th>No. of Demonstrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagos</td>
<td>66</td>
<td>NA</td>
<td>330</td>
</tr>
<tr>
<td>Ogun</td>
<td>123</td>
<td>1,543</td>
<td>269</td>
</tr>
<tr>
<td>Oyo/Osun</td>
<td>1,385</td>
<td>2,297</td>
<td>3,694</td>
</tr>
<tr>
<td>Ondo</td>
<td>155</td>
<td>936</td>
<td>783</td>
</tr>
<tr>
<td>Edo/Delta</td>
<td>197</td>
<td>911</td>
<td>1,149</td>
</tr>
<tr>
<td>Kwara</td>
<td>448</td>
<td>1,200</td>
<td>1,070</td>
</tr>
<tr>
<td>Kogi</td>
<td>N/A</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benue</td>
<td>257</td>
<td>1,105</td>
<td>1,222</td>
</tr>
<tr>
<td>Plateau</td>
<td>81</td>
<td>3,098</td>
<td>1,465</td>
</tr>
<tr>
<td>Taraba</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Adamawa</td>
<td>20</td>
<td>3,726</td>
<td>1,250</td>
</tr>
<tr>
<td>Bauchi</td>
<td>157</td>
<td>493</td>
<td>3,300</td>
</tr>
<tr>
<td>Yobe</td>
<td>N/A</td>
<td>NA</td>
<td>-</td>
</tr>
<tr>
<td>Borno</td>
<td>43</td>
<td>4,321</td>
<td>3,690</td>
</tr>
<tr>
<td>Abuja</td>
<td>25</td>
<td>350</td>
<td>102</td>
</tr>
<tr>
<td>Niger</td>
<td>161</td>
<td>559</td>
<td>462</td>
</tr>
<tr>
<td>Kaduna</td>
<td>370</td>
<td>1,620</td>
<td>6,053</td>
</tr>
<tr>
<td>Kebbi</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Kano</td>
<td>745</td>
<td>1,665</td>
<td>3,474</td>
</tr>
<tr>
<td>Jigawa</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Katsina</td>
<td>20</td>
<td>N/A</td>
<td>15</td>
</tr>
<tr>
<td>Sokoto</td>
<td>128</td>
<td>1,520</td>
<td>29</td>
</tr>
</tbody>
</table>

Establishing Contacts

The first column of table 2 provides some data on the number of women WIA groups which are in operation in the states, and for which extension service support is provided. As indicated earlier, women farmers are encouraged to form groups that may get registered as cooperative societies. Such WIA farmers’ groups provide for a more rapid dissemination of agricultural innovations, and easier access to farm inputs and credit, which may be more difficult for individual farmers to obtain.

Column 2 of the same table shows the number of women contact farmers that the Block and Village Extension Agents are working with in the various states.

Technology Sourcing and Demonstration

The constraint diagnostic studies and the monthly technology review meetings earlier discussed reveal the problems faced by women farmers. WIA Subject Matter Specialists respond to such needs by identifying improved technologies to resolve such constraints and enhance farm productivity. Such technologies are then demonstrated to women farmers at various times, for example, small plot adoption trials on farmers plots, and practical demonstrations at group meetings held in skill development centers or during individual contact sessions. Table 3 provides a list of the types of
technologies that were extended to women farmers in 1992 in the southeastern states of Nigeria. It is clear from the table that crops, livestock, fisheries and postharvest technologies were covered.

The last column of table 2 shows the total number of small plot adoption trials (SPATS) and technology demonstrations that were undertaken for the benefit of women farmers in the states by BEA (WIA).

**Linkage with Other Relevant Organizations**

The WIA program has been able to establish close links with other women organizations in the state. This has helped to avoid duplication of efforts and encouraged support for one another's activities. For example, WIA Subject Matter Specialists and Block Extension Agents have been requested on a number of instances to provide technical trainings and demonstrate the use of improved technologies to other groups in the area of agricultural production, processing, and utilization. Similarly the WIA women's groups have received valuable technical assistance from organizations such as Nigeria's Better Life for Rural Women and donor agencies such as International Labor Organization, FAO/UNDP, and UNICEF.

**Constraints**

The above modest achievements notwithstanding, both women extension officials and women farmers have faced a number of constraints in the implementation of the WIA program. With respect to Women Extension officials, the following problems have been most critical:

- The number of women extension agents working at the village and block levels had their basic training and earlier job experiences in home economics. This has necessitated their retraining in the area of agricultural production, processing and utilization. This retraining exercise has not been as fast as desirable.
- Subject Matter Specialists WIA and Block Extension Agents WIA are required to use group approaches in implementing their programs. Yet they have had little or no training in group formation and management to be able to give effective advise to the women's groups and cooperative societies being encouraged.
- In a sizeable number of cases there has been instability in the staffing situation brought about by conflicts between commitment to work and family responsibilities on the part of women extension staff. For example, the marriage of female extension staff and transfers of husbands to duty posts outside cities where their wives work have tended to lead to resignations of WIA extension staff. Thus, in general, it has been very difficult to retain the services of female extension workers over long periods.
- On the part of women farmers the most recurrent problems are the following:
  - Shortage of farm implements that are gender specific or engineered with considerations of women's particular environment in mind. However, attempts are now made to involve women farmers in needs identification, selection of innovations, and in decisions on necessary adaptations to ensure relevance of the final product.
  - Extension officials have complained of delayed decisionmaking by women on whether or not to accept some technologies. This has been attributed to the need to clear such decisions with their husbands. This has mostly been in the southeastern states.
Table 3. Technologies Extended to Farmers in Southeast Nigeria in 1992

<table>
<thead>
<tr>
<th>NO.</th>
<th>TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Crops</td>
</tr>
<tr>
<td></td>
<td>Yam/maize/cassava/egusi intercrops</td>
</tr>
<tr>
<td></td>
<td>Alternative row</td>
</tr>
<tr>
<td></td>
<td>Cassava/maize/egusi intercrop</td>
</tr>
<tr>
<td></td>
<td>Yam minisett/maize intercrop</td>
</tr>
<tr>
<td></td>
<td>Yam minisett sole</td>
</tr>
<tr>
<td></td>
<td>Late maize/cassava/cowpea intercrop</td>
</tr>
<tr>
<td></td>
<td>Cocoyam minisett</td>
</tr>
<tr>
<td></td>
<td>Plantain sucker production</td>
</tr>
<tr>
<td></td>
<td>Swamp and upland rice</td>
</tr>
<tr>
<td>B</td>
<td>Livestock</td>
</tr>
<tr>
<td></td>
<td>Rabbit production</td>
</tr>
<tr>
<td></td>
<td>- Brood selection</td>
</tr>
<tr>
<td></td>
<td>- Hutch construction</td>
</tr>
<tr>
<td></td>
<td>- Feeding and feeds</td>
</tr>
<tr>
<td></td>
<td>- Kindling boxes</td>
</tr>
<tr>
<td></td>
<td>- Handling of young rabbits</td>
</tr>
<tr>
<td>C</td>
<td>Fisheries</td>
</tr>
<tr>
<td></td>
<td>Construction of fish ponds</td>
</tr>
<tr>
<td></td>
<td>- Fish selection</td>
</tr>
<tr>
<td></td>
<td>- Stocking methods</td>
</tr>
<tr>
<td></td>
<td>- Feeding and Ponds</td>
</tr>
<tr>
<td></td>
<td>- Cultural practices</td>
</tr>
<tr>
<td></td>
<td>- Checking overflow</td>
</tr>
<tr>
<td></td>
<td>- Checking weeds</td>
</tr>
<tr>
<td>D</td>
<td>Postharvest</td>
</tr>
<tr>
<td></td>
<td>Processing of soybean</td>
</tr>
<tr>
<td></td>
<td>- Soymilk, moi-moi, akara, pancakes</td>
</tr>
<tr>
<td></td>
<td>- Fortification of soups, jollof rice etc.</td>
</tr>
<tr>
<td></td>
<td>Cassava processing</td>
</tr>
<tr>
<td></td>
<td>- Instant fufu, chips</td>
</tr>
</tbody>
</table>
order to reduce the time lag in such decisions, joint training sessions are now held for both male and female farmers on the same technologies. Similarly, collective decisionmaking at women’s group meetings has tended to reduce the lag in adoption of innovations.

- There have been reports that women farmers face difficulties when they decide to expand their cultivated landholdings. Women farmers are also hesitant to accept innovations that involve long gestation periods, for example, tree crops production, and soil conservation practices. The problem is that women farmers may only have use rights and not ownership rights for the land they operate. It is fair to add that local government authorities and chiefs have not hesitated to allocate unoccupied community lands to women farmers’ groups for long-term agricultural production purposes, when they are approached.

Lessons and Conclusions

A few lessons can be drawn from Nigeria’s experience with extension services for women farmers. First, there is the need to put in place an organizational system that extends to the village level and ensures a constant flow of innovations between the extension service and women farmers. Such a system must include a feedback mechanism such that the needs of women farmers are taken into consideration by Subject Matter Specialists and researchers.

Second, it is helpful to undertake studies aimed at identifying women farmers’ specific needs. This should aid in setting priorities that satisfy the multiple roles that women farmers play, for example, their roles within the family, in the village economy, and in agriculture.

Third, strong professional linkages with research institutions, universities and polytechnics, where technologies are developed, is helpful for the constant generation of new ideas. Thus, the involvement of resource persons from such institutions is an indispensable input for an effective WIA program.

Fourth, before the transfer or dissemination of identified innovations, there is a need to test and where necessary adapt such innovations to the environment and conditions under which women farmers operate. This will ensure that such technologies are technically usable by women, low cost, profitable, and backed by locally available spare parts and repair facilities. A participatory approach, which involves the women in the selection and adaptation of technologies, has been found useful.

Fifth, Nigeria’s experience shows that encouraging the formation of groups by women and working with such groups helps enhance innovation dissemination and decisionmaking by women farmers. It also provides for easier access to farm inputs and credit.

Sixth, following on the last point, Subject Matter Specialists and Extension Agents in WIA programs, require training in techniques of group formation and management, cooperatives, and credit institutions and their operation. This is in addition to regular training in agricultural production, processing, and utilization. Finally, Nigeria’s experience shows that the linkage of the WIA program with other women’s programs in the area, as well as with donor agencies who could provide support for the implementation of WIA activities is mutually beneficial to all parties.

In conclusion, given the dominant role that women play in agriculture in developing countries, it is becoming clear that if such countries are to make a success of their agricultural development strategies, the specific needs of women farmers must be addressed. In particular extension service support must design programs that enhance farm productivity and incomes of women. Nigeria’s experience in these respects indicates that if appropriate education and guidance are provided, women farmers are responsive and willing to adopt relevant innovations.
Acknowledgement

This paper is based on field reports submitted by Federal Agricultural Coordinating Unit's Women In Agriculture program and Extension Specialists in the four regional offices at Enugu, Benin, Kaduna, and Jos. I wish to acknowledge the specific inputs of the following: J. Abdullahi; V.C. Agu; R.O.C. Chukwunta; C.Y. Akinboade, P.O.S. Abeywardena, and A.D. Onyia.
Women in Agricultural Resource Management

Aruna Bagchee

Women in Indian Agriculture

While Indian agriculture, as a whole, has shown quite substantial gains especially since the mid-1960s, the recognition of women's roles in this sector has come more slowly and more recently, only in the 1980s. There is, today, more awareness of the fact that farm women carry a significant part of the responsibility not only in crop production and homestead gardens, but also in tending livestock, poultry, and dairy. Not only is the contribution of female labor obvious and important in certain farm operations like the transplanting of paddy, or harvesting and postharvest management of most crops, their role as owners and decisionmakers of the farms is also significant. The latter is particularly true in hill farming situations, among tribal populations, and elsewhere too where the men try to get at least parttime, off-farm regular employment, or in cases of more or less permanent out-migration of the males. Even in the case of more apparently male-dominated agriculture (as in some states of the northern plains region), women, nevertheless, take responsibility for fuel collection and management of livestock, as well as a number of other allied activities, including market gardening. The fact that rural women are thus intimately involved in the management of agricultural resources has now come to be well accepted.

However, it has to be admitted that this recognition of the role of farm women in Indian agriculture, has yet to make a significant impact in reorienting either agricultural research priorities or the developmental schemes. A determined effort is thus needed to translate this slow recognition of farm women's contributions to agriculture, into positive support and encouragement to their role in the further development of the country's agriculture.

How exactly this positive support should be given is, however, still a matter of debate. One strategy attempted (through bilateral assistance from DANIDA) has been to implement separate women-farmer oriented projects. In these, female supervisory and field extension staff identify the production constraints of women farmers, arrange for short-term in-house training, and for follow-up extension services thereafter. But these are isolated microlevel projects without any large-scale visible impact or wider replicability.

Another strategy, which has been considered, is to appoint more women contact farmers and village extension workers (VEWs) under the training and visit extension system. This would imply creating a parallel delivery system, which implies high costs, and in Kerala, where it has been tried, the impact is not very encouraging. A third approach sees the necessity of involving women farmers in mainstream development programs, such as the watershed development program, for example. This paper argues that involving women farmers in mainstream development programs is a sound strategy. Because the watershed development program is a major thrust area in the eighth five-year plan, a beginning can be made by strengthening women's roles in agricultural resource management through this program.

* Secretary of the Department of Tribal Development, Government of Maharashtra, Bombay.
The Watershed Development Programs

Watershed development aims at restoring a denuded catchment area to a properly managed system of replanted forest cover in the upper reaches, of adequate pastures and range lands, and of measures for maximum harvesting of rainfall. It is thus an important means of increasing the productivity of rainfed farming systems.

Given the extensive area under rainfed cultivation in the country, the Government of India has, in all its development plans, implemented various schemes for dryland agriculture. In the eighth five-year plan, 1990-95, particularly, it has embarked on a revised, more comprehensive program for improving rainfed farming systems on a watershed basis. The scheme's title is the National Watershed Development Programme for Rainfed Areas (NWDPRA). Besides the NWDPRA, there are operations research watersheds (ORP), sponsored by the India Council for Agricultural Research (ICAR) and agricultural universities, as well as several state level schemes. The watershed approach also is followed in some other important central schemes like the National River Valley Project, the Drought Prone Areas Programme, the Western Ghat Development Programme, and so forth.

However, in all of these schemes, the emphasis so far has been on developing the physical infrastructure of the watershed. Consequently, the programs largely consisted of traditional soil and water conservation measures, such as construction of check dams and diversion drains, contour and graded bunding, terracing, and so on. Much less effort has gone into training the farmers (both men and women) in on-farm scientific crop production systems (that is, in extension efforts to popularize in situ moisture conservation methods), and to encourage them to cooperatively manage the resources in a watershed on a sustainable basis.

However, in the eighth plan period, some of these shortcomings are sought to be corrected by:

- Placing greater emphasis on an integrated approach, which covers both arable and nonarable land treatment, as well as caters to the farmers' multiple needs for food, fodder, fuel, and income-generating activities.
- Relying more on low-cost and vegetative conservation measures. Thus, in situ moisture conservation would replace the earlier dependence on more expensive, earth and stone masonry engineering structures for water harvesting.
- Stimulating and promoting people's participation in project planning, implementation, and the management of community assets. For this, three contact farmers (Mitra Kisans) from the watershed villages are to be trained, and "care will be taken to select farm women as well" (Government of India 1990).

These revisions are welcome, and give great scope to strengthen the role of women in managing the resource base of the watershed. However, this paper argues that merely giving women a quota representation on the beneficiaries' committee will not be enough, and would amount to only tokenism. Much more serious thought and efforts are required to meaningfully involve women farmers in watershed management.

Strengthening the Role of Women in Watershed Management

Discussed below are some of the key interventions that seem required from this point of view. These include (a) underscoring the need to develop the watershed as a whole; (b) paying as much attention to institutional development as to the physical restoration of the watershed; (c) measures to train particularly the women in the watershed through functional literacy subprojects; (d) introducing...
farming systems research (FSR) subprojects that have a predetermined focus on the role of women; and (e) involving more voluntary agencies and documenting cases of success and failure at involving women in watershed management activities. An explanation of how these interventions would help women farmers follows.

Underscoring the Need for Integrated Development of the Watershed as a Whole

There is a need to reemphasize the concept of watershed as natural geohydrological units of planning in which land management practices at different gradients -- upland, midland, and lowland -- are interconnected. Because the watershed is, by definition, the unit of planning under this program, the need to develop the watershed area as a whole, through integrated planning, should be obvious. Unfortunately, this does not happen, partly because several agencies are responsible for implementing different components of the watershed development plan.

Water harvesting and drainage management are the responsibility of the soil conservation department, the on-farm moisture conservation practices are to be explained to the farmers by the extension staff, and afforestation in the upper reaches is the task of the social forestry department. In the absence of coordination between these agencies, the linkages between land use in the upland, midland, and lowland regional, and that between individual farming units and the wider resource base of a watershed are not very well recognized.

In the absence of such integrated development, many current watershed projects are reduced merely to the construction of a series of drainage management structures, called nala bunds, leaving on-farm cultivation practices and social forestry efforts untouched. However, this approach is bound to fail. Unless there is adequate tree and grass cover in the upper reaches of the watershed to "harvest" some of the rainwater and decrease the velocity of the runoff, there is little point in nala bunding farther downstream. Because individual landholdings are small and uneconomical in the rainfed areas, these farmers are dependent on the larger resource base of the watershed as a whole, which provides many of the free goods such as sisal for rope making, wood poles for housing, tools, and fuel, besides free grazing for the animals, and so on. There is, thus, an intimate linkage between the individual farm enterprise and the wider resource base of the watershed.

Women are particularly concerned with such linkages, as many of these allied activities concern them specifically. For example, most women from smallholder families not only work at crop husbandry in private farmlands, they are also charged with responsibilities for the grazing of livestock in the common pastures, fodder and fuel wood collection from the community lands, and gathering nutrition supplements (tubers, roots, honey, fruit, and pods) and other free goods (sisal, bamboo) from the nearby forests and making them into marketable items like rope and woven baskets. They are, therefore, critically interested that the entire watershed be treated as a resource base and as an integrated unit of planning. Such an approach thus would be directly in the interest of women in the watershed.

Institutional Development

Second, the current concept of watershed development tends to be limited to the physical restoration of a degraded environment. Thus, the components of watershed development are generally understood as planting more trees, constructing nala bunds, and developing pasture lands. However, a most critical ingredient of the farming system, namely human resource development (community
development), is completely ignored in such a concept. Yet, human resource development, including the development of appropriate institutions in the community, is the very cornerstone of scientific management of the resource base of a watershed. Unless people living in the watershed understand the linkages mentioned above, and unless they are motivated for collective action to manage the watershed for sustainable agriculture, government expenditure in afforestation or nala bunding per se is bound to be wasted, in the absence of maintenance and care, and proper institutions to manage the community asset.

A few examples from the successful experiment of watershed development in village Ralegaonsiddhi will make the point clear (Bagchee and Bagchee 1990). All watershed projects include a component of afforestation and pasture development. But in most cases the experience is that grasslands are fenced off and trees planted, at government cost, only to be encroached in by the local villagers. Only in Ralegaonsiddhi, because of local leadership, the newly forested commons are examples of "social fencing" – the villagers have strictly followed the discipline of not letting in cattle for free grazing. Not only this, but when the Ralegaon villagers found that villagers from a neighboring village were stealing wood and grass from this area, they went as a group and apprehended the trespassers. Each was forced to pay a fine of Rs. 111/-; the sum collected was, however, returned to the neighboring village as a lump sum for its school. This gesture so impressed the villagers in that village that they too have started thinking of community action along similar lines.

The reason that pasture development and afforestation works have succeeded in Ralegaon is that the economics of their management have been clearly worked out and a consensus built about the use and benefits to be shared from the assets so created. First of all, any alternate use that marginal croplands are converted to, such as pasture or grassland development, can be viable only in the context of the demand for fodder in the watershed, and the availability of foodgrains for the owners of these marginal croplands. Such lands are generally owned by the poorest cultivators, who grow minor millets (hulga, varai) in the kharif (monsoon season) for domestic consumption. They cannot forego this option merely because the soil conservation department declares these lands as unfit for crop cultivation, and recommends that they be developed as grasslands. In Ralegaonsiddhi the problem of the food security of the poorest villagers was first solved through a "grain bank" – a buffer stock of cereals contributed by the better-off farmers. Thereafter, land-use planning according to the land's capability became feasible, as the smallholders who were cultivating food crops on marginal lands were willing to use this land for grass and fodder production. The activity of fodder development also became worthwhile as all the farmers came together to work out the demand for fodder within the watershed. There has to be a balance between the livestock maintained by the farmers in the watershed village and the fodder budget worked out for them.

In Ralegaon when it was decided to take up such works, the villagers realized that if some of the common lands had to be temporarily closed for regeneration, the number of animals (then about 1,900) needed to be brought down to the carrying capacity of the available grazing grounds. Many of the small stock (goats) were sold off and some of the cattle were gifted away, until the number was reduced by half to 1,000. As the private marginal lands and the common lands started yielding grass, a fodder budget was worked out for each farmer. It was decided that the cultivators should, by and large, maintain as many heads of livestock as they could feed from their own grasslands and crop residues. The right to exploit the common grasslands was given only to the landless families who had no land of their own to maintain their livestock. Even in their case, there are no free rights: each family is charged Rs. 15 per month for the right to cut and carry grass from the common pasture lands and each is allowed only one headload a day. This has brought in a modest income (Rs. 3,000 annually) to the Gram Panchayat (that is, the Village Council). A set of rules have been worked out that serve the interests of all parties involved. It is this consensus regarding the ground rules for sharing the benefits of the newly created community assets that explains why "social fencing" of these pastures and grasslands has been possible and successful here. It is these social or
institutional arrangements that are generally lacking in merely executing the physical targets of a development program.

**Innovated Functional Education (IFE) Subprojects**

As mentioned above institutional development -- encouraging men and women farmers to collectively manage the watershed resources -- has so far been a neglected aspect in the program. It needs to be emphasized and moreso in the case of women. In many villages, however, in order that women can come forward and participate in such community action, they need some special training.

Therefore, an important component for strengthening the role of women in ongoing watershed projects would be to start innovated functional education subprojects for the women in these watersheds. Nongovernment organizations (NGOs) and other agencies (agricultural schools, Krishi Vigyan Kendras, and so forth) can be involved to organize innovated functional education subprojects for the women in the watersheds. The main thrust of the subprojects should be to evolve a need-based curriculum and a teaching model to train the women in the selected watersheds. They should have the following salient features:

- The curriculum should be need-based and locality specific (in some watersheds, there may be scope for introducing scientific beekeeping, in others, tussor silkworm rearing, in still others, for improving vegetable gardening or floriculture).
- The medium of instruction should be the local language, or even the specific dialect or subdialect that the women speak.
- Skill training should be an integral part of the literacy component, and the literacy material should be developed around the skills to be imparted.
- The skills and competencies taught should, besides being site-specific, be income generating so as to be meaningful to the participants.
- Emphasis should be placed on teaching nontraditional skills, such as the use of the simple A-frame, biogas plant installation, and even operation of electrical and diesel pumpsets.

The IFE subprojects can be run in clusters of twenty to thirty selected watersheds. Each subproject should start with a need assessment survey, development of site-specific curriculum, and literacy material as well as a plan for the skills training program.

**Farm System Research/Extension (FSR/E) Subprojects in Selected Watersheds**

Agricultural research that is oriented predominantly to varietal improvement and organized for specific commodities in watertight disciplines within university departments is not likely to serve the interests of women farmers, especially of women in smallholder families in rainfed areas. These women generally are engaged in mixed farming, on smallholdings and marginal holdings, and with many constraints of time, labor input, and cash. What is, therefore, essential is more field problem oriented research, that is moreover interdisciplinary, in that it looks at the whole farming system, rather than only at the main activity or dominant crop. There is a need for farming systems oriented agricultural research that has a predetermined focus on women farmers.

There have been a few attempts in this direction, such as the Ramakrishna Mission work in the Sunderbans areas, and the Ford Foundation-sponsored Eastern India farming systems network, but these are not specifically oriented to developing the watershed as a resource base. It is expected that women's interests in agricultural development would be better served by having a farming systems research and extension subproject linked to the watershed development program. In order to give the FSR/E subproject a consciously predetermined focus to improve the productivity of women farmers,
gender analysis must precede the drawing up of the research agenda, as well as the monitoring and field testing of new technologies. This would involve:

- Bringing together women farmers, extensionists, and scientists from the nearest agricultural universities, Krishi Vigyan Kendra (KVKs), or National Agricultural Research Management (NARM) centers, to do a joint diagnostic survey. A useful tool in this exercise is a gender differentiated activities calendar that lists all the activities in which the local farmers are engaged over the year. To provide a more accurate picture of the entire range of enterprises involved and of the seasonal constraints of labor and other inputs, the activities calendar should include all production activities, not just major crops. It should also include: (a) domestic production or home maintenance activities such as collecting fuelwood and water, childcare, cooking, house construction and repair, and so on; (b) any gathering activity, such as collection of minor forest produce; (c) nonfarm production of goods and services through wage labor and other work; and (d) home processing of farm produce or collected goods made into marketable items like woven baskets (Feldstein and Poats 1990).

- Such baseline data can then be used to design a research agenda, which gives high priority to addressing the identified constraints to increasing the productivity of women in the watershed. Unless this is done, quite frequently, gender analysis stops with diagnosis, that is, with charts showing men’s and women’s tasks. However, if there is an ongoing FSR project, with a predetermined focus on women, then gender analysis can form the basis for actual research work. It will be useful also in the field testing and evaluating of new technologies. For instance in activities like fertilization, foraging, pesticides, crop protection, postharvest home processing, and so forth, gender analysis would help in answering the key questions of who is affected and who must be taught techniques of application when new technologies are recommended. Are the new tasks labor saving or intensive? Are the opportunity costs correctly estimated according to the gender of who is doing the task?

In particular, we need to commission special studies with respect to: (a) conducting time-allocation studies, in different agroclimatic regions, to determine how women’s time is utilized before and after the completion of a watershed development project; (b) evaluating the extent of increase in the employment and income, which accrues to women as a consequence of watershed development activities; and (c) documenting the case studies of success and failure of women getting involved in watershed development activities.

Involving NGO’s and Documenting Case Studies

Besides training and research support another crucial element is mobilization for collective action. As mentioned above, the term watershed development has to be correctly conceptualized, so that human resource development (HRD) forms an integral part of it. HRD includes grassroots level efforts to motivate and organize the local farmers for collective action to manage their resource base. In this, voluntary agencies can play a very important role. Indeed more than government, it is voluntary agencies who can effectively play the role of catalyst agent to motivate farmers for collective action. Unfortunately, very few of the voluntary agencies working in rural India have yet turned their attention to watershed management activities. Even fewer have worked specifically with the women in the watersheds. Yet, the few exceptions that exist have shown very dramatic successes in making the watershed development activities an effective measure for changing the pattern of opportunities available to the local farmers. It is, therefore, necessary to support the involvement of voluntary
agencies in watershed development activities, particularly those addressing the problems of rural women.

Such support should be through (a) networking of the agencies already working in the field, (b) making available to these agencies published material and slides and films bringing out the interlinkages between all of the activities going on in the watershed, (c) encouraging them to more directly address the problems of women in the watershed, and (d) encouraging more voluntary agencies in the rural areas to focus on watersheds and particularly on the women in watersheds.

The experience of NGOs so far has shown that considerable motivational and organizational work has to be done to involve women in watershed development activities. Despite their considerable contribution in almost all aspects of farming, rural women have been handicapped in participating in development schemes because they lack direct access to information or to government or bank officials. Yet, there have been some quite remarkable experiences where women have learned to play leadership roles, have even formed all-women cooperatives, and are in a position to make demands on the system. More needs to be known regarding these initial mobilization efforts, the dynamics of group formation, emergence of leadership, and the interaction of women’s groups within the given system. Unfortunately, very little is documented about these efforts, even by those NGOs working in the field with women’s issues. There is an urgent need for documentation of case studies that throw some light on these aspects. Indirectly and in the long run, these case studies of success or failure will help us in refining further efforts to strengthen the role of women in the management of agricultural resources.

Conclusions

In brief I have discussed that women are obviously and significantly engaged in agricultural resource management in India. At the same time, it has to be recognized that rural India is a highly segmented society with clear-cut barriers of class status, hereditary caste occupations, and community and sex determined rules of interaction and tradition. All of these have important consequences for the organization of agricultural production, and these elements have to be considered while planning further agricultural growth. In such a situation, to effectively reach the women farmers with a viable strategy to support their agricultural activities is not an easy task. It requires determined efforts matched by a lucid perspective and clear-cut goals.

I have argued, further, that given this need, the strategies of reaching women in agriculture through separate microprojects or through a parallel extension and delivery system seem inadvisable on two counts. First, they do not appear to be cost-effective solutions. Second, they run the risk of marginalizing women’s contributions, for the women’s programs will, with certainty, be marginalized as far as both funding and staffing issues are concerned.

On the other hand, I argue that it is advisable instead, to conceive of ways in which the mainstream development programs reach and address the production constraints of women, as well as men, engaged in the farming system.

In this paper, I have outlined how the government’s major development program for the rainfed areas -- the watershed development program -- needs to be reconceptualized in order to serve the interests of the women engaged in this sector. This includes:

- Reemphasizing the need for integrated development of the catchment as a whole, so that individual farming units (particularly the women) can derive benefits from the wider resource base of a restored watershed.
- Stimulating and encouraging collective action at the village level to develop appropriate institutions (cooperatives, committees, whatever) for the management of common property resources developed in the restored watersheds.
- Introducing functional literacy subprojects specifically developed for the women in the watershed.
- Introducing FSR/E subprojects in the program, which will keep in mind the gender variable both while drawing up the research agenda and in evaluating the impact of newly introduced technologies.
- Involving nongovernmental organizations, who are better equipped than government, to be catalyst agents for change, particularly for motivating farmers in collective action for resource management.

Funding and policy directions are required to support these components in the watershed development program. For they in turn will go a long way in supporting farm women in the rainfed areas to better manage their agricultural resources.

References


Targeting Women in Extension

Willem Zijp

Introduction

I am going to make two of the most common mistakes in extension: I do not know you, but I will simply assume that my presentation will interest you. And I will deliver my presentation about an hour and a half after lunch, at a time that pleases the organizers, but may catch you longing for a cup of coffee. Please, bear with me.

While preparing for this presentation, I asked myself five questions about targeting women in agricultural extension: (a) why target women in extension; (b) who are those women to be targeted; (c) what do women want from extension; (d) how can extension for women be approved on; and (e) what could be the role of the World Bank.

Why

Rationale -- There seem to be four major reasons to target women in extension. First, important distortions do exist in female farmers' access and utilization of new technologies and information. Targeting women helps remedy the effects of these distortions. Second, if you don't target, experience shows that extension benefits go to those who are already better off. Third, extension has often treated farmers as one, more or less homogeneous, mass of people. We have a lot to learn from commercial marketing. I quote from the Smithsonian magazine of January 1993 in an article that describes how marketeers learn about consumer preferences: "...marketeers see the country as a patchwork of diverse populations -- single parent households, dual income households, working women, black consumer, hispanics and kids who have enough cash to make their own purchasing decisions (Larson 1993, pg. 70). Extension should also categorize its audience into different target groups. A fourth reason to target extension is to make it more efficient and sustainable. It would be very expensive to organize a separate extingent service for each farmer subcategory. Such separation would marginalize women.

Problems -- However, looking at extension now being targeted toward women, a number of problems emerge. For instance, women extension is often dominated by donor pet topics that are not necessarily the highest priority of women farmers. Bee keeping sounds very women friendly but in parts of Morocco, it is a traditionally male activity. Second, in many extension services for women there is little recognition of differences in resources and opportunities of different categories of women farmers. Third, there is a fear to criticize women extension. Women extension is now somewhat like motherhood: loaded with emotion that you don't criticize easily. Hence the plea to refrain from jargon. We used to talk about the sexual division of labor, or sex roles. At present, there is a lot of discussion about gender-sensitivity, gender-disaggregated data, gender-literacy. However, there is a significant difference between sex and gender.

Sex is a clear concept: you are either male or female. The categories are mutually exclusive and exhaustive. That means that every person in the world belongs to only one of the two categories
and that all males and females together constitute the whole of the human population. Gender is much more complex. Webster defines it as a set of two or more categories into which words are divided according to sex, animation, psychological association, or other characteristics. I suggest not to forget about the concept of sex, because most statistical information is disaggregated by sex, if at all, but not by gender. Such statistical information may immediately identify imbalances between the sexes. On the basis of those nonemotional imbalances between the sexes, one could start to formulate questions regarding gender.

Why Not? -- There are a number of arguments against targeting. Some people feel that targeting women diverts attention away from the bigger issue: targeting poverty. Also, many male extension practitioners feel that targeting women is threatening them. They consider extension a zero sum game. Resources going toward women farmers and women staff in the extingent service are not going to male farmers and male staff. Female and male extension managers feel that any preferential treatment of women ends up being counterproductive. Women run the risk of being perceived as having gotten their promotions because of gender rather than performance.

Who

Farmers -- Of all rural households in the world, one out of five is female headed (figure 1). In Africa, almost one out of three are female headed. At the same time, the number of rural women living in absolute poverty has risen 50 percent as compared to a 30 percent rise of men living in absolute poverty over the last twenty years.

Staff -- Worldwide there are about 37,000 female agricultural extension (figure 2). This is a very lean figure -- it excludes all office staff and nonagricultural extension. Most female agricultural field staff work in Asia (figure 3). The percentages of female staff in agricultural extension organizations range somewhere between 10 to 15 percent, with Europe being low and North America high.

Producer or Consumer? -- In my opinion the World Bank tends to see women more as labor than as producer. Hence, the Bank has invested strongly in human resources, education, and social welfare. Where the Bank has targeted women, it was more often for consumption than for production, partly because poverty alleviation is often seen as welfare. Of course, for women in agriculture, the two go together. This justifies stronger investment in the productive capacity of (small) women farmers.

What

Technology -- Women have a particular need for labor- and energy-saving technology. Many women are interested in technology and skills that increase their production at low cost. An implication for research in answering to these needs is to do more research on cultural practices instead of the present bias favoring genetic and chemical research. An implication for extension could be a continued dependency on public and collective extension with a limited role for the private sector. The private sector is hardly interested in low cost production increases by changing cultural practices that have no intellectual ownership.

Shifts in Technology Needs -- A number of shifts in the needs of women farmers are visible. These shifts require changes in the delivery of extension services. I suggest four shifts: (a) a shift from instructing what farmers should do, to advising them how to do better, given their opportunities and resources; (b) a shift from production only to income; (c) a shift from an exclusive focus on on-farm activities to inclusion of off-farm or even nonfarming activities; and (d) a shift from delivery by the public sector only to a mix of public, private, and farmer extension organizations.
Figure 1. Rural Household Heads and Rural Women in Absolute Poverty

Rural Households
World

Rural Households
Africa

Rural Women
In Absolute Poverty

Compare rise for men: 30%

50% rise

in Millions
Figure 2. Worldwide Female Staff in Agricultural Extension (FAO, Global Consultation 1988)

Female Staff
Agricultural Extension

Asia

Near East
North America
Latin America
Europe

total females
(37,000)

(Source: FAO, Global Consultation, 1988)
Figure 3. Worldwide Female Staff in Agricultural Extension by Regions (FAO, Global Consultation 1988)

Female Staff
Agricultural Extension

% females

(Source: FAO, Global Consultation, 1988)
How

Information is a crucial production factor. I have some suggestions to improve: (a) the supply of that information; (b) the formulation of demand for that information; and (c) the matching of supply and demand of information for women.

**Improved Supply**

Find out what female farmers need. I suggest a participatory systemwide way: is know-how a bottleneck for increased production, or not? If it is, where do gaps occur? Are they among female farmers only, or are there also "blind spots" among extension managers and policymakers. Finding out what know-how female farmers need should be done by a team, including female farmers and research and extension staff. That team should gather secondary data, go to the field, spend some nights in villages, listen to farmers. The major outcome of such a survey should be an agreement between farmers, researchers and extension staff on priorities that answer to the needs of different categories of farmers.

Plan for efficiency and effectiveness. Once the priorities are agreed upon, further agreement is needed on the distribution of tasks: who is going to do what. For instance, a farmers' interest group on tomatoes might organize variety demonstrations, a women's organization might demonstrate cheesemaking, while the public extension service would educate the public on soil conservation. Each organization chooses its appropriate channel of communication. Some organizations may feel the need for more female extension agents. To solve the present shortage of female extension staff, a female extension agent would start working with a group of women farmers. Once established, she could "hand over" that group to a male agent, freeing her to start with another women's group. Radio and television programs could be targeted to women, and also policymakers should be targeted.

Carry out the plan. Women farmer groups already exist. The trick would be to train male and female staff to recognize existing female groups and assist them. Much of the training of female extension staff seems to be supply driven. I suggest carrying out a skill gap analysis, early on in any extension project. Such a skill gap analysis would have three phases: (a) find out what kind of staff is desired -- what kind of experiences, education, skills, and attitudes are considered desirable -- ; (b) conduct an inventory of the kind of staff that is actually available; and (c) compare the desirable and the available in order to develop a training master plan and a plan for hiring and firing staff. Gender should be included in all three phases of the skill gap analysis.

Monitor the progress. I suggest using the same team again that did the diagnostic work, to monitor what actually has happened. How many farmers have changed their behavior? Such monitoring creates ownership and accountability. Also, staff formulate their own tasks more realistically if they know that they will have to implement them, and monitor their results, together with farmers.

**Better Formulated Demand**

The formulation of demand for advice can be improved upon by contracting out extension, because supplier and client need to be clear about what it is that they sign a contract on.
Support rural women’s organizations. There are two types of organizations that merit support. (a) commodity organizations, particularly livestock grower groups or vegetable growers for instance; and (b) general women’s organizations. Female representation in agricultural chambers or water users associations should be promoted.

Give female farmers control over (part of) the public extension budget. For instance, female farmers could decide on a bonus for staff who have performed exceptionally well, rather than spread any bonuses thinly over all staff, irrespective of performance.

Improved Matching

A new role for government is emerging in the field of extension. Governments are no longer simply implementing extension, crowding out many other initiatives. Governments are now setting conditions for a variety of organizations to implement extension. Such a new role for government -- matching supply and demand -- requires a much profounder understanding of rural information than is usually the case.

The government’s role in extension is probably threefold: (a) it sets conditions and provides a legal framework for farmers organizations and the private and public sectors to do extension; (b) it provides an infrastructure for communication and information, assuring affordability and accessibility of communication to all farmers; and (c) it may implement extension where a public interest exists, but where there is no private sector involvement. This changing role of the government in extension requires the recruitment of high level female staff in extension policy units.

Bank’s Role

The World Bank could invest in all areas that I just mentioned. To do that well, I think the Bank ought to do more substantive project preparation. Too few project documents are clear whether or not know-how is a limiting factor in increasing productivity. It is often assumed to be the case, but usually without specifying what kind of know-how would make a difference for what kind of farmer. The Bank could invest more in rural infrastructure, particularly in communication infrastructure, making information more easily accessible and more affordable to small, particularly women, farmers.

References


Endnotes

1. For instance, Pietronella van den Oever, Genesys project, personal communication.

2. World Bank Development Reports, FAO, Global Consultation on Extension.
Women and Fuel Issues

Augusta Molnar*

Women and Fuel

Rural women in many regions of the developing countries of Africa, Asia, and Latin America face severe constraints in meeting their household fuel needs due to deforestation, land and forest degradation, and rising population pressures on the existing agricultural lands. The fuel crisis has been a topic of research and popular concern that has led to the implementation of a substantial number of forestry, energy-saving, and conservation programs and projects by governments, donors, and nongovernmental organizations (NGOs).

As the knowledge base improves, it has become increasingly apparent that the fuel crisis and women's relationship to fuel supplies is extremely complex. Early calculations documented the large gap in supply and demand of woodfuels in Africa and Asia and measured the high consumption of agricultural residues and animal dung in cooking fuels. Studies of individual villages in fuel-short areas have documented fuel collection burdens of up to five hours per day (Cecelski 1985; Kaur 1991; and Rodda 1991). This added up to a perception of a crisis that was of such proportions and so widespread that a massive tree growing effort was initiated to combat it. What was not well understood initially was the wide range of variation in the extent of the crisis, local perceptions or nonperceptions of the crisis, and the variations in incentive structures needed to target the victims of the crisis. While there is no question that fuel is a key issue for women and their families, it is clear that early assumptions that any efforts to supply fuel would be advantageous have been tempered by a recognition that the wide range of different scenarios require quite tailored solutions. Programs have had to take a more careful look at their assumptions and their objectives, and develop a range of interventions that are site specific.

A background paper for the World Bank Forest Policy Paper (Mercer and Soussan 1992) has categorized the broad types of fuel situations in the developing countries into seven types of areas: (a) high woody biomass and low population density, where climax vegetation allows adequate supply to all but small areas of large population influx; (b) high woody biomass with medium population density, where intensive cultivation and scattered woodlands call for agroforestry for the land population and communal management for the land poor; (c) medium woody biomass and high population density, where fuel shortages are substantial and concerted resource management strategies are needed to meet fuel needs; (d) low woody biomass and montane, low population areas, where widespread poverty complicates design of programs to increase fuel; (e) low woody biomass, arid, low population density, where communal forest management systems supply important benefits; (f) urban areas; and (g) transition zones between areas, where a combination of measures is needed. Within these broad types are a range of variations related to local farming systems and social and cultural conditions.

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Identifying Shortages through Women’s Time Burden

One area where false assumptions have led to inappropriate interventions is in the identification of the nature and extent of women’s fuel shortages. It is not always easy to identify where the shortages of fuel are to be found, nor the types of interventions that are most appropriate to address that shortage. Measurement of the problem is made difficult by the lack of good survey methodologies and the failure to ensure that women interviewed understood the questions asked. Many of the early calculations in Africa and Asia documenting fuel collection times of four or more hours per household or per woman per day have been found to be erroneous due to faulty questionnaire design (in many of these examples, closer questioning of household members found the four or more hours recorded daily were actually only invested two or three days per week or only during a short, intensive collecting season). Changes in family diets attributed to fuelwood shortages, such as a decline in the consumption of beans, have in some cases been found to be related to the increased sale of these products outside the household. Studies, which accurately document such long hours of fuel collection, seem to identify not average situations found over large regions in developing countries, but the worst case scenarios where unusually stark conditions apply. Contrasts within country data sets can be quite substantial, as shown in tables 1 and 2 for the Himalayan region. Often the problem is not one of fuel shortage per se but of shortages of quality sources of fuel, increasing both cooking times and incidence of respiratory and eye problems from smoke exposure.

Even when the time spent in fuel collection is extremely high, there may be a wide range of perceptions about the cost of that time among both men and women, which affects their interest in changing the situation. A study in Northern India has shown that neither men nor women consider the large amount of time spent by women in dungcake preparation as negative, because neither gender places a high value on women’s time. Status hierarchies among women whereby lower-status daughters-in-law undertake most dungcake preparation exacerbates the problem. There will be little interest in such a society in growing woodfuel or adopting fuel-saving cookstoves. In a Beijer institute funded project in Kenya, it was initially found that women were spending long hours collecting roadside woodfuel, when their homesteads contained a variety of trees used by men for other purposes. Men did not perceive the lost productivity resulting from women’s fuel collection burden. When project extension focused on documenting the costs of women’s time to family members, this led to men encouraging their wives to grow and harvest homestead trees for fuel (Chavangi 1988). Studies in the Nepal and Indian Himalaya also have documented the foregone farm productivity resulting from women’s labor burden for fuel and fodder collection. Unless this cost is socially recognized, women and their family will have no incentive to change the situation. Programs may focus on fuel shortage issues when women have other priorities. In some areas women have expressed little interest in reducing the time burden for fuel collection, because they perceive other tasks, such as food preparation, as the main constraint on their time (Koenig 1986). Tree growing programs in Nepal found that women in some villages valued the water supply provided by a nursery site more than the trees, because their biggest time constraint was water collection (Molnar and Schreiber 1989).

Understanding the Nature of the Fuel Supply

Nor is the nature of the supply so simple. Despite a large discrepancy between the recorded supply of wood and the recorded consumption levels, there may be ample but unrecorded sources of woodfuel or biomass substitutes. Global Indian figures document a fuelwood demand of 230 million
Table 1.  
**Time Taken and Distance Traveled for Firewood Collection**

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Year of Data</th>
<th>Firewood Collection Time Taken</th>
<th>Distance Traveled</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>India</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamili (hills)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Dwing</td>
<td>1982</td>
<td>5 hr/day&lt;sup&gt;@&lt;/sup&gt;</td>
<td>over 5 km</td>
<td>Swaminathan (1984)</td>
</tr>
<tr>
<td>(b) Pakhi</td>
<td></td>
<td>4 hr/day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gujarat (plains)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Forested</td>
<td>1980</td>
<td>once every 4 days</td>
<td>n.a.</td>
<td>Nagbrahwan &amp; Samabrami (1983)</td>
</tr>
<tr>
<td>(b) Depleted</td>
<td></td>
<td>once every 2 days</td>
<td>4-5 km</td>
<td></td>
</tr>
<tr>
<td>(c) Severly depleted</td>
<td>1980</td>
<td>4-5 hr/day</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Madhya Pradesh (plains)</td>
<td>1980</td>
<td>1-2 times/week</td>
<td>5 km</td>
<td>Chand &amp; Bezboruah (1980)</td>
</tr>
<tr>
<td>Kumaon (hills)</td>
<td>1982</td>
<td>3 days/week</td>
<td>5-7 km</td>
<td>Folger and Devan</td>
</tr>
<tr>
<td>Karnataka (plains)</td>
<td>n.a.</td>
<td>1 hr/day</td>
<td>5.4 km/trip</td>
<td>Batliwala (1983)</td>
</tr>
<tr>
<td>Garhwal (hills)</td>
<td>n.a.</td>
<td>5 hr/day</td>
<td>10 km</td>
<td>Agarwal (1983)</td>
</tr>
<tr>
<td>Bahar (plains)</td>
<td>c. 1972</td>
<td>n.a.</td>
<td>1-2 km/day</td>
<td>Bhaduri &amp; Surin (1980)</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>n.a.</td>
<td>8-10 km/day</td>
<td></td>
</tr>
<tr>
<td>Rajasthan (plains)</td>
<td>1986</td>
<td>5 hr/day (winter)</td>
<td>4 km</td>
<td>personal observation (1988)</td>
</tr>
<tr>
<td><strong>Nepal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tinan (hills)</td>
<td>1978</td>
<td>3 hr/day</td>
<td>n.a.</td>
<td>Stone (1982)</td>
</tr>
<tr>
<td>Pangua (hills)</td>
<td>late 1970s</td>
<td>4-5 hr/bundle</td>
<td>n.a.</td>
<td>Bajracharya (1983)</td>
</tr>
<tr>
<td>WDA™ (lowlands)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) low deforestation</td>
<td>1982-83</td>
<td>1.5 hr/day</td>
<td>n.a.</td>
<td>Kumar and Hotchkiss (1988)</td>
</tr>
<tr>
<td>(b) high deforestation</td>
<td></td>
<td>3 hr/day</td>
<td>n.a.</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**  
* Firewood collected mainly by women and children.  
<sup>@</sup> Average computed from information given in the study.  
n.a. Information not available.  
** Western Development Area.

**Source:** Bina Agarwal, 1992, page 46 (sources cited in detail in Agarwal paper).
Table 2. Patterns of Participation (In-Village Activities) in Eight Villages of Nepal (Population of 15 Years and Above)

<table>
<thead>
<tr>
<th></th>
<th>Tibeto-Burman</th>
<th>Indo-Aryan</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tibetan speaking</td>
<td>Lohorung Rai</td>
<td>Kham-Magar</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Sphere I: Domestic activities</td>
<td>0.75</td>
<td>3.78</td>
<td>0.86</td>
</tr>
<tr>
<td>Fuel collection</td>
<td>0.58</td>
<td>0.07</td>
<td>0.28</td>
</tr>
<tr>
<td>Fetching water</td>
<td>0.06</td>
<td>0.26</td>
<td>0.10</td>
</tr>
<tr>
<td>Total work hours per day</td>
<td>2.15</td>
<td>2.03</td>
<td>0.39</td>
</tr>
<tr>
<td>Sphere III: Market activities</td>
<td>3.70</td>
<td>6.88</td>
<td>1.77</td>
</tr>
</tbody>
</table>

*a/* Not included in the current analysis.

Source: The Rural Women of Nepal: An Aggregate Analysis and Summary of 8 Village Studies by Meena Acharya and Lynn Bennett
tons per annum as against a recorded supply of half that figure. This has led policymakers to worry about serious land degradation due to diversion of other biomass sources to fuel. In practice, the supply figure ignores many of the unrecorded sources of fuelwood, such as lops and tops of harvested trees or clippings from roadside or farmside shrubbery. In addition there is a great variation in the impact that diversion of agricultural residues to fuel can have on the farming and ecological system. In more marginal areas of South Asia, the diversion of biomass to fuel can seriously reduce agricultural productivity, as in the upland farms in Nepal, where biomass is essential to increase the water-absorbing capacity of the soil (Carson 1991). In the highly productive, irrigated parts of India, however, farming practices and high yields generate so much agricultural residue and animal dung, that burning these materials may have little negative impact on the farming system or on women’s lives. Programs that seek to address a large-scale fuel gap have applied the same incentive structures for tree growing where the needs and interests are radically different.

Increased supply of trees in a given area may not be channeled to women or give their families greater access to woodfuel. Areas with woodlots, such as homesteads in parts of Kenya, or villages near public forests, may be the site of severe fuelwood shortages because women lack tenure rights to the trees concerned. Hoskins (1989) reports visiting a village in Burkina Faso where an ample supply of trees was growing but where women faced severe fuel collection problems due to their limited tenure over the trees. Communal sources of fuelwood may also be in danger of land-use shifts in land use or ownership. Women, particularly poor women, in the plains of India have suffered drastically from the conversion of marginal communal lands to private pastures or urban development. According to Jodha common lands in India have declined drastically in the dryland areas over the past two decades (Agarwal 1992). In both Africa and Asia, government or community woodlot establishment programs have closed formerly open-access lands to women. In drought-prone areas, communal lands provide an important source of fuel in famine periods and income for the poor. This social security cushion is lost with privatization (Agarwal 1992).

**Conservation of Biomass Fuel through Improved Cookstoves**

Another intervention that has been introduced to help address the demand side of domestic fuel use is improved cookstove technology to reduce the consumption of fuel domestically. This type of intervention has proved to be very difficult to successfully design and implement. In order to keep the cost of cookstoves to a minimum, programs have concentrated on low-cost technologies that often did not deliver a durable or high-quality product. In addition the wide range of variation in cooking habits and requirements have made it difficult to identify stove models that are appropriate to local needs. Many of the wood-burning models have been found to save much less fuel than anticipated or to require drastic changes in cooking habits that women are not interested in making. The improved stoves that have been most successful are charcoal stoves, targeted to urban and peri-urban users who already pay high prices for woodfuel and charcoal. Programs of this type have been extremely successful in Mali, Senegal, and Thailand.

The problems with dissemination of improved cookstoves have led to more emphasis on promoting changes in fuel management and cooking practices that reduce the consumption of fuel without the need for a new technology. In urban areas where charcoal is not a viable option, policy makers are finding that the most important measure to reduce woodfuel and biomass consumption is making alternative fuels more readily available in an assured supply, such as petroleum products, electricity, or gas. In many urban areas, fuelwood prices are already high enough, that even without subsidies, consumers will switch to alternative fuels as long as the supply is relatively stable.
Fuel and Women’s Income-Earning Strategies

Another dimension to the relationship between women and fuel is income generation. Programs to increase women’s access to fuel initially focused on the domestic cooking and heating supply needs of rural people and failed to analyze the relationship of fuel use for domestic cooking and tree and woodfuel use for other purposes. A large number of rural women collect fuel for other needs within the household economy and, in areas accessible to markets, for sale to urban centers to earn cash. Rural women use biomass fuels for a variety of home-based enterprises, including processing of foods and liquor for sale, drying or processing fibers for crafts, extracting natural medicines from leaves and barks, and making dyes. The cost in time, money, and effort required to obtain fuel can be an important factor in whether or not women engage in value-added processing or fuel-demanding income-generating activities.

Studies in Africa and Asia document a growing female-dominated market for the sale of fuelwood, charcoal, and animal dung. It is estimated that there are four million headloaders in India who subsist mainly from the collection and sale of wood. Between 10,000 and 70,000 Ethiopian women around Addis Ababa depend on the sale of fuelwood for their livelihood. In the Sahelian countries, charcoal production for sale to urban markets is an important source of income for men and women, with women making up an increasing proportion of the sellers to urban areas (Rodda 1991).

Incentives to Produce Wood from Plantations or Managed Forests

Evaluation of the progress of a large number of agroforestry, communal planting, and forest management programs has revealed a number of incentive issues for women and men’s participation in these activities. Both men and women usually view trees as a multipurpose investment rather than as a source of fuelwood. Except in areas with a well-developed fuel market and a shortage of accessible woodlands from which collectors can gather wood at no cost but labor, farmers generally grow trees for a number of other purposes with fuelwood as a byproduct. Where fuelwood has a low price, homesteads may have little incentive to grow trees unless the shortage of fuel is acute. Women with greater fuel collecting responsibilities have stronger incentives for growing trees for fuel, fodder, fruit, and timber than men, but usually lack the security of tenure to grow trees. Many programs to encourage women to raise trees on marginal lands have had to confront the problem that once the trees grew successfully and the value of the land increased, men began to try to get control of the land. NGOs have had to take special measures to help women and poor men to maintain control in many instances (Chen 1990).

It is now well understood that women’s biomass shortages may be more acute in the case of fodder than fuel, and the programs to provide fodder sources that provide fuel as a byproduct create much stronger incentives for participation. Fuelwood programs in the past have sometimes received strong resistance from women, as in Pakistan where pine plantations were established on lands traditionally used for fodder (Carpenter 1991). Had fodder trees been encouraged instead, women would have been active participants. Increasing women’s participation in improved forest management has shown to be a promising and rapidly expanding area of intervention, particularly when promoters and technical personnel recognize that women are not solely interested in managing forests for fuel.
Interventions to Increase Women’s Access to Fuel: Where Are We?

Programs and projects designed to increase women's access to fuel have evolved considerably in their objectives and approaches, an evolution that parallels the increased understanding of the complexities of women and fuel use. Early tree growing and forest regeneration projects had a limited impact on women’s fuel and tree product needs because they failed to: (a) tailor interventions to the site-specific needs of women and their families; (b) properly analyze the costs and benefits to women and men from tree-growing and forest management, and create the appropriate incentive structures for these activities; (c) successfully address the fuel demand side; and (d) remove structural constraints on women’s participation, such as lack of capital, tenure, information, or time. Objectives focused on increasing the supply of fuelwood and reducing demand through the introduction of fuel-saving cookstoves, but interventions were not well-tailored to ensure the increased supply was channeled to women. Nor were interventions included that emerged from a careful analysis of women's potential and incentives to participate actively in plantation or forest management initiatives.

The challenge for large-scale projects, such as those financed by the World Bank, has been how to design programs and interventions that are more tailored to women’s needs and their active involvement (Molnar 1990). The main success stories for meeting women’s fuel needs have been those undertaken by small-scale projects and initiatives promoted by nongovernment agencies often funded by private foundations. There are a number of examples of small-scale agroforestry programs and forest management programs targeted to women or which have included women as major participants. A number of such programs were presented by the women leaders of these initiatives in the Global Assembly of Women and the Environment in preparation for the 1992 "Earth Summit" at Rio de Janeiro (UN Environment Programme and WorldWide Network 1991). In Asia these include (a) programs for involving women in wasteland afforestation with fuel, fodder, and commercial, nontimber species (oilseed, charcoal, and mulberry silk-rearing); (b) tree nurseries run by women or women’s groups; (c) homestead forestry, involving multipurpose species women can manage easily; (d) involvement of women’s groups in natural forest management; and (e) improved stove programs.

There are fewer examples of successful programs that have worked on a large scale or which have spread from an initial site to a large area by their own momentum. The challenge for agencies like the World Bank is how to provide the tailored interventions to women facing a diverse set of fuel situations and address the site-specific and often structural constraints to participation at an overhead cost attractive to a borrowing government.

Asia Region Experience in World Bank-Assisted Projects

Recently, a desk review was carried out in the Asia region of the treatment of gender concerns in the Bank’s agricultural sector portfolio. This paper presents the findings of that review regarding the projects that treated fuel issues and presents the key issues these findings raise for the evolution of future projects and investments. The review analyzed project documentation for 398 agriculture sector projects appraised between 1978 and 1990 of which 76 included gender-specific interventions in their design. Of these projects, fourteen were in the forestry subsector and six in the tree crops sector. Another twenty-five agricultural development programs included forestry activities. See figures 1 and 2 for a description of the portfolio analyzed. Many of the concerns raised by the analysis of the portfolio as a whole were pertinent to the forestry programs. Some were specific to the natural resource management sector.
Figure 1. Asia Region: Breakdown of Projects with WID by Agriculture Subsectors

1979-1991
Figure 2. Growth in Number of Projects with WID 1979-91

- Number of Projects
Because the desk review was unsupported by field knowledge of the particular projects except as team members had previous experience with the project, it was a considerable challenge for the review team to elicit complete information about the Women in Development (WID) interventions in a given project from the often sparse documentation available on this aspect. Nevertheless the team did manage to gain a fairly reliable sense of how gender concerns were treated in the projects and the suspected reasons for this. About thirty-six different types of gender-specific measures were identified in the portfolio, and their incidence recorded by sector.

There are two main trends in Bank projects in the sector. The range of measures included in projects increases after 1987. In addition the number of gender-specific measures included per project increases dramatically. These trends indicate a more complete analysis of gender concerns in project design, due in part to greater sensitivity to and knowledge about WID issues in Bank work, the increase in the number of Bank projects in resource-poor areas where participation is more central to design, and reflection of the addition of gender-specific measures in a second or third phase of an on-going project. What is not present overall is a clear intention to create a synergy, whereby the combination of interventions set into effect a dynamic reaction. Another problem area is that promising measures are not always successfully implemented and may appear better on paper than in reality.

What is usually not explicit in Staff Appraisal Reports (SARs) or other project documentation is the underlying rationale for the choice of a particular gender-specific measure, that is, the objective that the measure is intended to achieve. A main task facing the desk review team was to compile a list of the objectives and complementary strategies that seem to underlie the choice of the gender-specific measures identified. These strategies are listed below, along with a sample of the types of measures chosen for each objective. In the analysis of the portfolio and the forestry subsector in particular, the team examined the types of measures included and tried to put these in the context of the underlying design objectives. The team identified trends in the treatment of gender issues in the portfolio, and included types of measures that were not in the projects reviewed, even though such measures have been recommended for similar projects targeting women.

**Strategy 1:** Women are identified in the project documentation as one set of target beneficiaries who should be targeted for products to be generated through the project, recognizing the importance of those products to women's livelihood and interests. Examples of measures in this category include: (a) irrigation water and related drinking water supplies of value to women; and (b) fuel and fodder produced in project of value to women.

**Strategy 2:** Particular measures are designed to alleviate perceived constraints in women's participation in a main project component. These measures may be outside of the main activities included in the project but expected (indirectly) to increase women's participation in the main components. Examples of such measures are: (a) childcare facilities, (b) labor-time saving technologies and devices introduced, (c) improved health facilities, (d) literacy programs to increase women's confidence or awareness and skill level, (e) involvement of NGOs with strong outreach to women, perhaps involved in activities not directly related to project components, and (f) measures to increase women's use rights over land, water, and forests.

**Strategy 3:** Interventions are designed to increase women's access to information and to the extension services available in the project. Examples of these measures are: (a) training existing extension staff to reach women or deal with gender issues, (b) recruiting women extension agents to target women clients, (c) changing extension message content, revising research priorities, or changing the timing and location of message delivery to better target women clients, (d) targeting extension to women in groups rather than as individuals, (e) focusing extension on female-dominated crops or subsectors, (f) training trainers to be sensitive to gender concerns, and (g) targeting women farmers for training programs.
Strategy 4: Interventions are designed to increase women's earnings from existing activities or to create new opportunities/expanded opportunities for earning. Examples of such measures are: (a) improved crop technologies for women farmers and laborers, (b) time-saving devices to free women for productive work, (c) assisting women in marketing and transport operations, (d) increasing access to and return from home-based microenterprises, (e) increasing supply of raw materials for enterprises (fodder for livestock, raw materials for handicrafts, wood for commercial baking), (f) targeting wage employment in a project to women workers, and (g) supporting the development of new enterprises for women.

Strategy 5: Interventions are designed to support strategy 4 above by providing women more access to capital and inputs or securing their property rights. Examples of measures in this category include: (a) land titling and new asset titling (joint if conjugal partner), (b) increasing women's use rights over land, water, or forests, (c) targeting financial services to women, (d) training women in skills and awareness to enable them to get access to services or inputs, and (e) strengthening or creating female-dominated and shared institutions that enable women to access inputs or services and NGO involvement-development.

Strategy 6: Interventions are included to improve the quality of gender analysis in design, increase borrower's awareness of gender issues, allow detailed inputs on gender into design or implementation, or provide specific planning and management inputs on gender. Examples of measures in this category are: (a) including women beneficiaries/clients in R&D and project design efforts, (b) hiring WID specialists to help in design work, (c) training borrower and implementing agents in gender issue analysis, (d) targeting gender issues and indicators in monitoring and evaluation, (e) including WID specialists in project management team, and (f) working with NGOs that complement government capacity to work on gender issues or with women clients.

The forest subsector is very like other subsectors in that the range of measures and their underlying strategies have increased in number over time (see table 3). The intensity of gender-specific measures per project also have increased. While early projects focused on an almost kneejerk response to the crisis -- grow more trees and women will benefit -- more recent projects have attempted to better target benefits to women and capitalize on their roles as resource managers and farmers and tree growers. Projects are increasingly seeking to improve women's income generation through their involvement in the forest sector. This is an area where much more work remains to be done. While a number of projects have acknowledged the importance of managed forests or planted trees to supply traditional markets for recently commercialized nontimber forest products (NTFP), like leafplates (India), condiments, fibers, or silk-rearing, few as yet have analyzed NTFP-based activities and the long-term benefit flow to women (or men) in any depth. Both Bank and NGO-assisted projects have assumed acceptable returns to women's and men's inputs of time, money and organizational work would accrue without any systematic market or economic analysis, nor with any monitoring of actual returns during implementation. A great danger in NTFP-based initiatives is that as products gain greater marketability, men tend to displace women in the higher return processing and marketing activities. (A list of these is in Annex 1.)

All projects evaluated suffered from the problem of delivering the interventions as promised. A key issue appears to be that gender analysis during design is incomplete and interventions are not well thought through by the SAR stage. This is a serious problem in the entire Asia agriculture portfolio and equally for forestry. Extension support, focus on working with women in groups, channelling of credit inputs, or encouraging income-generating activities for women have often been included, but without a clear idea of what resources would be available to carry out the intervention.
Table 3. Forestry Subsector WID Interventions

<table>
<thead>
<tr>
<th>Gender-specific interventions that have been considered/included</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Increasing production of forest products women need and value, such as fuel, fodder, and nontimber forest products (NTFP) sold commercially or used domestically.</td>
</tr>
<tr>
<td>• Targeting of women for extension efforts through hiring female extension agents, training extension staff about gender issues, targeting women's groups for extension, or focusing messages on products and trees of interest to women.</td>
</tr>
<tr>
<td>• Increasing women’s access to land for trees through tree tenure schemes or allocation of public lands for forestry (one case).</td>
</tr>
<tr>
<td>• Encouraging measures to involve women in community forestry initiatives, including participatory forest management.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender-specific interventions that are not well defined or included</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Measures to increase the range of and value of NTFP that women gather, market, or use as manufacturing raw materials that increase women's opportunities to earn income.</td>
</tr>
<tr>
<td>• Measures to ensure women are key actors in decisionmaking regarding communally managed forest resources; no synergy of interventions in participatory forest management to ensure women become key actors.</td>
</tr>
<tr>
<td>• Measures to reorient FDs (research and management/extension staff) to recognize value of technical models and harvesting patterns that maximize products women prefer and need.</td>
</tr>
<tr>
<td>• Measures to change composition of foresters and forestry staff in government agencies to include more gender plurality at all levels.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Marked changes in portfolio post-1988</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Large increase in number of measures to target extension to women (six to twenty-three).</td>
</tr>
</tbody>
</table>
Strategies are incomplete to ensure adequate and appropriate staff, specialists, or local technicians to deliver the promised service. The review identified this problem as one of lack of synergy in the design of gender-specific interventions -- partial analysis of women's demands, involvement in the sector, and poor analysis of constraints they face led to design of interventions that were not implementable. Often they required complementary measures that only in combination with the main proposed intervention -- income-generation support or tree growing -- would lead to women's involvement in the desired activity.

The hottest area for involving women in forestry is in projects that seek to improve natural forest and existing forest management. Not surprisingly, foresters have discovered that women are strong lobbyists for improved forest management of public forests used by surrounding communities and forests on communal lands. Women's involvement in such schemes has been greatest in regions where forests provide a major part of household income -- in the Himalayas to support the farming system or in tropical forest areas that yield a wealth of subsistence and communal wood and nonwood products. Large-scale projects face the problem, however, that the lack of appropriate extension staff or group organizers limit the number of project-targeted communities in which women are able to play key management roles. Women often remain behind the scenes organizers who leave formal decisionmaking forums to men. Or they may only sit on committees as the communication link to other women to pass messages regarding male-dominated decisions.

Recent projects designs have looked more closely at tenure issues -- trying to allocate marginal public lands to men or giving women's groups management control over and benefits from communal and privately owned trees. They have also looked more closely at capacity building and technology transfer -- giving women high quality technical advice and training and bringing in more women as professionals in the forestry discipline. But Bank projects, like many projects of government and nongovernmental donors, have found it difficult to deal with structural reform issues raised by increasing women's access to resources, land, and information. Successful gender sensitive fuel programs empower women as well as increasing their access to fuel. This raises issues of acceptability of the programs to the traditional members of the society and the ability of project implementers to deal with the social change put in place. Projects that do deal with such real issues become complex and resource-consuming to implement, particularly if these issues were not well-analyzed during the design phase.

The key issues facing the integration of gender concerns into the sector at this point in our experience are:

- How to move from "automatic" attention to products women use and need -- fuel, fodder, NTFP -- to clear measures that channel an increased number of products to women.
- How to address the institutional strengthening issues entailed when introducing ambitious extension components that borrower and implementing agencies are not well-equipped to deliver (and how to develop interim extension delivery mechanisms).
- How to ensure that training components include the necessary measures for the development of appropriate curricula and include the staff and consultant resources for training of trainers and follow-up.
- How to continue to develop projects that focus on productive, income-generating activities as well as basic need products, but which at present depend heavily for success on the availability of qualified, local NGOs to implement.
• How to turn the promising forest management programs into initiatives that develop
women's roles as resource managers, rather than continuing to allow men to dominate
these initiatives.

Only when these problems are solved will the crisis of women and fuel and women and
resource degradation diminish and pave the way for balanced development.

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Endnote

1. The objectives of the desk review were: (a) to gain an overview of how and to what depth gender concerns were being treated in the region's portfolio; (b) to pinpoint interesting trends; (c) to identify major problem areas or important success stories Task Managers can learn from; and (d) to gather information to help in planning the next stages of the Asia Region Women in Development team's support to the sector (see Molnar and Naqvi 1992).
Annex 1. Forestry Projects Reviewed in the Asia Agriculture Portfolio Which Included WID Interventions

INDIA:  
West Bengal Social Forestry Project  
Gujarat Social Forestry Project  
Uttar Pradesh Social Forestry Project  
Kerala Social Forestry Project  
Karnataka Social Forestry Project  
National Social Forestry Project  
Jammu and Kashmir and Haryana Forestry Project  
Maharastra Forest Sector Project  
West Bengal Forest Sector Project  

NEPAL:  
Community Forestry Development and Training Project  
Forestry II  
Forestry III  

BANGLADESH: Forestry II  
Forestry Resource Conservation Project  

INDONESIA: Forestry Research and Institutions Project  

Note: There are a number watershed development and rainfed agricultural development projects which include gender-specific interventions in forestry, but these were analyzed within the context of the rural development or agricultural development subsector.
POVERTY AND AGRICULTURAL RESOURCE MANAGEMENT
The Population, Environment, and Agriculture Nexus in Sub-Saharan Africa

Kevin Cleaver and Götz Schreiber

Introduction

Over the past thirty years, most of Sub-Saharan Africa (SSA) has experienced very rapid population growth, agricultural stagnation, and severe environmental degradation. Increasing concern over these vexing problems and the apparent failure of past efforts to reverse these trends led the authors to take a fresh look at the available research findings and operational experience. The objective was not to compile and address all of the agricultural, environmental, and demographic issues facing Africa or simply to juxtapose these three sets of problems. It was to gain a better understanding of the underlying causes and to test the hypothesis that these three phenomena are interlinked in a strongly synergistic and mutually reinforcing manner.

The need to survive -- individually and as a species -- affects human fertility decisions. It also determines people's interactions with their environment, because they derive their livelihood and ensure their survival from the natural resources available and accessible to them. Rural livelihood systems in SSA are essentially agricultural, and agriculture is the main link between people and their environment. Through their agricultural activities people seek to husband the available soil, water, and biological resources in order to "harvest" a livelihood for themselves. Such harvesting should be limited to the yield sustainable from the available stock of resources in perpetuity in order to ensure human survival over successive generations. Improvements in technology can increase the sustainable yields or reduce the resource stock required. Population growth should, thus, be matched or surpassed by productivity increases in order to safeguard the dynamic equilibrium between the stock of resources and the human population depending on it for survival. Over the past thirty years, this has not been the case in Sub-Saharan Africa.

This study's findings confirm the hypothesis of strong synergies and causality chains linking rapid population growth, degradation of the environmental resource base, and poor agricultural production performance. Traditional African crop and livestock production methods, traditional methods of obtaining woodfuels and building materials, traditional land tenure systems and land-use arrangements, and traditional gender roles in rural production and household maintenance systems were well suited to survival needs on a fragile environmental resource endowment when population densities were low and populations were growing slowly. But the persistence of these traditional arrangements and practices, under severe stress from rapid population growth, is causing severe degradation of natural resources, which in turn contributes further to agricultural stagnation. Rapid population growth is the principal exogenous factor, which has triggered and continues to stimulate the downward spiral in environmental resource degradation, contributing to agricultural stagnation and, in turn, impeding the onset of the demographic transition. The traditional land use, agricultural

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production, wood harvesting, and gender-specific labor allocation practices have not evolved and adapted rapidly enough to the dramatically intensifying pressure of more people on finite stocks of natural resources.

Many other factors also have a detrimental impact on agriculture and the environment. These include civil wars, poor rural infrastructure, lack of private investment in agricultural marketing and processing, and ineffective agricultural support services. Inappropriate price, exchange rate, and fiscal policies pursued by many governments have reduced the profitability and increased the risk of market-oriented agriculture, prevented significant gains in agricultural productivity and contributed to the persistence of rural poverty. A necessary condition for overcoming the problems of agricultural stagnation and environmental degradation will be, therefore, appropriate policy improvements along the lines suggested in the 1989 World Bank report on Sub-Saharan Africa's longer-term development prospects (World Bank 1989). These policy changes will be instrumental in making intensive and market-oriented agriculture profitable — thus facilitating the economic growth in rural areas necessary to create an economic surplus usable for environmental resource conservation and to provide the economic basis for the demographic transition to lower population fertility rates.

The Three Basic Concerns

Three basic concerns -- population growth, agricultural performance, and environmental degradation -- are discussed.¹

Population Growth

Sub-Saharan Africa lags behind other regions in its demographic transition. The total fertility rate (TFR) -- the total number of children the average woman has in a lifetime -- for SSA as a whole has remained at about six and one-half for the past twenty-five years, while it has declined to about four in all developing countries taken together. As life expectancy in Sub-Saharan Africa has risen from an average of forty-three years in 1965 to fifty-one years at present, population growth has accelerated from an average of 2.7 percent per annum for 1965-80 to about 3.1 percent per year at present. Recent surveys appear to signal, however, that several countries -- notably Botswana, Zimbabwe, and Kenya -- are at or near a critical demographic turning point.

Agricultural Performance

Agricultural production in Sub-Saharan Africa increased at about 2.0 percent per annum between 1965 and 1980 and at about 2.1 percent annually during the 1980s. Average per capita food production has declined in many countries, per capita calorie consumption has stagnated at very low levels, and roughly 100 million people in Sub-Saharan Africa are food insecure. Food imports increased by about 185 percent between 1974 and 1990, food aid by 295 percent. But the food gap (requirements minus production) -- filled by food imports, or by many people going with less than what they need -- is widening. The average African consumes only about 87 percent of the calories needed for a healthy and productive life.
Environmental Degradation

Sub-Saharan Africa's forest cover, estimated at about 679 million hectares in 1980, has been diminishing at a rate of about 3.7 million hectares per annum, and the rate of deforestation has been increasing. As much as half of SSA's farm land is affected by soil degradation and erosion, and up to 80 percent of its pasture and range areas show signs of degradation. Degraded soils lose their fertility and water absorption and retention capacity, with adverse effects on vegetative growth. Deforestation has significant negative effects on local and regional rainfall and hydrological systems. The widespread destruction of vegetative cover has been a major factor in prolonging the period of below long-term average rainfall in the Sahel in the 1970s and 1980s. It also is a major cause of the rapid increase in the accumulation of carbon dioxide (CO\textsubscript{2}) and nitrous oxide (N\textsubscript{2}O), two greenhouse gases in the atmosphere. Massive biomass burning in Sub-Saharan Africa (savanna burning and slash-and-burn farming) contributes vast quantities of CO\textsubscript{2} and other trace gases to the global atmosphere. Acid deposition is higher in the Congo Basin and in Côte d'Ivoire than in the Amazon or in the eastern United States and is largely caused by direct emissions from biomass burning and by subsequent photochemical reactions in the resulting smoke and gas plumes. Tropical forests are considerably more sensitive than temperate forests to foliar damage from acid rain. Soil fertility is reduced through progressive acidification. Acid deposition also poses a serious risk to amphibians and insects that have aquatic life cycle stages; this risk extends further to plants that depend on such insects for pollination.

Key Elements of the Nexus

This section discusses the major elements impacting agriculture and the environment in Sub-Saharan Africa -- shifting cultivation and transhumant pastoralism, women's time and their role in agriculture and rural production systems, land tenure systems, and forest and woodland exploitation.

Shifting Cultivation and Transhumant Pastoralism

Shifting or long-fallow cultivation and transhumant pastoralism have been appropriate under conditions of slow population growth, abundant land, limited capital, and limited technical know-how. The ecological and economic systems were in equilibrium. The key to maintaining this equilibrium was mobility. People shifted to a different location when soil fertility declined or forage was depleted. This allowed the fertility of the land to be reconstituted through natural vegetative growth and decay. For field cropping, this typically involved farming a piece of land for two to four years, then leaving it fallow for as long as fifteen to twenty-five years. Herders' mobility generally involved a far greater geographic range, but a far shorter temporal cycle, dictated by the seasonal availability of water and forage.

As long as land was abundant, more land could be gradually brought into the farming cycle to accommodate the slowly growing populations. Where population density increased slowly, the traditional extensive agricultural production systems gradually evolved into more intensive, and eventually permanent, systems which included soil conservation, fertility management, various forms of agroforestry, and the integration of livestock into farming systems. This has happened, for instance, in the Eastern African highlands and in the more densely settled areas of northern Nigeria.
But in most of Sub-Saharan Africa the scope for further expansion of crop land has drastically
narrowed. Large areas of forests, wetlands, river valley bottoms, and grassland savanna have already
been converted to farmland. On average, per capita arable land actually cultivated declined from 0.5
hectare per person in 1965 to slightly less than 0.3 hectare per person in 1990 (it was 0.3 hectare per
person in India in 1990). In many areas, rural people are increasingly compelled to remain on the
same parcel of land, yet they continue to use their traditional production techniques. Soil fertility and
structure deteriorate rapidly where fallow periods are too short and traditional cultivation methods
continue to be used. As a result, crop yields decline and soils erode. In most areas, population
growth has been so rapid that the reduction of arable land per farmer and the associated soil
degradation have greatly outpaced the countervailing innovation and adjustment by farmers. When
farming is no longer viable, people migrate to establish new farms on land previously not used for
farming -- in semiarid areas and in tropical forests where soil and climatic conditions are poorly
suited to annual cropping. Migrants bring with them the knowledge of only those farming techniques
they practiced in the areas they left, and these are often detrimental to their new environment.

In some countries land still appears to be more abundant in relation to their current population.
But much of this land is under tropical forests that need to be preserved. Yet even in these more
land-abundant countries, rapid population growth is pushing settlers to extend farming and grazing
into areas that are agroecologically unsuited to these forms of land use.

One of the conditions that stimulated Asian farmers to adopt "green revolution" technology --
the abundance of labor relative to cultivable land -- is increasingly emerging in parts of SSA (Pingali,
Bigot, andBinswanger 1987; Lele and Stone 1989). But institutions and individuals have not been
able to adapt quickly enough in the face of very rapid population growth. Slow technological
innovation because of ineffective agricultural research and extension systems is only part of the
reason. The poor transport infrastructure throughout most of SSA severely blunts farmers’ incentives
to switch from subsistence to market production and from extensive to intensive farming.
Inappropriate agricultural marketing and pricing as well as fiscal and exchange rate policies have
reduced the profitability of market-oriented agriculture, prevented significant gains in agricultural
productivity and contributed to the persistence of rural poverty. Poorly conceived and implemented
agricultural projects have not helped.

Women's Time and Their Role in Agriculture and Rural Production Systems

The widespread prevalence of gender-specific (gender-sequential and/or gender-segregated) roles and
responsibilities in rural production systems may be a major factor contributing to agricultural
stagnation and environmental degradation and even to the persistence of high fertility rates. In many
areas, women have primary or sole responsibility for food crop production, and they usually manage
separate fields for this purpose. Women also tend to have significant obligations concerning labor to
be performed on men’s fields and with postharvest processing activities.

Given women’s triple roles -- childbearing and rearing, family and household maintenance,
and production and income-earning activities -- the pressures on their time continue to intensify.
With increasing deforestation, combined with growing populations requiring more fuelwood,
fuelwood has become scarcer. Women must walk further to fetch it or reduce the number of hot
meals prepared. Increasing populations put greater pressure on available water resources, while
environmental degradation reduces the availability and accessibility of water. Women must walk
further to fetch water, and get their daughters to help them. Throughout much of rural Sub-Saharan
Africa, women also are the primary "beast of burden." In the absence of adequate rural transport
infrastructure and of means of transport other than human porterage, women spend substantial time headloading not only water and fuelwood, but farm produce and other commodities to and from their homes.

As growing numbers of men leave the farms to work in towns and cities, women are increasingly taking on primary responsibility for farm operations while their recourse to adult male labor is diminishing. About 70 percent of Congo's farms are today managed by women, for example, and in Ghana more farmers are women than men. Moreover, the expansion of higher-input cash cropping under male control tends to increase demands on female labor for traditional female activities such as weeding and harvesting. In Zambia, women in farm households headed by males contribute more hours daily than men to farm work (8.5 hours versus 7.4 hours) and nonagricultural tasks (5 hours versus 1.1 hours). At the same time, women are traditionally confronted with severe restrictions on access to land and capital. These restrictive attitudes persist and today are reflected in limited access to extension advice, to productive land, to institutional credit, and to improved production, processing, and transport technology. In Botswana, a 1984 study found women contributing almost 70 percent of the value of crop production, but receiving the benefit of less than 15 percent of national agricultural outlays. These constraints, combined with intensifying pressures on women's time, severely impede productivity improvements and intensification of women's farming operations. Most women farmers have little choice but to continue practicing traditional low-input, low-productivity farming, which with sharply shortened fallow periods is neither environmentally sustainable nor viable in terms of longer-term agricultural productivity. The severe pressure on women's time also retards progress in cash crop production controlled by men that depends on significant female labor input at critical times.

The heavy pressure on women's time also has implications for infant and child welfare and, hence, infant and child mortality, with significant repercussions on fertility aspirations and attitudes toward family planning. More contentious is the hypothesis that the multiple work burdens and the heavy time pressure on women may be a contributing causal element behind the persistent high fertility rates — additional labor being the only factor of production that women can easily add, or are able or even compelled to add, in order to meet their multiple and increasing production and household management responsibilities. The combination of traditional attitudes and constraints with greatly increasing workloads of women may, thus, be part of the explanation for the continuing extraordinarily high fertility rate in SSA, now about 6.5 (compared to 4 in other developing countries).

There are, of course, many other factors that contribute to these high fertility rates. Traditional attitudes which favor numerous offspring and particularly sons, play an important part. Polygamy and the widespread practice of women marrying considerably older men are both phenomena that tend to increase women's economic and social dependency on sons and, hence, their willingness to bear many children. High infant and child mortality rates, resulting, inter alia, from poor nutrition and poor maternal and child health care, are potent inducements to maintaining high fertility rates. The relative importance of these and other factors has not been established, and may never be. Nevertheless, the severe and increasing pressure on women's time and the significant gender-based constraints faced by women in their pursuit of both traditional and non-traditional farming activities may be preventing the emergence of women's demand for fewer children and thereby contribute to the persistence of high fertility rates.
Land Tenure Systems

Traditional land tenure systems provide considerable security of tenure on land brought into the farming cycle (clearing, cropping, fallowing, reclearing) through customary rules of community land ownership and allocation of use rights to members of the community. In most cases, the tenurial security enjoyed by members of the community is sufficient to induce investment in land. Outsiders, or strangers (that is, nonmembers of the community) may obtain use rights of various types, but in many cases with considerably less long-term security. As long as populations increased only slowly and the demand for land-use rights by migrants from other communities remained modest, traditional systems were able to accommodate the emerging need to move toward de facto permanence of land rights assigned to community members.

There are, however, other aspects of traditional land tenure systems that have not adjusted rapidly enough to changing economic conditions. In most traditional systems, for instance, the individual users' ability to transfer land-use rights is subject to significant constraints, due to customary norms and/or the absence of effective administrative and legal mechanisms. Tree tenure arrangements are often distinctly separate from land-use rights pertaining to the cultivation of annual crops and can result in serious conflict. Much common property land -- forests, wetlands, and range lands -- has become de facto open-access land and has been converted to farming, often with significant negative environmental consequences. In many areas where traditional land rights systems provided for overlapping and complementary uses by sedentary farmers and transhumant herders, the development of valley bottoms into permanent crop land has created major constraints on the mobility of herders, with negative implications for environmental integrity. Increasing population pressure and agroenvironmental problems are inducing considerable rural-rural migration. Because migrants often come with conflicting traditions of land allocation and land use, strangers' tenurial rights and their implications for land resource conservation are of increasing concern. These various pressures are causing traditional land tenure systems to break down, reducing tenurial security.

Most governments and donors have mistakenly believed that traditional tenure systems provide inadequate tenurial security and that these systems are not conducive to the introduction of modern agricultural technology and market-oriented agriculture. They also witnessed the erosion in customary laws and practices regulating land use which occurred as a result of significant rural-rural migration, changes in social values and customs, and ambiguities created by the overlaying of "modern" land administration systems over traditional ones. In many instances, this led to the emergence of de facto open-access systems that are not conducive to resource conservation or to private investment in soil fertility maintenance and land improvement.

Many governments have responded by nationalizing the ownership of land -- and then allowing customary rules to guide the use of some land, while allocating other land to private investors and public projects. Often, the well-connected have used their influence to wrest land from its customary owner-occupants. The result has been reduced, rather than improved, tenurial security. In most cases, this has accelerated the breakdown in customary land management and the creation of open-access conditions, especially in forest and range areas. In open-access conditions, settlement and exploitation by anyone are permitted and environmental degradation is invariably rapid. Where governments allocated individual land titles -- as in Kenya, Zimbabwe, and Côte d'Ivoire -- this generally ignored the prior existence of customary tenure arrangements, and more often than not, the actual results have differed considerably from the stated intent. Local community and individual land resource management has been discouraged, while political and economic elites have succeeded in alienating the land from its traditional owners and users. This has skewed land distribution and intensified the exploitation of land resources for private short-term gain.
Forest and Woodland Exploitation

The heavy dependency on wood for fuel and building material has combined with rapid population growth to contribute to accelerating forest and woodland destruction. This is particularly severe around major urban centers where it has led to the appearance of concentric rings of deforestation. Fuelwood has generally been considered a free good, taken largely from land to which everyone has the right of access. This has impeded the development of efficient markets for fuelwood. Urban woodfuel prices reflect primarily transport costs, not the cost of producing trees, and there is no incentive to plant trees for fuelwood production until transport costs to urban markets become high enough to justify peri-urban planting. This is beginning to happen around some cities and in very densely populated areas, but the scale of such planting is very inadequate. Alternative fuels, such as kerosene or liquefied petroleum gas (LPG), are more costly to obtain and not available in open-access conditions, and are therefore not replacing woodfuels in significant quantities.

Commercial logging has significantly contributed to deforestation. Although directly responsible for no more than 20 percent of forest destruction in SSA as a whole, it has been considerably more destructive in some countries, such as Côte d'Ivoire. Moreover, logging usually leads to a second phase of forest destruction: logging roads provide access for settlers who accelerate and expand the process of deforestation that the loggers have begun. Logging concessions rarely take into account the traditional land and forest use rights of forest dwellers. These rights, once eroded, are disregarded by new settlers penetrating along the logging roads.

The degradation and destruction of forests and woodlands accelerates soil degradation and erosion, eliminates wildlife habitat, leads to loss of biodiversity, and has severe implications for local and regional climates and hydrological regimes. Deteriorating climatic and hydrological conditions negatively affect agriculture. The worsening fuelwood situation forces women and children to walk further and spend more time to collect fuelwood. Closely related, and increasingly of concern, is the fact that animal dung and crop residues are being used as fuels. Under conditions of shortening fallows, characteristic of much of SSA, the economic utility of dung and crop residues is far greater when they are used to maintain soil fertility. People also must walk further and/or pay more for building materials and the many important nonwood forest products they depend on for medicinal purposes, home consumption, and traditional crafts and industries. For forest dwelling people, forest destruction threatens not merely their lifestyles and livelihood systems, but their very survival.

An Action Plan

The appropriate policy response and action program to address these problems are not easily brought into compatible focus. Many of the most immediately attractive remedies have been tried and have failed. For example, individual land titling -- intended to clarify resource ownership, prevent further degradation of common property regimes into de facto open-access situations, and improve tenurial security -- has been tried in several countries and has been beset by significant problems. Similarly, efforts to introduce "modern" agricultural technology in the form of higher-yielding varieties, chemical fertilizer, and farm mechanization have not met with great response from farmers. Soil conservation and forest protection efforts have had little success outside relatively small areas. And efforts to slow population growth through programs based primarily on the supply of family planning services and the distribution of contraceptives have not been very successful in most SSA countries.
Some Basic Targets

Indicative aggregate targets regarding fertility rates, food availability, agricultural growth, and environmental protection illustrate the magnitude of the effort required. Reaching these targets will be far more likely by focusing on the synergetic effects inherent in the linkages of the nexus. There are, of course, wide variations in what is necessary and attainable in each country, and country-specific targets will need to reflect this.

For Sub-Saharan Africa as a whole, agricultural production needs to grow at about 4 percent per annum during the period 1990-2020. Daily per capita calorie intake should be increased from the present average of 2,027 to about 2,400 by the year 2010. Although the share of the population that is food insecure should be reduced from the present 25 percent to zero as rapidly as possible, it is more realistic to aim for a reduction to 10 percent by the year 2010 and to 5 percent by 2020. The rate of deforestation needs to be slowed, and the area of forests and woodlands should be gradually stabilized. Loss of remaining wilderness areas should also be minimized: about 23 percent of SSA’s total land area could be maintained as wilderness (compared with about 27 percent today). To preserve wilderness and forest areas, cropped land can only be increased from 7.0 percent of SSA’s total land area at present to about 8.3 percent in 2020. The arithmetic of these indicative agricultural, food security, and environmental objectives requires a reduction in population growth from the present average annual rate of over 3.1 percent to 2.3 percent per annum in the third decade of the next century. This will require lowering the average TFR by 50 percent between today and the year 2020.

Reducing Fertility Rates

A key aspect will be to increase demand for fewer children. Increasing girls’ school enrollment rates is critical. Better health care services and access to safe water will improve child survival rates and, hence, lower the demand for children. Educational efforts, directed at both men and women, are needed to raise awareness of the benefits of fewer children. Women’s work loads need to be eased to reduce the need for child labor. Dynamic agricultural development and improved food security will also reduce the demand for children. Kenya, Zimbabwe, Botswana, and Mauritius, where the TFR is declining, provide strong evidence. These countries have relatively high population densities on cultivated land, relatively high female school enrollment rates, relatively low infant mortality, active family planning (FP) programs, and among the best agricultural performance records.

As demand for reducing fertility rises, it must be effectively met with increased supply of FP services and contraceptives. But supply must follow demand -- it cannot lead it. Where AIDS is a problem, improved health care, FP services, and education focused on preventing sexually transmitted diseases and increasing the use of condoms become even more important.

Promoting Environmentally Sustainable Agriculture

Farm productivity per unit area must be raised significantly to generate more output with little increase in the area farmed. To minimize negative impacts on the environment, much more emphasis is required on "environmentally benign and sustainable" technologies. Land-saving technology will allow forests and other fragile areas to be protected. Numerous environmentally benign and economically viable agricultural techniques have been developed and successfully applied, often
through adaptation of traditional practices that have evolved in response to local agroecological and socioeconomic conditions. Examples include contour farming, minimum tillage, mulching, "managed" fallowing, numerous crop rotation and intercropping systems, vegetative and soil bunding, a variety of agroforestry practices, integrated pest management, water harvesting, and small-scale irrigation. Integrating livestock into farming systems and promoting animal traction will be important. Soil and moisture conservation need strong emphasis.

Agricultural research and extension services need to focus less on monocrop technologies and farm mechanization and much more on the above types of technologies, adapting them to local conditions and making them available to farmers in "menu" form for selective adoption. Women must become the target of such efforts to a much greater extent. Prescriptive approaches to agricultural intensification are far less suitable in the varied environments of Sub-Saharan Africa -- where conservation and management of natural resources, integrated production systems, and risk management are critical -- than in more homogenous high-potential regions such as the Indo-Gangetic Plain. Many of these ideas have been incorporated into the recommendations for reform of agricultural research in Africa by the Special Program for African Agricultural Research (SPAAR).

However, intensification with the above technologies alone is unlikely to be sufficient in most SSA countries to achieve agricultural growth rates of 4 percent per year and more. Improved variety/fertilizer/farm mechanization technologies will also be necessary. Increased use of fertilizers will be especially important to raise yields and maintain soil fertility. So will diversification of production into higher-value crops, for domestic and export markets, to increase rural incomes and to improve food security through income stabilization. It would also be unrealistic, and unnecessary, to preclude bringing more land under cultivation.

There has been little incentive for farmers to abandon their traditional practices. Intensive and resource-conserving agriculture must be made less risky and more profitable. This requires appropriate marketing, price, tax, and exchange rate policies as well as investments in rural infrastructure, health and education facilities. Creating parks, reserves, and community-owned range land and protecting these against conversion into crop land will be important to conserve natural resources and biodiversity. So will reducing infrastructure development in forests and other fragile areas to discourage settlement in these areas. Because this will limit the scope for further expansion of cropped land and, potentially, the scope for agricultural production growth, there is a tradeoff between conservation and agricultural growth. Creating additional protection areas will only be feasible and sustainable if agricultural production can be intensified at the rate suggested here (that is, to about a 3.5 percent annual increase in farm output per unit of land farmed). In this sense, conservation and agricultural intensification are complementary. As African farmers have shown, land scarcity leads to agricultural intensification -- and if the necessary advice and inputs are available, intensification can be made sustainable and the rate of intensification greatly accelerated. Strengthening tenurial security will also stimulate greater concern for soil fertility management and conservation as well as tree planting. Some sustainable agricultural practices, such as soil conservation, may require initial subsidization to offset externalities.

**Easing Women’s Time Constraint and Improving Their Productivity**

Initiatives in research, extension, infrastructure development, rural technology, and education are needed to ease women’s time constraints and improve their productivity. Much can be learned in this regard from the experience of local and international nongovernmental organizations (NGOs) in establishing rural water supply systems managed by women’s groups, developing and popularizing
locally appropriate fuel-efficient and time-saving stoves, providing improved farming and crop processing techniques and tools to women, facilitating women's access to land and institutional credit, improving village-level transport infrastructure, and providing intermediate means of transport. Such initiatives should be pursued through projects dealing with agricultural research and extension, rural water supply and transport, credit and land tenure, and in education and training policies that more effectively reach women.

**Clarifying Resource Ownership**

Urgent action is needed to eliminate open-access systems and to provide legal protection to traditional and private land owners. Local community or individual ownership and management responsibility for natural resources appear to be the only workable arrangement in Sub-Saharan Africa. Governments alone are not able to protect and conserve land, forest, and pasture resources. State-ownership of farm land should be eliminated. Where traditional tenure arrangements continue to work and are evolving toward explicit recognition of individual ownership and transfer rights, these systems should be recognized and protected by law and supported by appropriate administrative arrangements. Land title, or at least legally secure user rights, should be provided to traditional communities, and community land can continue to be allocated according to customary practice. Where traditional mechanisms have completely broken down, individual land titling is likely to be necessary, but it should be provided only on demand and to the traditional or customary owners and occupants. Women need equal rights to land and equal tenurial security as men, especially in view of the increasing number of female heads of households in many rural areas. These actions will require effective mechanisms to assess land ownership and use rights and to ensure legal protection to holders of either traditional or modern titles.

Wherever possible, state-owned pasture and forest lands should be returned to traditional owners and/or local communities, with clear and legally established utilization rights tied to the responsibility for conservation. This must be done with care, however, because many of these communities and their traditional land resource management systems have broken down under the pressure of logging, settler influx, and government ownership. Where this is the case, resource destruction may simply accelerate if people are given the opportunity. Communities will need appropriate technical assistance in managing these resources.

**Addressing the Fuelwood Problem**

Efforts to promote agroforestry need to be greatly expanded to have a significant impact on the agroecological environment, the rural energy economy, and women's time. Investment in fuelwood production and tree farming, on a large scale, by farmers and by community groups and private enterprises will not occur unless it is profitable. The incentives are gradually emerging, particularly around major urban areas, as populations grow and forests and woodlands are depleted. But woodfuel markets are developing too slowly, impeded by inappropriate forest, land tenure, and energy policies. The pace of market development will accelerate if open-access sources of fuelwood are eliminated, cutting in protected areas is restricted, farmers are not restricted in marketing wood from their own land, fees are levied on bringing fuelwood to urban centers so as to provide incentives for wood production near cities, and communities and farmers have uncontested ownership of local forests and woodlands. On the demand side, there is a great need for more fuel- and time-efficient
wood and charcoal stoves that can be made by women themselves or by local artisans on a commercial basis.

*Rural Infrastructure and Settlement Policy*

The importance of rural infrastructure for promoting agricultural development is well established. Research across a number of African countries has also shown that adequate transport links to markets are major factors associated with the intensification of farming -- even where population densities are comparatively low. Careful locational targeting of infrastructure development can also be a powerful instrument to guide spontaneous population movement into environmentally robust and resilient areas with agricultural potential and to keep migrants out of areas that should not be opened up to farming. Infrastructure development also has major impact on the productivity of rural labor, particularly of women -- and on key determinants of fertility -- such as infant mortality and female education. In the context of the Nexus, rural health and education facilities and services are particularly important in terms of their impact, respectively, on infant and child mortality and on female education both critical determinants of fertility preferences.

Rural transport is a major constraint to agricultural and rural development, and women bear the brunt of the rural transport burden because the bulk of rural commodity transport (water, fuel, farm inputs and farm produce) is done in the form of headloading by women. Rural road density in Nigeria today barely equals that of India in 1951, and transport costs account for 30 to 40 percent of food prices in Nigeria. Distances from villages to major towns and all-weather roads are very substantial. Rural roads are also poorly maintained. Hence, markets are poorly integrated, price variations are very large, and incentives to switch from subsistence to market production are very weak.

The rural water situation is another key constraint. Less than 20 percent of Nigeria's rural population, for instance, has convenient access to safe water. There is a direct link between safe potable water and a reduction in infant mortality. Women's stake in convenient access to safe water and sanitation facilities is much broader, however, given their responsibility for collecting, transporting, boiling, and storing water for drinking and cooking and for washing household effects and laundry, for disposing of waste water, and for the maintenance of the family sanitation standards and facilities. A major direct benefit to women and girls of better access to safe water is the time saved fetching water from distant sources. This time can be used instead for other productive activities, attending school or technical training, tending to children's health and educational needs, or simply rest and recuperation.

Urban areas represent outlets for population increases, markets for agricultural products and fuelwood, sources of manufactured inputs and consumer goods for farmers, and centers for the provision of educational, health, and other services. Urban development needs to be one component of land-use plans. Further, urban policy should be developed in part as a function of likely growth of the urban population, linkages between urban and rural product and labor markets, communications needs in rural areas, and environmental constraints. Generally, policies that promote development of secondary cities and rural towns, rather than of a few mega-cities, will be far more conducive to efficient, equitable, and sustainable rural development. This requires spatially well-distributed public investment, which is not biased in favor of mega-cities, and sound and substantial investment in infrastructure throughout each country (rather than concentration in mega-cities). It further requires functioning markets and market-based pricing for petroleum and other energy sources, avoidance of transport monopolies to increase the likelihood that the entire country is adequately served by private
transport providers, promotion (through industrial extension, investment codes, credit facilities) of small and medium enterprises located in secondary cities and rural towns, and decentralization of political decisionmaking outside capital areas to facilitate greater responsiveness to demand for services outside the major cities. These are not only crucial elements of sound urbanization policy, but are important for rural development because well functioning secondary towns and cities are more likely to provide services and markets for rural areas than are distant mega-cities, which tend to be heavily oriented to overseas supplies.

Natural Resource Management and Environmental Protection

Environmental resource protection and sustainable management are urgently needed to prevent further degradation and destruction. Establishing conservation areas and protecting forests is conducive to promoting agricultural growth, because they protect watersheds and stabilize local and regional climate and hydrological systems. If the rate of agricultural intensification can be increased as postulated here, the constraining impact of expanding conservation areas on crop land expansion can be offset and conservation will be fully consistent with agricultural growth. Protection of rural environments also ensures the sustainable provision of crucial forest products and environmental services. Particularly urgent are establishment and maintenance of conservation areas and effective regulation and taxing of logging.

Land-use planning is a useful tool for reconciling the objectives of natural resource management, settlement and population policy, and agricultural and infrastructure development. These objectives come together in specific locations and can be effectively integrated in regional and local land-use plans. These can be prepared within environmental action plans or as separate planning exercises. Land-use plans should identify areas to be protected, areas to be farmed, areas to be utilized for sustainable logging, and so forth. Land allocation and use, land tenure systems, agricultural technology, infrastructure development, and conservation efforts must be tailored to the specifics of each region and location. Local communities and individuals need to be directly involved in the development and implementation of such plans, and they must have outright ownership of, or strong and legally recognized rights to, natural resources as an incentive to manage and conserve them. Mobilization of community and individual participation in natural resource management may be the most important step now waiting to be taken.

In the final analysis, however, successful agricultural intensification and much reduced fertility rates and population growth are the critical elements to preventing further degradation of the rural environment.

Conclusions and Issues

Past efforts have, on the whole, failed to reverse the direction of the downward spiral that is driven by the synergetic forces of this Nexus. Part of the explanation appears to be that past efforts have been pursued too narrowly along traditional sectoral lines -- matching established institutional arrangements and traditional academic disciplines -- while crucial cross-sectoral linkages and synergies have been ignored. At the same time, primary emphasis in most sectoral development efforts has generally been placed on the supply side, that is, on efforts to develop and deliver technology and services. Far more emphasis needs to be given to promoting effective demand for environmentally benign technologies, which intensity farming, for family planning services, and for
resource conservation. The synergies inherent in the Nexus provide considerable potential in this regard. To address these issues requires appropriate cross-sectoral analysis and the development of action programs that address the linkages and synergies among sectors. These programs should focus on price incentives, trade and fiscal policies, public investments, and asset ownership (such as land) as tools to promote sustainable resource management. To facilitate efficient implementation, action should, however, be defined within single sectors.

In analytical work that should precede the formulation of action plans and developmental interventions, far greater attention needs to be paid to the social organization of production and consumption, of decisionmaking and resource allocation, of access to resources and services. These systems and structures can be very complex and often differ substantially among communities. This implies the need to use relevant "units of analysis." The "household," the "family," and the "family farm" may not be appropriate if these terms are simply taken to convey concepts of social and economic arrangements familiar to 20th-century industrialized economies. Where societies are characterized by complex resource-allocation and resource-pooling arrangements for both production and consumption purposes, based on lineage, kinship, gender, and age-groups, it is imperative to be cognizant of these, to analyze the impact of development interventions on individuals in this context, and to design development efforts such that traditional groups can implement and manage them. Gender issues are particularly critical, especially in terms of gender-specific divisions of responsibilities, tasks and budgets, as well as in terms of access to resources, information, and markets. Interventions and incentives do not necessarily work in the same direction or with the same intensity for men and women.

Enough is already known to incorporate the recommendations made here in projects and policy. The main areas where action can be defined are as follows:

- Promote demand for smaller families and family planning based on cultural and agricultural and economic incentives, rather than simply on the supply of family planning services.
- Create farmer demand for "sustainable" agricultural technology, partly through appropriate research and extension, partly by the elimination of open-access land tenure conditions, partly by policy created artificial scarcity of farm land, and necessarily through agricultural policy reform of the kind identified in Sub-Saharan Africa: From Crisis to Sustainable Growth which will make farming less risky and more profitable.
- Pursue measures necessary to create a market for fuelwood. This will require mainly land tenure reform, extension advice on agroforestry, and fuelwood plantations.
- Ensure that agricultural services and education serve women, to stimulate reduced demand for children, improve women's farming practices, reduce work burden in water and fuelwood gathering, saving women's time for family management and food production and nonagricultural income generating activities.
- Reduce forest and wildland degradation by land tenure reform, agricultural intensification, infrastructure policy, migration policy, and population policy.
- Focus environmental action plans on agricultural and population causes to environmental degradation.
- Link urban policy to population, agriculture, environment (as safety valve for population increase and market for agriculture and fuelwood products).
- Make greater use should of spatial plans incorporating the above elements for specific localities.
- Acknowledge community and individual management of implementation is critical. It can be induced by affirming community and individual ownership of land and water
resources and stimulated by fiscal and pricing incentives, allocation of public funds for community initiatives, adjustment of external assistance in support of local action, reorientation of public support services to back local initiatives, and training of community leaders.

Several SSA countries have begun to implement various elements of this action plan. Over twenty national environmental action plans are under preparation. Macroeconomic and agricultural policy reforms are underway in over half the African countries, although with mixed success. A few countries have successful family planning programs, but others are developing promising programs. Agricultural research and extension systems are beginning to place more weight on "sustainable" technology and responsiveness to varying farmer demand. A very few countries have brought much of this together and obtained positive synergies between agricultural growth, environmental protection, and reduction in fertility rates. Kenya, Zimbabwe, Botswana, and Mauritius are examples. Others, such as Ghana and Tanzania, are moving in the right direction. Major deficiencies remain in rural health care and education (particularly female education), rural infrastructure, participation of local communities in development efforts, forest and conservation policy, land tenure reform, urbanization policy, and family planning programs.

Machakos District in Kenya

The experience of Machakos district in Kenya demonstrates that the right policy framework and investments of the kind recommended here will work (English, Tiffen, and Mortimore 1992). Significant soil degradation and erosion was observed in Machakos as early as 1920. Substantial efforts have been undertaken over the past sixty years to combat these problems and to prevent further deterioration. By 1990 with nearly five times the population as in 1920, the district's agricultural production had increased more than fivefold -- yet land degradation had not merely been arrested, but reversed. Contributing to this has been a good economic policy environment that has made intensive, market-oriented farming profitable. Relatively good transport infrastructure facilitated the movement of farm inputs and output at affordable costs. Secure land tenure encouraged investment in land. Rural education and health services have also been relatively good. In this setting, farmers were receptive to good extension advice, based on solid research, regarding soil conservation and moisture retention, the intensification of farming, and tree planting. Efforts to slow population growth are only now beginning to show the desired impact, but the combined effect of these other measures has been so positive that photographs taken of the same locations in 1930 and again in 1989-90 suggest improvement of the rural environment simultaneous with greatly increased production.

Remaining Questions

To help answer some of the remaining questions, and to adapt the analysis to the situation of specific countries, the follow-up to this study has been launched. It includes the preparation of "Nexus" studies in Côte d'Ivoire, Ethiopia, Malawi, Nigeria, Rwanda and the Sahelian countries as a group. In addition concurrent monitoring is underway regarding the progress of preparation and implementation of national environmental action plans and of national population programs. The mechanism for the former is the "Club of Dublin," consisting of representatives of African governments and donor agencies. The institutional mechanism for deepening the population agenda
for Sub-Saharan Africa and for monitoring its progress is the African Population Advisory Committee, with similar membership. It is intended that a similar African Agricultural Advisory Committee, managed by prominent Africans, will also be established. Finally, the donors have agreed to focus on "Nexus" issues as part of the donor coordination effort entitled the "Special Program for Africa."

References


Endnotes

1. Data is from World Bank, World Development Indicators 1992, and World Bank, African Development Indicators, 1992.

2. Certain "developmental" investments and interventions also tend to disrupt and destroy traditional tenurial arrangements and practices. An example is that of irrigation development in valley bottoms in arid and semiarid regions, which pushes pastoralists and their herds out of their traditional migration routes.

3. Country specific targets have been established in the book of the same title as this paper by the same authors referred to on page 1.
Economic Stagnation and Deforestation in Costa Rica and the Philippines

Maria Concepcion J. Cruz

Introduction

For many developing countries, the global economic crisis of the 1980s had its adverse effects not only on unemployment and poverty but also on environmental degradation. In the decade prior to the crisis, excessive government intervention and inward-looking policies had already led to long-standing problems of generating sufficient jobs to absorb a rapidly expanding work force. With growing population density in limited areas of fertile agricultural lowlands, and with cities offering fewer job opportunities, excess rural labor turned increasingly to the frontier. The flow of migration to urban centers declined while the flow toward fragile, forested sites intensified. Thus, when the economic crisis struck, the resulting economic contraction merely intensified population pressures that were already growing on marginal resources in many countries.

This paper presents case studies of frontier migration in Costa Rica and the Philippines. Mass migration into forest sites is viewed as a process that directly links the impacts of economic contraction on increased deforestation. The objective is to show that for countries already experiencing population pressures on resources, worsening economic conditions create additional stress on open access, frontier lands.

The general economic condition during the crisis years of the early 1980s is described in the beginning of this paper and then the effects of the economic crisis on frontierward movements in general and on migration toward open forested lands in particular are examined. Migration patterns are presented across regions of varying forest cover as well as across time periods before and after the crisis years. Finally, a summary and set of recommendations is provided.

The Economic Crisis

Following the oil price shock of 1979 and the global recession, the economies of Costa Rica and the Philippines suffered their deepest slump in more than two decades. Urban, industrial employment failed to increase at rates that could adequately absorb excess rural labor. Low commodity prices reduced agricultural incomes and aggravated rural underemployment. While industrial and agricultural output contracted, rural wages, which were already low, fell even more. These intensified the push toward marginal sites and reversed the urbanward migration pattern of the 1970s. In both these countries severe economic problems coincided with dramatic shifts in population movements.

The duration of the economic crisis in Costa Rica was shorter than in the Philippines, but its effects were more severe. With falling foreign exchange reserves and rising interest rates, Costa Rica experienced increasing difficulty in servicing its external debt at the close of the 1970s. By 1981 inflation reached triple digits and the government was forced to devalue its currency by over 400 percent, forcing the country to postpone payments on its external debt (Ulate-Quiros and Rodriguez-Cespedes 1984).

Open unemployment had been growing throughout the 1970s, but unemployment and underemployment rates rapidly increased from 1981 to 1982. Urban underemployment rates rose by over 2.5 times 1980 levels (United Nations 1985). New jobs created during this period were mostly in the urban informal sector and in agriculture (OIT 1987). Real wages dropped by 30 percent in just two years, between 1981 and 1982. Public sector real wages fell even more rapidly, by 40 percent (United Nations 1985). This economic contraction was attributed to a general decline in domestic demand which dropped by 33 percent during the same period. Another factor was a decrease in investment level, which declined to less than one-third of 1980 investment before it began to recover in 1983 (United Nations 1985).

As a consequence the number of poor people below the poverty line increased by 50 percent, from 600,000 in 1977 to 900,000 in 1983 (Hall 1985). The fall in per capita incomes in the late 1970s and early 1980s was so large that even though poverty incidence declined from 25 to 10 percent between 1981 and 1989, per capita income by 1989 was still less than in 1981 (Saborio 1990; Cruz, M.C. and others 1992).

The Philippines

Like Costa Rica and many other developing countries, the Philippines was severely affected by the debt crisis. Because of inappropriate development policies, employment growth was already lagging behind labor force increase in the 1970s.

Industrial employment decelerated from 3.4 percent per year during the 1960s to just 2.9 percent per year in the 1970s so that employment grew too slowly to take pressure off marginal resources (Cruz, W. and Repetto 1992). Whatever growth in employment that occurred in 1980 to 1985 was primarily in the services sector. Employment growth in agriculture and industry declined as both agricultural output and industrial production contracted. Annual growth in agricultural employment declined from 3.2 percent in 1970 to 1980 to 2.6 percent in 1980 to 1985. Rural nonfarm employment fell much faster, with negative growth occurring between 1982 and 1985 (World Bank 1988).

The number of underemployed agricultural workers grew from 2.1 million in 1976 to over 3.2 million in 1986, or a yearly increase of about 4 percent (Reyes, Milan, and Sanchez 1990). Urban underemployment increased at a slower pace, from 8 percent of total employment in 1976 to 11 percent in 1984.

During the crisis years, real earnings and income in agriculture, services, and manufacturing registered marked declines from previous years. Real daily wages in the capital city of Manila and in agricultural areas fell by 18 percent between 1980 and 1985.

Thus, the number of poor people increased by more than 10 million between 1971 and 1985. Over half of total Philippine population in 1985, more than 30.5 million people, were living below the poverty line. Of the 3 million families in the 30 percent lowest income bracket, 2.5 million lived in rural areas and worked in agriculture (FIES 1985). Agricultural households received the lowest
annual average incomes in 1985 of $85. This was way below the national average of $580 (FIES 1985).

Frontier Migration and Deforestation

The economic crisis, which aggravated poverty in both countries, provided the push conditions that motivated out-migration from depressed rural and urban areas. Although both countries experienced shifts in internal population movements toward the frontier, population pressures and tenure policies differed, providing contrasting factors that pull migrants toward open forest sites.

Unchecked Population Growth and Reversal of Movements

As shown in table 1, the annual population growth rates in Costa Rica and the Philippines fell from an average of 2.7 percent in 1965 to 1980 to 2.4 percent in 1980 to 1990. Even so, total population now stands at 3.02 million in Costa Rica and 62.4 million in the Philippines.

Costa Rica Population Trends and Policies

Costa Rica's population is about 3 million. With a land base of just over 5 million hectares, the population density is approximately 60 persons per square kilometer. Annual population growth in the country peaked at 4.1 percent during the 1950s, one of the highest in the world. But throughout the next two decades, birth rates fell and the annual increase in population declined dramatically. By 1980 the growth rate dropped to 2.6 percent per year, but this is expected to rise because a large percentage of Costa Ricans -- 36.2 percent in 1990 -- are under the age of fifteen.

Although the percentage of young residents in Costa Rica is much lower than the average in Central America (of 45 percent), the projected population size is expected to double in the next century, reaching 6 million people (World Bank 1992).

Improvements in controlling population growth rates are largely due to effective family planning and health care programs in the country. The percentage of women using contraceptives in 1990, about 70 percent, is comparable to the average in the United States and other developed countries (UNFPA 1991).

At 9.5 percent of gross national product (GNP), government spending on health and education is also much greater than the average for developing countries. As a result infant mortality is only 17 per thousand population, one of the lowest in Latin America (Sadik 1992). However, as in most developing countries, rural areas still have significantly higher birth rates than urban areas, 34.3 births per thousand population, compared to 26.6 in urban areas (UNFPA 1991).

Philippine Population Trends and Policies

Population pressures are greater in the Philippines. The population density of 200 persons per square kilometer is much larger than Costa Rica, which has just 60 persons per square kilometer. Future population growth will also exert more stress on resources. Almost 43 percent of the current Philippine population is below fifteen years of age. The total fertility rate of 3.7 births per woman is
expected to produce large yearly increments in population in the next 10 to 20 years. The population is projected to increase 1.6 times the current level before it is expected to stabilize sometime in 2010. Because already one-third of the population reside in frontier forest sites, this means that about 1 million persons a year may be added to the frontier before the turn of the century.

Table 1. Demographic Profile of Costa Rica, the Philippines, and Developing Countries

<table>
<thead>
<tr>
<th></th>
<th>Costa Rica</th>
<th>Philippines</th>
<th>Developing countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population 1990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number (millions)</td>
<td>3.02</td>
<td>62.41</td>
<td>4,086</td>
</tr>
<tr>
<td>Frontier population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number (millions)</td>
<td>0.76a</td>
<td>17.5</td>
<td>b</td>
</tr>
<tr>
<td>Percent of Population</td>
<td>25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Average annual population growth rate (percent)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National: 1965-80</td>
<td>2.7</td>
<td>2.8</td>
<td>2.1</td>
</tr>
<tr>
<td>1980-90</td>
<td>2.4</td>
<td>2.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Frontier: 1965-80</td>
<td>2.6c</td>
<td>2.8</td>
<td>b</td>
</tr>
<tr>
<td>1980-85</td>
<td>3.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban: 1965-80d</td>
<td>3.5</td>
<td>4.0</td>
<td>3.8</td>
</tr>
<tr>
<td>1980-90d</td>
<td>3.3</td>
<td>3.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Total fertility rate (TFR), 1985e</td>
<td>3.1</td>
<td>3.7</td>
<td>3.9</td>
</tr>
<tr>
<td>Percent population under 15 years old, 1990f</td>
<td>42.2</td>
<td>42.8</td>
<td>36.0</td>
</tr>
</tbody>
</table>

a. Frontier population defined as follows: in Costa Rica, population five years and older occupying lands classified as LUC 6-10 or lands used for extensive grazing, plantation forestry, forest management, and protection forest; classification of LUCs from TSC and WRI (1991); in the Philippines, population residing in classified upland areas or lands with 18 percent or more slope in mountain zones.
b. Developing countries as defined by the United Nations; no comparable data on frontier population available.
c. Available data for 1973-84 only.
d. Urban population data from World Bank (1992); some urban population included in frontier lands population because of the way "urban" is defined.
e. Total fertility rate (TFR) is the average number of children a woman will have assuming current age-specific fertility rates. A TFR of 2.1 to 2.5 is normally considered "replacement level."
There will be pressures from a rapidly growing working-age population. During the 1990s, the economy must generate about 4.4 million jobs each year just to employ the young people entering the labor force in the next 10 to 20 years. Between 1990 and 2015, working-age population is projected to increase from 35.3 million to 65.6 million (UNFPA 1991).

Family planning services are concentrated in Manila and other urban centers. Between 1980 and 1983, when cuts in family planning programs were imposed, the reductions were greater in rural areas while the budget for urban centers increased by 6 percent (de Guzman 1987). In the last two decades, government spending for population, health, and education was less than 3 percent of GNP. In 1987 this dropped even further to only 2.7 percent, one of the lowest among developing countries in the region.

Frontier Migration and Deforestation

Population pressures on forest lands are much greater in countries where frontier movements come largely from an increasing number of landless, poor migrants who seek out open access forest sites as sources of livelihood. While unemployment and poverty push migrants out of areas with declining economic opportunities, unprotected forest lands pull migrants onto areas with the potential for crop cultivation. Because forested lands in Costa Rica and the Philippines are sloping in terrain and generally unsuitable for cultivation, and because without security of title to the land, migrants have little incentive to adopt conservation measures, degradation is almost inevitable. Thus, the economic crisis, by exacerbating poverty and population pressures at the frontier, is closely linked with tenurial policies that encourage mass movements into open forest sites.

The case studies are based on new data from population censuses which were completed in the mid-1980s. By comparing population data since the 1950s with current census information, historical patterns of frontierward movements are described. In addition the data are broken down by region so that differences within areas with varying forest cover are also evaluated. Despite numerous differences between the two countries, in both the urbanward migrations of the 1970s were reversed in the early 1980s, and the shift signified increased pressures on mostly marginal forest sites.

The Costa Rica Case Study

To measure population pressure on the land resources of Costa Rica, and to identify the areas in which major changes in forest cover occurred, population census figures were cross-classified with identifiable land-use categories. Using the results of a Land Use Capacity (LUC) study conducted by the Tropical Science Center (TSC), the LUC categories were used to adjust the proportion of the population within forest and previously forested sites.

The country was divided into 860 land units and these were later aggregated into ten major LUC divisions. As shown in table 2, LUC categories one to five refer to areas that are generally suitable for cultivation of annuals and perennials and some grazing. These represent 21 percent of the nation’s land area. LUC categories six to nine have poorer soils that are primarily for extensive grazing and plantation forest. But these comprise almost 42 percent of total land area. The rest of the land (37 percent) are for managed or protection forest. Because of the condition of the soils and steep terrain, these are considered ecologically fragile sites.

The distribution of population in table 2 indicates that aside from the strong attraction of areas with fertile soils in and around the urban centers of the Central region, the other populated areas have
been the peripheral towns that contain mostly marginal soils. The soils in these lands are normally suitable only for grazing and forest.

Table 2. Population By Land Use Capacity in Costa Rica, 1984

Land use capacity (LUC):

<table>
<thead>
<tr>
<th>Description</th>
<th>LUC</th>
<th>Area (sq km)</th>
<th>Percent of total land area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual crops</td>
<td>1-3</td>
<td>701</td>
<td>14.0</td>
</tr>
<tr>
<td>Perennial crops</td>
<td>4</td>
<td>297</td>
<td>5.9</td>
</tr>
<tr>
<td>Intensive pasture</td>
<td>5</td>
<td>62</td>
<td>1.2</td>
</tr>
<tr>
<td>Extensive grazing</td>
<td>6</td>
<td>494</td>
<td>9.9</td>
</tr>
<tr>
<td>Plantation forestry</td>
<td>7</td>
<td>298</td>
<td>6.0</td>
</tr>
<tr>
<td>Forest management</td>
<td>8-9</td>
<td>1,300</td>
<td>26.0</td>
</tr>
<tr>
<td>Protection forest</td>
<td>10</td>
<td>1,841</td>
<td>37.0</td>
</tr>
</tbody>
</table>

Population distribution:

<table>
<thead>
<tr>
<th>Total population</th>
<th>Population density (persons/sq km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan area</td>
<td>719,533</td>
</tr>
<tr>
<td>San Jose periphery</td>
<td>541,642</td>
</tr>
<tr>
<td>Rural dense</td>
<td>60,381</td>
</tr>
</tbody>
</table>

Rural (Non-dense):

<table>
<thead>
<tr>
<th>LUC</th>
<th>Total population</th>
<th>Population density (persons/sq km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6</td>
<td>217,924</td>
<td>28</td>
</tr>
<tr>
<td>6-8</td>
<td>390,916</td>
<td>22</td>
</tr>
<tr>
<td>&gt; 8</td>
<td>486,413</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>2,416,809</td>
<td>48</td>
</tr>
</tbody>
</table>


The Pattern of Frontier Movements

The history of rural-to-rural migration in Costa Rica can be divided into three periods. The first period covers the early pioneering phase that lasted until the early 20th century. These moves were motivated largely by the attraction of coffee plantations in the Meseta Central area.6
The second period is the movement outside of the Central region into the peripheral towns and surrounding mountainous districts. Most of such movements were for labor recruitment in large plantations. During this period large tracts of forested lands were cleared for banana and oil palm plantations (Harrison 1991).

Coinciding with large movements of laborers into the peripheral towns was the settlement of frontier sites in the Guanacaste and Nicoya Peninsula areas in the Northwestern region (Saenz and Knight 1971). Many of these settlers established residences and farms, claiming land ownership under the Homesteading Law of 1885. Later migration of this type moved toward the mountains and plains of the San Carlos and Sarapiqui areas and southward toward Tururrabares and the Upper General Valley. By 1950 less than one-third of the Pacific North region's land was forested, most of the area being converted for grazing. In fact land extensive cattle ranches began to flourish in this region long before the start of the export beef boom in 1954.7

The third period, the movement of squatters or precaristas, began in the early 20th century and accelerated during the 1960s. Unlike earlier pioneer settlers, the precaristas became subsistence farmers only for a short time period, residing in the area merely to establish "possessionary or occupancy" rights to the land. Afterwards, the land was sold mostly to cattle ranchers establishing, in effect, the "professionalization" of squatting and land speculation.8

Movements During the Crisis Years

During the early 1980s, there was a significant increase in frontier migration, in general, and a rise in the number of out-migrants from the San Jose metropolitan region, in particular. There was also a net outflow of migrants from urban centers into peripheral towns. The number of people moving from the city toward rural areas more than doubled between 1968 and 1973 and 1979 and 1984.

The number of migrants moving to rural destinations exceeded those that went to urban centers. Indeed, the number of net migrants from rural areas moving to the San Jose urban areas actually declined from 17 percent of all migrants in 1968 to 1973 to just 9 percent in 1979 to 1984. Correspondingly, there was an increase in the number of migrants going toward rural districts and originating from the Central region.

There were substantial intrarural movements as well. Most of such migration was toward lands with more fertile soils and open forested lands. One of the largest moves, for example, came from the cattle regions of the Pacific plain such as in Guanacaste and Nicoya Peninsula. Migrants from these areas eventually settled in more fertile lands (LUC < 6) and in agricultural areas in the San Jose periphery. There was a net loss of population in marginal lands (about 9 percent of total migrant population).

Migration destination areas are broken down by percent forest cover in 1966 and 1984 (see figure 1). Overall, there was a consistent decline in net migrants in lands with less than 50 percent forest cover, totaling some 42,000 out-migrants from 1968 to 1973. There were less outflows in the 1979 to 1984 period, registering about 18,000 migrants (using both 1966 and 1984 forest cover maps).

In contrast, areas with 50 to 80 percent forest cover had a net gain of migrants. Lands with dense forest (> 80 percent) received a net of over 9,000 migrants between 1968 and 1973. Most of these migrants moved into forested lands with good quality soils. A smaller number moved into poorer or marginal soils, indicating that migrants were selective of agricultural potential in their destination choices.

Migrants during the crisis years tended to be poorer. More than 40 percent of all migrants were squatters belonging to the lower 20 to 30 percent income bracket. Between 1979 and 1984, over 43,000 state-assisted settlers moved into forested lands. More than 66 percent of these settlers went to
lands with less than 50 percent cover, a pattern that is inconsistent with the 1968 to 1973 moves. This indicates that because later-period movers were from poorer households, they had less resources to undertake the costly procedure of land clearing.

Figure 1. Net Migration Rates in Costa Rica by Forest Cover, and Land Use Capacity in Rural Non-Dense Areas

Source: Cruz, M.C. and others (1992); Figure 20.
Note: Original artwork not available.
Spontaneous migrants in the 1979 to 1984 period moved heavily into dense forest sites while state-assisted movers continued to occupy less dense (<50 percent) forest sites. This is attributed to the partial closing of semicleared forest sites.

Land-Use Changes from Crisis Migration

Most squatted-on lands were sold to cattle ranchers. When the economic crisis made ranching unprofitable, large tracts of spoiled pastures were later abandoned. Soils under such conditions deteriorated rapidly, affecting the quality of surrounding lands and waterways.

Lands converted for pasture rapidly grew from just 935,200 hectares in 1963 to over 1.7 million hectares in 1984 or an increase of over 46 percent. Meanwhile, crop cultivation expanded by just 8 percent, gaining only an additional 55,400 hectares during the same period (TSC and WRI 1991).

Because of the nature of frontier settlement during this period, land uses fell below their potential capacity. Of the total area planted to annuals, for example, only 32 percent were cultivated in lands suitable for cultivation (LUC 1-3) of such crops compared to almost 45 percent of annuals planted in marginal forest sites (LUC 8-10). Another 20 percent of cultivated lands were in areas suitable only for pasture (LUC 6-7). One-half of perennial crops were found in lands suited for forest (LUC 8-10).

By contrast, as much as 21 percent of pasture lands and 15 percent of forest were in areas suitable for crop cultivation (LUC 1-4), representing an underutilization of fertile farm lands. Also because most of frontierward migration in Costa Rica was to marginal areas, conversion of lands for crop cultivation had less of an impact on improving domestic food supply. Instead most of land conversion was in the form of unsustainable grazing, which contributed to the country’s rapid soil loss.

The Philippines Case Study

Topographic and cadastral maps were combined with aerial photographs to delineate forest lands in the Philippines. Unlike the method of categorizing by land-use capacity in Costa Rica, this approach merely separates lowland from upland population. In addition to this classification, the population was also broken down by ethnic and migrant groupings, rural and urban classes, and population in State-owned versus privately-owned lands (see figure 2).

Lands that are generally suitable for intensive cultivation are mostly found in the lowlands. About 14.1 million hectares of such lands have slopes that are less than 18 percent, which is the official cutoff for defining state-owned forest lands and so-called "alienable and disposable" or A&D lands. About 8.6 million hectares of marginal lands have slopes between 18 to 30 percent and these can be cultivated but require adequate conservation practices. Another 6.5 million hectares have slopes greater than 30 percent. These steeply sloping lands are suited only for forestry.

Most of lands that are forested are state-owned and cannot be titled to private owners. However, large areas of previously forested state lands have already been converted into farms (World Bank 1989; DENR 1989). During the 1960s, cultivated area in forested and previously forested lands amounted to only 10 percent of total cropped area. By the mid-1980s, this had increased to about 40 percent, with upland cultivated area increasing at an average of at least 7 percent per year during the past three decades (NEDA 1988).
Figure 2. Breakdown of the 1985 Population of the Philippines by Land Classification and Indigenous and Migrant Population (in Millions)

<table>
<thead>
<tr>
<th>Total Upland Population</th>
<th>17.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Upland</td>
<td>7.1</td>
</tr>
<tr>
<td>Rural Upland</td>
<td>10.4</td>
</tr>
<tr>
<td>Upland A&amp;D</td>
<td>4.2</td>
</tr>
<tr>
<td>Forest Land</td>
<td>2.9</td>
</tr>
<tr>
<td>Indigenous</td>
<td>0.6</td>
</tr>
<tr>
<td>Migrant</td>
<td>2.3</td>
</tr>
<tr>
<td>Upland A&amp;D</td>
<td>8.1</td>
</tr>
<tr>
<td>Forest Land</td>
<td>2.3</td>
</tr>
<tr>
<td>Indigenous</td>
<td>4.7</td>
</tr>
<tr>
<td>Migrant</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Source: NCSO (1985), National Barangay Census; adjusted for upland population by Cruz, Zosa–Feranil and Gocoe (1988); indigenous population figure from DENR (1989)

Note: Original artwork not available.

Pattern of Frontier Expansion

Population increases and the pressures from a growing number of landless, rural workers underlie the spread of farming in the uplands. The vast majority of upland population are lowland migrants, comprising 70 percent of the entire upland population in 1985. As shown in figure 2, more than 40 percent of the upland population were classified as "urban." Most of tribal population, about 4.7 million, resided in rural upland areas that are state-owned forest lands. In contrast almost all residents of upland sites that are privately owned are occupied by migrants. A significant 5.7 million migrants have already moved into interior, state forest lands, accounting for more than one-half of forest land population (see figure 3).

The largest concentrations of upland population were in logged-over timber lands. In these lands migrants provided ideal sources of inexpensive labor, especially in the task of clearing underbrush and other vegetation which interfered with hauling timber. By 1985 the total population in timber lands reached more than 9.1 million, representing over one-half of the entire upland population in the country. Timber land population grew at an annual rate of about 4.6 percent between 1948 and 1970 but rapidly increased by 6.1 percent per year between 1980 and 1985.

A large number of upland households moved during the early period of settlement in the 1950s. Some migrants came as state-assisted settlers. Between 1959 and 1963, state-assisted settlers converted from 100,000 to 200,000 hectares of forest land each year (Paderanga 1988). Some spontaneous movements occurred in the next decade, but these were much less in number compared to urbanward migrants.
Frontier migration accelerated in the early 1980s, registering more than 2.5 million upland migrants originating from rural towns and urban places. Net upland migrants accounted for 14.5 percent of total upland population in 1985, the highest rate since 1950. Upland receiving areas continued to have an increasing flow of migrants while the number of sending areas grew to include even agricultural towns and cities.

Because of the rapidly increasing flow of migrants, destination places also expanded in the 1980s to include more remote forested sites. However, the largest net increase occurred in upland urban sites with relatively higher population densities. This pattern can be explained by the composition of later-period migrants. Unlike earlier pioneer settlers, the poorer migrants preferred semicleared, settled sites where they could sell or exchange their labor in order to have access to upland fields.  

Three regions have upland population densities of over 100 persons per square kilometer in steeply sloping lands (over 40 percent slope). Because long fallow rotations will be unable to support this population size, more frequent cropping occurs, eventually leading to greater soil loss.

Average population densities in moderately sloping lands are relatively large, exceeding 217 persons per square kilometer. Three regions have population densities that are twice the national average. More accessible uplands with less steep slopes are likewise heavily populated. Two of such regions in Southern Tagalog and Ilocos have upland population densities greater than 500 persons per square kilometer. These sites are surrounded by an extensive network of logging trails, secondary roads, and agricultural markets.

Environmental Effects of Upland Migration

The earlier pattern of agricultural growth by expanding acreage during the 1960s reappeared in the 1980s, but now with more extensive cultivation of forested and marginal lands. Cultivated area in forest grew from 9 percent of total cropped area in 1960 to over 31 percent in 1985. However, because of highly skewed agricultural land distribution, only three-fourths of potentially arable lowlands (with slopes less than 18 percent) have been intensively cultivated. More than 500,000 hectares of good quality agricultural lowlands remained idle or underutilized.

The increasing size of landless agricultural laborers is an indicator of the inadequate access to land in the country. Arable land per person employed in agriculture declined from 0.72 hectares in 1970 to 0.53 hectares in 1980. Farm laborers and landless workers comprised 40 percent of all agricultural workers in 1975 and 56 percent in 1980, indicating the increasing size of the rural work force without access to land.

Between 1980 and 1987, cropland expanded by 2.7 million hectares, but almost 60 percent or some 1.6 million hectares, occurred in previously forested lands with slopes between 18 and 30 percent. Some deforestation also comes from small-scale timber cutting (locally called carabao logging), harvesting of nontimber forest products such as rattan, bamboo and nipa leaves, and fuelwood.  

When forest conversion occurs in the upstream areas of multipurpose irrigation projects, the off-site effects from high runoff and siltation are larger. For example in the Magat Multipurpose Project site, annual losses in erosion averaged less than 2 tons per hectare per year for land under forest cover but rose to 122 to 210 tons per hectare per year soil loss for newly established pasture and farm lands (David 1988).
Figure 3 Philippine Upland Population, Annual Growth Rate of Upland and National Population, 1950-85

The on-site replacement cost of soil nutrients lost with this level of erosion is estimated at $50 annually per hectare (Cruz, W. and Cruz, M. C. 1991). In the Magat watershed site alone, the cost of soil losses coming from 6,000 households cultivating 176,800 hectares in the upstream site of the project amounted to a substantial $8.8 million (World Bank 1989; Cruz, W. and Cruz, M. C. 1991).

Summary and Recommendations

Economic stagnation, occasioned by the debt crisis, created such massive unemployment and poverty that internal migration patterns drastically changed. Frontier migration, already present in both countries since the 1950s, accelerated while urbanward movements, which were dominant in the 1970s, declined. Most migrants could only turn to open access forest lands. Such lands had mostly fragile and easily erodible soils, which were in steeply sloping areas, upstream portions of watershed projects, and previously logged-over lands.

Unchecked population growth aggravates the pressures to overexploit resources. Because population increases continue to feed the flow of migrants, even traditional community management systems will be hard pressed to maintain the resource when population densities exceed the community's capacity to manage the resource. Governments of both countries have also failed to develop technical and institutional support to the growing forest populations, most of whom are poor and lack access to basic services. The consequences are severe. Farming in forest continues to increase as migration intensifies. Shorter fallow periods and permanent cropping have led to the mining of soil resources and declining yields.

This pattern of agricultural extensification contrasts with the traditional expectation that as a country's population increases, cropping systems progress from land-extensive to input-intensive techniques of cultivation (Boserup 1965, 1990; Binswanger and Pingali 1989). Up to the mid-1960s, agricultural output growth came primarily from an expansion of cultivated area. In the 1970s, yield increases came from use of modern crop varieties and inputs. Irrigation and marketing systems were developed to meet growing food demand. Both countries even exported agricultural commodities, with export earnings accounting for 20 to 40 percent of gross domestic product (GDP) during the 1970s. However, the expected transition to agricultural employment and absorption of surplus labor in industry did not take place during the 1980s. Instead, lagging industrial output and inadequate labor absorption in modern farming and manufacturing failed to siphon off excess rural labor, prematurely pushing the extensive margin of agriculture outward. Meanwhile, large tracts of lowlands remained underutilized while cropland expansion moved heavily into fragile, forested sites.

In Costa Rica, as of 1984, only 10 percent of land area is cropped although at least 14 percent is suitable for intensive cultivation (TSC 1985, 1991). Of the 525,160 hectares that is farmed, one-fourth is in previously forested areas. In some of these areas, soil erosion has reduced the land's productivity and pastures have begun to replace crops. Already, one-quarter of Costa Rica's soils have been depleted from moderate erosion of its surfaces while another one-fifth of land area suffers from severe erosion (Hartshorn and others 1982).

As much as 25 percent of total arable lowlands in the Philippines remain underutilized (NEDA 1988). Meanwhile, cultivated area in forest has expanded from 23 to 31 percent of total cropped area between 1980 and 1987. Although cultivable, these sloping lands require adequate soil conservation to reduce erosion and to minimize loss of valuable soil nutrients.

Inappropriate farming practices on sloping lands have led to reduced land productivity. When cultivation occurs in the upstream portions of multipurpose projects, the off-site effects are multiplied, as the Magat watershed project in the Philippines demonstrates. The cost of such losses are substantial while the costs of programs aimed at reducing the flow of migrants to these sites may be much lower.
Another important consequence of frontierward expansion is the breakdown of community institutions and resource management practices that have evolved through many years of using the resource. Communal forests, some of which are managed as common property resources, are now either sold or abandoned because of pressures from more aggressive migrants. Even among tribal mountain groups, fences are built to protect once common areas. With the decline in open hunting and gathering territories, and with reductions in crop-fallow rotations, sharing of forest products is now hardly practiced, leaving many forest dependent populations (young and elderly) competing for scarce resources.

State property laws and community-based property institutions have been slow in responding to changes in resource demand especially when these changes occur over a short period of time. In some cases private property displaces common property when population densities are large. In addition because land rights at the frontier are often insecure, those with clear property rights tend to be the ones who need them less, such as the rich cattle ranchers in Costa Rica or the small number of timber concessionaires in the Philippines.

Land laws in Costa Rica were the major causes of extensification. These laws encouraged the professionalization of squatting on open access forest lands. Because these laws granted possession or ownership rights, they induced short-term use of these lands by promoting land speculation. Combined with tax, credit, and price support, and other incentives to cattle ranchers, frontier land conversion turned increasingly into degraded pastures.

Some Recommendations

Breaking the cycle of population pressure, impoverishment, and environmental degradation will require interventions with four related objectives. The first is to reduce population growth which feeds the flow of migrants. The second is to alleviate poverty and improve economic opportunities to absorb excess rural labor. Third, a genuine land reform program is needed to reduce pressures from landlessness and to promote better use of agricultural farm lands. Fourth, there is a need to improve farm forestry technologies aimed at increasing output and income levels of upland farmers.

Population Programs

A cross-section evaluation of forest communities will reveal varying degrees of population pressure. Some forest areas will have much higher population densities, a larger proportion of people aged fifteen and below, an unequal number of old versus new residents, or an unusually high fertility rate due to differential levels of poverty. In each of these sites, a combination of site-specific population support programs will be required.

The information generated from national studies such as these will be helpful in identifying key population stress areas. When combined with data on land use and potential for environmental damage, some way of classifying priority sites can be designed. The important condition is the evaluation of both long-term and cross-section changes in population.

There is a need to provide basic health, education, and population information services in these sites. Opportunities to increase women's participation in production and conservation activities are necessary support schemes aimed at encouraging long-term fertility declines. Age- and gender-sensitive economic programs are required especially at the frontier where markets are imperfect and where government support services are less accessible.
Economic Development Programs

The case studies of Costa Rica and the Philippines have shown that price, trade, and tariff reforms are needed in order to reduce the net outflow of resources from agriculture. Urban- and industry-biased programs must be eliminated, especially the overprotection of inefficient manufacturing industries and unequal support given to large landowners and cattle ranchers through credit, taxes, and price subsidies.

Programs aimed at expanding employment and absorbing excess rural labor will be important in reducing the flow of migrants to the frontier. Macroeconomic and sectoral policies will have to be designed so that they do not work at cross purposes. A useful method is to trace the intersectoral linkages of policies with changes in land use and population distribution. Site-specific programs can be designed through the conduct of case studies. The description of critical forest sites -- those with high population densities in steeply sloping lands, or sites with large populations of poor migrants and displaced tribal mountain residents -- is useful in identifying some of these areas.

Credit, price, and tax reform that are sensitive to changes in household incomes at the frontier include those that affect rural energy use (fuelwood), domestic timber (small-scale logging), and marketing of upland crops. These must be reviewed carefully, alongside regional variations in economic costs and returns of alternative upland livelihood schemes.

Agricultural Land Reform

Inequitable agricultural land distribution contributes to pressures to expand cultivation in marginal areas, as the case studies of Costa Rica and the Philippines indicate. By increasing the number of landless workers seeking land and alternative income sources, landlessness provides one of the basic incentives for moving out of lowland agriculture.

Landlessness tends to be pronounced in areas occupied by large plantations. This is supported by out-migration patterns in Costa Rica and the Philippines, with most outflows coming from banana plantation sites in the northern and southern Pacific areas of Costa Rica and in the Visayas sugar plantation regions of the Philippines.

Large farms in Costa Rica cover almost one-half of all agricultural lands in the country. In the Philippines just a fraction of large farms occupy over one-third of agricultural lands. Such highly skewed land distribution patterns prematurely induce the closing of the lowland agricultural frontier long before economic, institutional, and demographic factors are at work.

However, tenure policies are unavoidably linked to economic and population policies. Population programs that failed to reduce pressures on employment and resources underlie many of the problems associated with increased poverty and environmental degradation. At the same time economic policies that depress wages and lower incomes create the conditions for larger families. Lack of access to agricultural lands aggravates population pressures and economic decline by inducing mass movements out of traditional agriculture onto open, forest sites.

Technical Support

Already, millions of people reside in forested lands. Most of them will be clearing lands and cultivating plots with time horizons ranging from two to several years. Because migrants' expectations
of yields and incomes are normally high in the first few years of settlement, it is at this stage of settlement when government support is most critical. Such support may be in the form of technical training in sustainable farm forestry.

A critical period is the burning and clearing stage, when less damaging techniques are needed in order to control the negative effects of deforestation. Technical support is also needed in the next stages of crop cultivation, in the form of planting strategies, choice of crops (ones which are less erosive), soil conserving approaches, and many others.

In fact there are numerous examples of sustainable farm forestry that have been documented worldwide. Some of these cases are found in the Philippines, such as elaborate terraces for controlling water flow in steeply sloping rice paddies and application of organic materials and mulching. Although many of these examples are in tribal communities, with hundreds of years of experience in forest farming, some notable cases have also been seen in migrant communities. One such community of migrants in Laguna province, for example, uses multilayered cropping, combining trees with crops in fields and maintaining polycultural home gardens.

These suggested interventions -- in the areas of population programs, economic policy reform, land tenure, and technical support -- are complementary efforts that can contribute to breaking the cycle of population pressure, poverty, and environmental degradation that we are witnessing in many parts of the world. However, given the enormity of the problem there will need to be firm commitment from governments and international development institutions to initiate programs that can really matter.

References


Endnotes

1. Population figures for both countries are from demographic tables summarized in UNDP (1990), from reports of the U.N. Population Division.

2. However, women have less access to employment opportunities. The ratio of women to men in the labor force is only 28 percent, way below the 51 percent average for developing countries (UNDP 1990).

3. The total fertility rate (TFR) is the average number of children a woman would bear in her lifetime at current fertility rates.

4. The projected population of the Philippines in year 2025 is 101 million (Bulatao and others 1991). Pressures will be more intense, however, in rural areas where population growth rates are much higher among the rural poor. Rural women, on average, have almost twice as many children as their urban counterparts. For example, total fertility rates in 1980 were larger among rural women, at seven births per woman compared to just 3.8 for urban women (NSCB 1989).

5. The administrative and land-use maps were taken from the Instituto Geographico Nacional. For a description of the LUC methodology and results, see TSC (1985) and TSC and WRI (1991).

6. Some migration occurred in the Pacific coast but these were insignificant compared to the movements toward the Central region.

7. As data from the 1950 and 1963 censuses indicate, rural-to-rural migration was a dominant feature of settlement of rural towns, with over one-third of the population having moved since birth (Hall 1985). There was a steady outflow of people from the Central region toward nearby towns.

8. Land rights were established by the 1892 Ley de Cabezas de Familia and the Ley de Poseedores en Precario, which allowed squatters to receive compensation for cleared lands.

9. A large 36 percent of perennials are planted in LUC 1-3 lands and only 6 percent are actually planted in lands that are well adapted for perennials (LUC 4).
10. Economic losses from depreciation of soils were estimated by TSC and WRI (1991). The average 
depreciation in 1970 from pasture was estimated at US$35.8 million. By 1984 this increased to 
over US$40.1 million. Total soil losses from all types of land conversion amounted to more than 

11. The most important reason for encouraging migrant encroachment into logged-over sites is that 
loggers use this as an excuse for not undertaking the costly procedure of residual stand 
improvement and reforestation. There are, in fact, reports of loggers who purposely invite 
landless farmers to cut trees and clear land even while logging operations are still ongoing (Puyat 
1972).

12. A study in the Mount Makiling upland site in Laguna province showed the increase in new 
migrants working as laborers in upland farms (Cruz, M.C.J. with A. Alcantaro, W. Cruz, F. 
Lannigan, R. Mendoza, and P. Sajise 1985). In return for their services, the new migrants are 
given an average of 300 square meters of homelot and use-rights to clear forest land. A similar 
arangement was observed in Mindoro province. Visayan migrants were provided homelots and 
woodlots in exchange for weeding and harvesting labor (Costello 1986).

13. The regions with high population densities in its upland sites are Southern Tagalog, Western 
Mindanao, and Northern Mindanao. Conklin (1980) estimates a maximum carrying capacity of 
200 persons per square kilometer for shifting cultivation systems in the Philippines.

14. The data on landless workers is supported by national studies conducted by Ledesma (1982) and 

15. Carabao logging involves the cutting of commercial timber by upland households using carabaos 
or water buffalos and other animals to haul down timber. The wood is sold to local handicraft 
and furniture cottage industries.

16. In 1985 more than one million persons resided in these watershed sites. The watershed area 
population grew by 1.8 percent per year and the net migration rate increased from 2.2 percent 
in 1975 to 1980 to over 5.3 percent in 1980 to 1985.

17. An example of the kind of intersectoral linkage analysis can be found in Wilfrido Cruz and 
Robert Repetto, The Environmental Effects of Stabilization and Structural Adjustment Programs: 
Credit and Environmental Rehabilitation: A Case for Supply-Led Credit?

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"A perceived imperfection in rural financial markets that generated a discrepancy between social and private costs and benefits has provided a justification for intervention in rural credit markets. As private returns were estimated to be below the social ones, the intervention was intended to overcome this failure and to spur investments that would not have materialized otherwise" (Yaron 1992).

Introduction

Credit for the purpose of environmental rehabilitation involves social benefits to a greater extent than almost any other form of credit. It may include a variety of activities, such as (a) tax credit to individuals or enterprises for undertaking ecological rehabilitation or work of benefit to the environment (the U.S. tax credit for taking land out of production, though not established for this purpose is an example of this; (b) credit to governments to finance environmental rehabilitation, that is, Global Environmental Facility (GEF) or International Development Association (IDA) financing for environmental rehabilitation projects; (c) small-scale credit to communities or in the last instance to enterprises or individuals for environmental rehabilitation; (d) environmental rates of return applied to such lending; and (e) environmental criteria applied to the approval of credit by banks, such as the Swiss Banking Corporation that examines potential environmental consequences of the undertaking financed under the credit. This is often the practice in financial institutions that own major stakes in industry, as in Japan or Germany, to ensure environmentally prudent investment (Goodland 1992).

The United Nations Environment Programme (UNEP) Declaration on Banking and the Environment provides a set of standards for environmentally conscious financing in this vein.

This paper will explore issues around small-scale credit to finance environmental rehabilitation to communities and smallholder farmers. The paper begins with a review of the link between environment and poverty. It then proceeds to an examination of key issues and contradictions in credit provided for environmental rehabilitation. The paper summarizes different schemes of environmental credit undertaken by the International Fund for Agricultural Development (IFAD), but it should be noted that many other international and nongovernmental organizations are also active in this field. The available evidence of the success or failure of small-scale environmental credit schemes is then examined. This is followed by an analysis of issues and problems emerging from experience in environmental credit. The alternatives to using small-scale credit for environmental rehabilitation are discussed next. In conclusion the experience to date is evaluated, and lessons and recommendations for further research are outlined.

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Environment and Poverty

The need for environmental rehabilitation, on a global, regional, or national scale hardly needs stressing as the concern over global warming and the follow-up of the Rio Conference occupies a large space in the current environmental agenda. The consequences of environmental degradation on rural poverty and vice versa are important aspect of this agenda. Environmental degradation and the economic marginalization of rural groups presents a cycle of mutually reinforcing factors. Moreover, the poor may represent a latent resource for environmental rehabilitation: the potential role of the poor in environmental rehabilitation has been inadequately explored. However, comparatively little attention has been paid to the few but significant efforts to address this issue by a number of international and nongovernmental institutions in the field of credit.

This lack of attention is not surprising: credit and environmental rehabilitation appear to be orthogonally opposed concepts, in time as well as in space. At its simplest level, credit is taken and given for the short-, medium- or long-term; the long-term does not usually extend beyond the life of the debtor or the enterprise. Wider social benefits do not enter into the calculation of the borrower. Credit is taken for a clearly definable benefit to the person or the enterprise. Environmental rehabilitation, on the other hand, has major externalities, particularly positive externalities; it is usually long-term and includes benefits to others, even to generations to come. In addition, environmental rehabilitation, whether air, water, or soil rehabilitation usually will often have benefits that extend spatially far beyond the creditor, his/her community or even the country. For example, in East Java, silting of irrigation works in the lowlands must be addressed through soil conservation in the highlands, and highland farmers must be compensated for their soil conservation work. Similarly, combating silting and flooding in Bangladesh will require forest and watershed rehabilitation of the Ganges and Bramaputra upstream in India, Tibet, and Nepal. With only a small portion of the benefit accruing to the debtor and the remainder spread widely to nondebtors, environmental rehabilitation is clearly not a prime target for credit.

Environmental Credit Projects

Nevertheless, there are a number of small-scale examples of environmental rehabilitation, working with poor and marginal groups, that seem to have overcome these fundamental difficulties in environmental credit. A number of IFAD projects in Asia have combined components for environmental rehabilitation and credit for small farmers. These include the Small Farmer Development, Production Credit for Rural Women and the Hills Leasehold Forestry and Forage Development Projects in Nepal, Andhra Pradesh Tribal Development, and Oxbow Lakes Projects in India, are the Sichuan Integrated Livestock Development, Shandong/Yantai Integrated Agricultural Development, the Hebei Agricultural Development, and the Northern Pasture Livestock Development Projects in China. Working with the poor in ecologically fragile areas, 63 percent of recent IFAD projects address environmental issues, but not all involve credit. This paper focuses on projects with credit in Asia, but there are also a number of projects in Africa, the Middle East, and Latin America that address these issues in a similar manner and affirm the findings of the projects in Asia.

Credit may include short-term production credit, and medium- and long-term investment credit; the latter includes long-term investment credit for environmental rehabilitation. Environmental credit can be seen as a subset of agricultural investment credit. In the latter category are credit for terracing, irrigation rehabilitation, gully control, tree crop planting, desalination, pasture improvement, and smokeless stoves. Environmental credit therefore shares many of the problems of
agricultural credit generally, and has found a number of ways of overcoming these; yet others are particular to environmental credit. If credit is seen as a continuum, credit for environmental rehabilitation is at one end of the continuum, next to long-term agricultural investment credit, while short-term market or production credit is at the other.

It is important to note that these projects have evolved very considerably over the past ten years. Already in the early 1980s some projects were designed with the explicit objective of combining poverty alleviation, credit for smallholders and the landless, and environmental rehabilitation, while many projects included such components within the broader objective of furthering agricultural growth. The projects are at different stages of development. Some, such as the Northern Pasture and the Hebei Agricultural Development Projects in China, the Rajasthan Command Area Development Project in India were initiated around 1980 and have already been completed. Others, for example, in Indonesia and Nepal are under implementation; yet others are on the process of preparation. Nevertheless, these projects do provide the first lessons and experiences for the design and implementation of new operations in this field. Only as environment and credit focused projects complete the implementation phase, can more firmly based conclusions be drawn on how to design the interface between credit for smallholders and the landless and environmental rehabilitation. The present review, therefore, is limited to examining a wide variety of projects for their implications on credit and environmental rehabilitation and to identifying key issues in this area.

The projects reviewed here range in size from about US$100 million to US$10 million, with credit as one of several project components, usually not the largest. Credit is used in a number of different ways. In several projects, credit is used directly for environmental rehabilitation to finance tools, fertilizer, fencing pasture seeding, pump stations, and so forth; this was done in two projects in China. In other projects credit is given to cover the cost of labor for earthworks or tree planting, as in Nepal. In yet others, credit is used as an incentive for environmental rehabilitation; and is given for income earning activities and other activities not directly related to the environmental rehabilitation. An example of this is the provision of credit for fishing equipment in the rehabilitated and restocked oxbow lakes in Bangladesh. In order to address the survival strategies of poor households spreading risks, credit is also given for other, unrelated income generating activities to diversify the household income and reduce dependence on activities depleting the environment, for example, in the Nepal project. In some projects, credit is provided for activities that may at first glance appear to run counter to environmental rehabilitation; this refers, in particular, to credit for large livestock, also in Nepal. In this project, which aims to reduce deforestation and erosion in the Hills through reforestation and forage development on forest land leased to farmers, credit is available for the purchase of high-yielding livestock on proof of upgrading of forest land and fodder production. These buffalos or goats, which must be stall-fed, replace the low-yielding breeds that feed by grazing (and overgrazing) the forest.

Key Characteristics

These environmental/credit projects have several points in common with respect to the provision of credit. These points are not unique to environmental credit, but are shared with other forms of rural and agricultural credit. There are five key features of special relevance to environmental credit schemes: (a) focus on the poor, (b) bridging operations with formal financial institutions, (c) nontraditional collateral, (d) market interest rates, and (e) savings mobilization.

Focus on the poor. Although not all poor live on marginal lands and not all who live on marginal lands are poor, the focus on the poor narrows the scope of credit to activities of interest
only to those with limited resources. Targeting by activity is one of several methods of targeting the poor, which is the central aspect of IFAD lending, because of its mandate to alleviate rural poverty. The projects address the link between poverty and environmental degradation directly as well as indirectly. The rural poor have limited access to resources, except to increasingly marginal and agroecologically fragile land, which is of little interest to wealthier groups in the community. A large number of projects also involve the management of common property resources. It is the poor who are the users of marginal land, and the poor who have the strongest interest and benefit from its exploitation or its rehabilitation. Thus, there is a market niche (Von Pischke 1992) for environmental credit, of limited interest to other groups. This is one of the strongest arguments for environmental credit.

Bridging operations with formal financial institutions are another key feature using group support, control, and administration. They serve the twofold purpose of outreach to the poor and reduction of transaction costs. These are relevant to all types of credit to the poor, but central to environmental rehabilitation, which involves wider social benefits that require broad group and community support. Equally significant, however, is the role of group control and administration in lowering transaction costs for the small loans taken by the poor. The group serves as the financial intermediary between the small borrower and the bank. This intermediation not only provides outreach to the poor, but decreases the administrative cost per loan for the bank. In addition, it serves the equally important function of reducing the time, travel, and administrative burdens of the borrowers using formal financial institutions rather than moneylenders in the informal financial markets.

Nontraditional collateral, (social collateral) in the form of group guarantee, is key in many projects. Many, but not all of these environmental credit projects, rely on group collateral rather than physical assets to guarantee the loan. All group members are responsible for the repayment of arrears or defaults of each member, so that social pressure acts to discourage default. Moreover, further access to credit, individually or as a group, is denied as long as one group member is in default. The experience with group guarantees to date is mixed. They generally work well when the group is small (fewer than a dozen members); when it is socially, economically, and geographically homogeneous; often with one sex groups; when the principle of group responsibility is rigidly applied; and future access to credit is dependent on good repayment performance. For larger groups, composed of both rich and poor and where the group guarantee has been relaxed, group guarantees have been less successful. Once social pressure for repayment is removed, default can sometimes increase in a chain reaction: after penalties are imposed, it is in nobody's interest to repay.

Market interest rates. As a matter of policy, IFAD credit projects on-lend at market rates of interest to the final borrower. In projects operating in areas where subsidized credit has been provided, market rates are introduced stepwise over a period of time. Dual interest rates for environmental and income generating activities are otherwise avoided. The experience with one project in China demonstrated the fallacies of a dual interest structure for environmental rehabilitation. This project introduced subsidized interest rates for environmental rehabilitation of marginal lands for a minority population in Inner Mongolia. Farmers repaid the higher interest bearing loans of the Agricultural Bank of China before repaying less expensive project credit for environmental rehabilitation. Intensive supervision and adjustment of interest to prevailing rates were required to solve the problem of arrears.

Savings mobilization has been included in several projects, which refute the notion that the poor are too poor to save. Where savings form part of the credit scheme, they serve three important functions: (a) to provide collateral for credit; (b) to provide information to lenders and borrowers about each other in a continuing relationship, which builds confidence in the credit operation and assures a durable consensus around the environmental goals (equally important to lender and
borrower); and (c) to foster banking habits in the target population, especially when the borrower has little experience with formal financial institutions, and vice versa. This is simply good credit policy; although relevant to lending to the poor, it bears no special relationship to environmental credit. However, it underscores the need for good banking and credit practice in environmental credit projects: these projects can be no exception.

**Preliminary Lessons**

Although projects are still at an early stage of development (implementation phase or just after) and the full development, sustainability, and long-term impact cannot yet be assessed, a number of preliminary lessons can nevertheless be drawn for the design of projects that combine credit with environmental rehabilitation. These include, first of all, considerations essential to good lending; neither the financial system, the lending institution, the environment, nor the poor are well served by poor lending practices. There are, however, also environmental considerations that do not necessarily coincide with good banking practices. The means have to be found to mesh the two without jeopardizing the viability of the credit. Seven major issues in merging banking and environmental considerations in the design of credit for the poor have been identified as (a) lack of demand, (b) high establishment costs, (c) combination of grant and credit, (d) intensive technical assistance, (e) close monitoring and follow-up, (f) repayment considerations, and (g) fungibility and are outlined below.

**Lack of demand for environmental credit.** Environmental credit contains larger social elements than other types of credit: it creates social as well as personal benefits; and ecological rehabilitation is long-term in nature. These considerations overshadow the issue of "credit need," which becomes less relevant. There is rarely an unmet need, nor an unmet demand for such credit. There is, in fact, no shortage of funds to meet the demand for environmental credit, but also no false demand. Demand both for environmental rehabilitation and for credit has to be encouraged and fostered. In contrast to traditional types of credit, the justification cannot rest on demand (or need) but must lie elsewhere. Credit is one of a variety of ways to encourage environmental rehabilitation. As we shall see below, it has several advantages, and some drawbacks.

**High establishment costs.** Environmental rehabilitation is long-term and costly. Credit for the poor, in addition, requires considerable investment to overcome the lack of institutional structures suited to small-scale lending and to lending to the poor, to develop bridging mechanisms between formal financial institutions and the small borrower, to nurture the experience of the poor with formal credit, to build their trust as well as that of the lender, to overcome the distance between marginal areas and the government, and to monitor operations closely to identify start-up problems. Ecological credit, as a result, generally has start-up costs that are very high, when evaluated against standard economic criteria. Once the high initial costs have been met, costs tend to decline to manageable limits. It is likely, however, that the high initial costs of environmental credit have to be written off in the interest of wider social benefits. Some of these costs may be justified by the process approach to project design that usually accompanies group participation.

**Combinations of grant and credit components** are often used to bridge the gap between environmental and investment criteria. The poor are among those least able to afford the cost of environmental rehabilitation that will benefit the population at large.

A variety of options in combining credit and grants for environmental rehabilitation to offset costs for activities with benefits beyond the target group have been tried. These fall into three broad categories: (a) credit is given directly for environmental rehabilitation work; (b) credit is given for subsidiary activities; and (c) credit is used to finance income generating activities on or off farm to
broaden the resource base of poor households in marginal areas and lessen pressure on the environment. Incentive payments, including subsidized items such as energy-efficient, smokeless stoves have also been used. In the Nepal project, for example, tree seedlings, grass seeds, and lining of water holes for livestock are provided on a grant basis, while smokeless (and more energy efficient) stoves are heavily subsidized. In addition, incentive payments are used to finance the interest on credit for the labor costs (household or other) of forest development and upgrading. The credit component of the project at positive rates of interest, on the other hand, is for labor inputs in land rehabilitation, livestock purchase, and off-farm income generating activities that will lessen household dependence on forest resources. In other projects, production credit is given for environmental rehabilitation covered by grants. In an on-farm soil and water conservation project in East Java grants are given as an incentive, for civil works, survey, and layout work, while food for work is provided for beneficiary labor, and credit is provided on a group basis for production inputs on the improved land. In China, watershed protection and rehabilitation is similarly financed through the combination of grant and credit, with priority for poor households.

**Intensive technical assistance.** Like all interventions with a strong element of participation, group credit requires group organizers and other community workers, in addition to agricultural, forestry, and environmental extension services. Community participation is indispensable; it is the glue that binds together not only credit and repayment but also the commitment to environmental rehabilitation. Group organizers are key to community participation. This entails high costs initially when group credit is established, but these can be reduced as communities develop self-reliance and take over some of the functions of the group organizer over the longer-term.

**Close monitoring and follow-up.** Innovative by nature with respect to credit for the poor, participation and environmental rehabilitation, environmental credit projects need closer monitoring and follow-up to a greater extent than other types of credit. The approaches being tried require testing and assessment; implementation problems need to be identified as they arise and action quickly taken to rectify them; lessons need to be drawn for wider application. Environmental credit projects also carry a stronger need for proof than traditional projects because the burden of proof necessarily rests on the innovative project design. Close monitoring and follow-up is a must.

**Repayment considerations.** Special care also needs to be taken to ensure repayment schedules that match the household income cycle or the crop cycle so that repayments are due when money is available. Several approaches are being tried: deferred payments for a few years, interest rebates in the establishment period, and careful calculation of borrowers' cash flows, combined with different forms of village level banking to ensure that the mechanics of repayment support social pressure in group lending.

Dual credit for environmental rehabilitation has not yet been tried extensively. It is based on the Grameen Bank model of lending (whose overall purpose is not ecological). Credit is provided for a combination package of investment of short- and long-term yield. Loans for cattle raising, which provide no short-term yield to meet the weekly repayment requirements of the Grameen Bank, are combined with an activity with immediate yields, such as egg production, to help with the cash flow and repayment of the long-term credit. For environmental rehabilitation, which is by definition long-term in yield, variants of the dual credit system provides possible options not yet fully explored.

**Fungibility of funds.** This has been a major issue in the provision of agricultural credit. How can we ensure that the funds borrowed are not replacing other funds in environmental rehabilitation? There is no simple answer, because substitution of funds can occur in environmental credit as well as in long-term agricultural investment credit. Certain aspects suggest that it may be less of a problem, but there is no firm evidence. First, it has been argued that the poor are less likely to substitute credit for own funds in environmental rehabilitation, if only because they have so few assets. Second, there
is little or no environmental rehabilitation undertaken without credit; environmental rehabilitation satisfies the criterion of being additional more clearly than other activities supported by credit.

In short, credit for environmental rehabilitation presents a number of problems from a strict banking perspective and does not abide entirely by the rules and practices laid down for other credit programs. Extending financial services to marginal groups has required modification of the textbook approach to credit. Flexibility is essential, while at the same time safeguarding a number of key principles to ensure the financial soundness of operations. So for example, the grant element that is used in many of the projects to permit the poor enough compensation to participate may be seen by some as a form of disguised subsidy that is ill suited to credit. To remedy this, intensive efforts are necessary to distinguish the credit aspects of the project, which need to be implemented according to the principles of sound financial management, and the grant element that is necessary both to initiate environmental rehabilitation and to compensate for the proportion of benefits that accrue to nonborrowers. This distinction, it is worth noting, is not a matter only of project design, but more importantly, it must exist in the minds and calculations of the participants and the implementing institution. If it does not, the grant element runs the risk of compromising not only the environmental credit operation but the rural financial market as well. There is as yet no evidence whether this is the case.

Alternative Options in Environmental Rehabilitation

Experience with credit for rural and agricultural development, particularly in developing countries, suggests the need for a careful examination of the alternatives to government intervention in the provision of credit, with or without international assistance. Credit is clearly not the only option for environmental rehabilitation. It is not *prima facie* obvious that credit is the best mechanism to encourage adoption of new technologies in agriculture, much less so then for environmental rehabilitation. There are many ways to address environmental rehabilitation: grants, public works, tax incentives, user charges for pollution. Under what circumstances is credit the most appropriate approach? What are the advantages of credit over other mechanisms or over leaving things to market forces?

The first option would be to *allow rural financial markets to address the existing demand.* This, of course, fails conspicuously to take into account the inherent contradiction in assuming debts for benefits that others will enjoy; it fails to capture the social good of environmental rehabilitation. Existing rural financial markets do not normally address socially desirable goals per se and have not so far financed environmental rehabilitation spontaneously. The issue, then, is not shortage of funds for credit, but rather the lack of an investment market for environmental credit, that is, no clearly identified demand for credit for environmental rehabilitation.

A second option would be to *work within existing markets,* to assist local moneylenders to add environmentally sound lending to their existing portfolios. This has all the attendant advantages of knowledge of local markets, risks, and clients. It is difficult, however, to identify the local moneylenders' interest in adding environmental to financial criteria in lending, if there is a market. This is not to say, however, that they should at all times be ruled out as financial intermediaries.

A third option would be to *provide grant financing.* Here it is necessary to consider cost, commitment, and sustainability. Would it in fact be cheaper to provide grant financing, rather than incurring the high costs of developing group organization? All costs of group organization cannot be attributed to credit development, because group organization has many other benefits in providing information, participatory development, and decisionmaking. It is also necessary to consider the
commitment of the local population to the rehabilitation project, during the course of implementation and, in particular, after its completion. Group credit has shown itself to be an effective means of ensuring the local support and commitment needed for environmental rehabilitation. A personal financial stake in environmental rehabilitation remains a simple but powerful means of building and sustaining commitment. The sense of ownership of the project needed to ensure sustainability is obviously stronger when it is based on economic facts rather than on skillful communication and persuasion. Debt obligation and the expectation of future profit reinforce each other in creating a long-term personal commitment. Credit is a form of participation as much as it is a form of financing.

A fourth option would be to let existing agricultural credit mechanisms also address environmental credit, in whatever combination of formal financial institutions, government sponsored credit programs, and moneylenders. Here there are two major issues: demand and bridging mechanisms between the financial institution and the poor. Existing mechanisms have not been sufficient to address environmental rehabilitation. (In some cases agricultural credit has contributed to environmental deterioration.) The issue, then, is in what way existing mechanisms of extending agricultural credit need to be modified to accommodate credit for environmental rehabilitation. This paper has summarized a number of such accommodations. Bridging mechanisms to reach poor and marginal farmers and at the same time give promise for environmental credit have to be tried.

Research Issues

The initial experience holds considerable promise for expanding efforts in the combination of environmental rehabilitation and credit for the poor. A number of initial lessons can already be drawn; further work is needed to broaden the empirical, in particular the numerical basis for these conclusions. In addition, research is needed in a number of areas that are relatively unexplored. These include sustainability, alternative costing, and drawing lessons from small-scale environmental rehabilitation for other types of agricultural credit.

Sustainability has two dimensions: social sustainability and environmental sustainability, which are closely interrelated. Social sustainability of group activities and group guarantees have been strong elements in the provision of credit for marginal groups; an evaluation of the long-term sustainability and benefits of such credit schemes is still needed. Social sustainability is a necessary but not a sufficient condition for environmental sustainability, which also needs to be assessed in the longer term.

Costs and benefits of environmental credit projects traditionally quantify only individual or household benefits, but do not include wider social and environmental benefits. Estimating and quantifying the environmental benefits of these schemes also need further attention in the future. In this vein, the cost of establishing credit schemes with social collateral will need to be assessed against the longer-term, wider social and environmental benefits. Alternative scenarios for reaching these on a sustainable basis need to be costed and compared to determine the viability of environmental credit as opposed to other forms of promoting environmental rehabilitation. Cost recovery of environmental rehabilitation projects is a vital issue in itself, independent of credit. The cost of environmental credit projects compared to other types of credit is of less interest here; we would expect them to cost more, given the externalities that must be included.

Last, distilling those lessons from environmental rehabilitation credit that could usefully be applied to standard agricultural credit should be explored. Can reform programs in the field of agricultural credit benefit from the experiences drawn from environmental credit schemes? Social
collateral and group lending to reduce transaction costs give promise of wider application than credit for the poor for environmental rehabilitation and other purposes.

Conclusion

Is environmental rehabilitation a case for supply-led credit? The answer to our initial question is neither "no" nor "yes." From the point of view of environmental rehabilitation, credit is one of several means of achieving environmental rehabilitation; it gives promise of being more cost-effective, of tapping new resources, and being more sustainable than other forms of environmental rehabilitation, in addition to alleviating poverty. At the same time, from the point of view of banking and credit, many of the problems experienced in agricultural credit also apply to environmental credit; in addition, it is more costly and less efficient than other forms of credit; there is a fine line, which is important to maintain between credit and grant funds. One way of looking at environmental credit may be to regard it as a means of participation, rather than as a means of finance.

References


Introduction

The most frequently cited work in modern science is a thin history of physics called *The Structure of Scientific Revolutions* by Thomas Kuhn (1970). Kuhn's book introduces the concept of the paradigm switch, in which an existing scientific belief system is overpowered by a new belief system, which then becomes the dominant paradigm of the field. The book is so frequently cited because it fits not only the field of physics, but also every other realm of scientific endeavor. Today, it fits the field of conservation. The old paradigm of conservation held that the best way to protect biological diversity was to mark off the territory, build a wall around it, and patrol it with a machete or machine gun. The idea was to keep the plants and animals out of the hands of the human beings. In the old conservation paradigm, people were frequently seen as the enemy.

There were two major problems with this paradigm of conservation. First, the preservation model was increasingly seen as unethical. Conservation workers resisted the idea of pushing people off lands they may have occupied for centuries. And they began to oppose the vision of declaring national parks while rural families suffered malnutrition around its borders.

The second problem was that it didn’t work. In areas of the globe with the most important biological diversity — the humid tropics — rural families ignored the signs around national parks, tore down the fences, and invaded the reserves.

In reaction, the social sciences began to blend with biology, and a new conservation paradigm emerged. In a nutshell, the message of the new conservation is this: human beings must be the focus of conservation efforts. Placing people as the focus is sound on ecological, ethical, and economic grounds.

The New Conservation

The new paradigm of conservation still defines its goal as the conservation of biological diversity, but it achieves this goal by working with human beings instead of against them. The new paradigm is morally correct in that it works with and for rural families. Equally important is the fact that it is practical. It works to achieve the conservation of biological diversity. The tool that allows us to achieve this is economic development with a focus on sustainability through time.

The new paradigm of conservation concentrates on these questions: how can we satisfy the needs of current human populations without threatening future generations? How can we do this without destroying biological diversity and the ecological processes that are the foundation for human life and other species? Some people call this package of questions the search for sustainable development; others call it conservation-based development. But by any name, it is the new paradigm of conservation.

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Today, conservation sees the enemies to be -- not people -- but greed and poverty. There seem to be individuals in every society who are willing to exchange the natural resources of their region and their fellow citizens for their own personal benefit. To counter this form of greed, we have legal systems, moral codes, and investigative reporters. The more intractable challenge is poverty. Today, we recognize that the lack of economic alternatives lies at the root of most environmental degradation. In trying to provide for their basic needs, families without economic alternatives will destroy the very natural resources their lives depend on.

Today, we know that protecting biodiversity is inextricably linked to improving the living conditions of the rural poor. Conservationists understand now that the long-term protection of a natural area depends less on what happens inside a national park than on what happens outside -- in the lives and communities of people living on the borders of national parks and forest reserves. Now, we concentrate more on the buffer zones around protected areas than on the inner core areas that safeguard a park's biodiversity. To achieve one goal is to effect the other. In the new conservation, people are the most important allies in keeping biological diversity alive.

This new focus seeks to ease rural poverty by helping families exist in economic and ecological balance with their environment. Today, conservation increasingly promotes agroforestry and reforestation efforts. By increasing food production on land that is already cleared, rural families lessen their need to clear additional forests. For example, in Conservation International's work in Costa Rica and Panama, we work with farmers in the buffer zone of La Amistad National Park, on both sides of the international border. World Wildlife Fund's activities in Belize focus on agricultural intensification in the buffer zone of the Columbia River Forest Reserve. In Honduras and Guatemala, CARE is reforesting buffer zone regions around other national parks and wildlife reserves, and The Nature Conservancy works with human communities on the land surrounding Guatemala's Sierra de las Minas Biosphere Reserve.

The Biosphere Reserve Model

One of the clearest models of the new vision of conservation is the biosphere reserve. Biosphere reserves emerged from the United Nations Educational, Scientific, and Cultural Organization (UNESCO). They combine wildlands conservation and work with nearby human communities by merging biological conservation and economic development.

Another promising element of the new conservation is the extractive reserve, a land-use system that provides employment to local families and creates economic incentives for conservation through the harvest of natural products. The Brazilian rubber tappers and Brazil nut gatherers are the best known inhabitants of extractive reserves.

In Guatemala, an extractive reserve and a biosphere reserve have been combined to form the Maya Biosphere Reserve of the northern Petén. The Maya Biosphere Reserve covers 1.6 million hectares of lowland tropical forest, natural savannahs, and wetlands, including the largest freshwater wetland in Central America. The reserve was declared in 1990 and includes four national parks, three wildlife reserves called biotopos, and a large multiple-use area designated as an extractive reserve. The Petén extractive reserve focuses on three renewable forest products: chicle gum, allspice, and xate palms. Combined, the three employ 6,000 people and produce between 4 and 7 million dollars per year in export revenues for Guatemala, all without destroying the natural tropical forest cover.

More than 100 million stems of xate palm are exported from the Petén each year, destined for the United States, Switzerland, Germany, and the Netherlands for use in the floral industry. Florists
in the United States and Europe use the fronds of xate palm as a green backdrop for cut flowers. Usually, they spread the fronds out as a flat screen in flower arrangements, and then lay cut flowers in front of them. The resulting flower arrangements are used most frequently in funerals and weddings.

The appeal of xate as a forest resource and as a basis for the Petén extractive reserve is the fact that the palms can be harvested every three months without damage to the plant or to the forest. Xate harvesters, called xateros, search for the palms in the understory of the tropical forest and cut only one or two leaves from each plant. Using a pocket knife, they take only mature, green leaves. Experienced xateros are careful not to cut leaves that are spotted or torn and always to leave the tender, new leaves so that the palm stays alive.

Three months after harvesting the useable leaves from a xate palm, the xatero can return to the same palm and harvest another one or two leaves. In such a fashion, xateros can harvest leaves from the same palm and from the same area of forest throughout the year. The fact that the tropical forest is not degraded by xate harvesting means that the process can continue indefinitely.

Guatemala began to export xate during the 1950s. Even today, though, many Guatemalans -- including many xate harvesters -- don’t know what the plant is used for in the United States and Europe. Some xateros guess that the leaves are used to make contraceptive pills. Others say it goes into green dye to print dollar bills. And several xateros told me that the plant is exported to the United States so that hippies can smoke it.

On an excellent day, a good xatero makes as much as US$32. But, depending on the amount of xate growing in the area, he may also make only US$16 or US$12. That’s still far better than the US$2 to US$3 a day that laborers in the Petén make working on cattle ranches or harvesting corn.

After the xate is delivered to processing warehouses, workers grade it, sort it, and discard unusable leaves -- those that are discolored, poorly formed, or too small. Xate buyers in Guatemala City report that up to 40 percent of the xateros’ harvest is discarded at this stage, a clear indication that the harvesting process must be improved. The 60 percent of the leaves that survive the selection are wrapped and transported by refrigerated truck either to the Guatemala City airport or to the port of Santo Tomás del Castillo.

About 80 percent of Guatemala’s xate exports is exported by air to European countries. The rest is packed into refrigerated containers and loaded onto cargo ships for export to Miami and New Orleans. Combined, sales of these two species of xate reach almost $4 million per year.

Xate production also creates jobs in a country plagued by underemployment. At least 6,000 professional xateros live in the Guatemalan Petén today, and another 200 professional sorters work year round in processing warehouses in the Petén and in Guatemala City. As well, several thousand Petén farmers gather xate during a few months each year to earn additional income.

The key point in this discussion is that xate harvesting allows rural families to produce an export product and solid income from a renewable natural resource within the tropical forest. Xate production aids the protection of biological diversity, because xateros are economic allies in tropical forest conservation. Understanding that their families’ economic future grows in the understory of the tropical forest, xateros have become one of the forest’s most vocal defenders. Finally, xate is an important export product for Guatemala, bringing in more foreign exchange than the Petén tropical forest would produce if cleared for farmland and cattle pasture.

On top of this, xate is only one of three major products the Petén’s multiple-use reserve produces. A second important product is allspice, the dried unripe berries of the tropical forest tree known in Guatemala as pimienta gorda. Exported to the United States and Europe, allspice is used in fruitcakes, pies, sausages, meat broths, gravies, and pickling liquids. It is one of the chief flavoring agents in pumpkin pie, and pickled herring is pickled in allspice.
In Guatemala's Petén forest, allspice is gathered each year during June, July, and August by pollarding seed-bearing trees of their branches and drying the harvested seeds. Although the practice sounds destructive, allspice trees soon sprout new branches, and the tree can be harvested again after six years of regrowth. Enough trees exist within the Petén forest to support the export of approximately 1 million pounds of allspice per year.

Many Petén xate harvesters also work August to November collecting chicle gum, a latex harvested by cutting cross-sections in the outer bark of the chicle tree. Properly cut, chicle trees are not harmed by harvesting. Chicle is exported mostly to Europe and Japan for use in the chewing gum industry. Japan especially is currently undergoing a surge in the use of "natural chewing gum." Official statistics indicate that exploitation of chicle has reached as high as US$1.4 million per year, but official statistics on forest products from the Petén are notoriously underreported, due to attempts to prevent paying taxes on the extracted products.

The harvest of these three renewable resources -- xate, allspice, and chicle -- promotes the conservation and sustained use of the Petén tropical forest by producing a combined income of 4 to 7 million dollars per year.

By protecting the forest for renewable resources, the families are also protecting the region's major source of income -- tourism. The Classic Maya civilization left behind ruins that are today one of the most important tourism destinations in Latin America. The Petén receives 85,000 foreign visitors each year, who leave behind 30 million dollars. More than anything, it is the combination of ruins and rainforest that draws them there. Combined, these figures mean that the Maya Biosphere Reserve is worth more than 35 million dollars per year as forest, not including timber extraction, which can add another 7 million dollars per year, though currently with questionable sustainability.

**Challenge of Extractive Reserves**

As one of the most successful examples of the new form of conservation, extractive reserves simultaneously produce income for rural families and national governments and protect biodiversity. They are not, of course, without problems.

One challenge is that markets change. Through history, many extractive products have been replaced by plantations, which are sometimes cheaper and more reliable. This happened to chocolate, quinine, guarana, and rubber, and to some extent to allspice, which is grown on plantations in Jamaica.

It is less likely to happen to chicle and xate in the Guatemalan Petén for the simple reason that the Petén forest is what Dr. Charles Peters calls an oligarchic forest, a forest dominated by a few specific species. Chicle appears in the Petén tropical forest at the rate of twenty to thirty trees per hectare. Xate and allspice also appear in rates of very high density. Most people see this as a sign that the forest was actively manipulated by the ancient Maya. But the key point is that it makes no sense to convert this productive forest into plantations producing the same products that are already producing high yields in a natural state.

A bigger challenge is overexploitation of these resources. Xate and allspice production in the Guatemalan Petén is already threatened by inexperienced harvesters. They see that extraction can bring them big money, but they don't always have the cultural knowledge that allows them to harvest the resources without destroying them. New xateros sometimes cut all the leaves of a palm and kill the plant. Inexperienced allspice gatherers may cut down the tree to harvest the seeds in a one time rip and run operation.
Fortunately, several million dollars are currently being invested in monitoring and improving these industries, through funding from the U.S. Agency for International Development (USAID) and carried out by U.S. conservation nongovernmental organizations (NGOs) like Conservation International, The Nature Conservancy, and CARE, working with Guatemalan government agencies and NGOs. Another challenge to extractive reserves is guaranteeing families continued access to forest resources. How do we prevent the tropical forests that produce xate, chicle, and allspice from being destroyed for other uses? In Latin America, a forest that provides income to several thousand rural families can quickly become the weed-choked pasture of a cattleman with political connections and a government subsidy.

Loggers may move into productive extractive reserves and open new roads that lead to colonization of the area by landless families from other regions of the country. Having no experience in sustained-yield forest extraction, these families end up exchanging a solid economic future for three or four years of corn production.

At the core of both those challenges lies the constant question of who controls the land, and for whose benefit? There are several important lessons hidden in the answers to those questions. One of the most important is that secure land tenure or guaranteed access through strong government control is mandatory for extractive forest systems to be sustainable. Some countries are trying private landholdings dedicated to the extraction of natural forest products. In Guatemala, the government allows extraction within the multiple-use areas of the federally controlled biosphere reserve, while simultaneously trying to prevent colonization and illegal logging.

At the foundation of any of these systems is the continual need to demonstrate to central governments and local families that forest land is worth more as forest than cleared and burned for cornfields and cattle pastures.

But another lesson hidden in that statement is that economic logic is not enough to protect extractive reserves. Some sectors of society will oppose sustainable forest systems despite their economic superiority if these systems oppose their own personal interest. We’re faced here with the 10,000 year old choice between bringing small benefits to the many versus bringing big benefits to the corrupt few.

An extractive reserve may bring a few thousands dollars each, per year, to 6,000 families for their entire lives, or logged, cleared and burned into a cattle pasture, it may bring much larger wealth — in one quick flash — to a single, well-connected family. This is an eternal challenge that goes beyond the purview of extractive reserves or the World Bank.

**Beyond Extractive Reserves**

Finally, there is the realization that forest products and extractive reserves are not sufficient to prevent forest families from slipping into poverty. There are families in the Guatemalan Petén who live entirely — and live well — from nontimber forest products. But more numerous are the families who harvest forest products for steady cash income while they simultaneously plant crops for food.

Agriculture is a constant companion of extractive reserves. Our goal must be that while extraction takes place in the forest, agriculture takes place in the buffer zone around the forest. The ideal model is a national park for biodiversity protection, surrounded by an extractive reserve producing income, which in turn is surrounded by sustainable agricultural systems. Extraction provides cash for medicines, clothing, schools, and gasoline. Agriculture provides food, and the national park provides a biological guarantee for the future, as well as income from tourism.
There is plenty of need for work on the intensification of agriculture, but keep in mind that this is also part of the new conservation. If people are able to remain prosperous and productive on buffer zone lands they are less likely to move into forest reserves and national parks to clear more land for agricultural production.

Again, the best model for sustainable production, forest extraction, and biodiversity protection is the biosphere reserve. In the center lies the national park or wildlife reserve to protect biodiversity. Around the park lies the extraction zone to produce cash income. And around the extractive reserve is the agricultural zone for the production of food for subsistence and for sale.

The central message here is that all three areas and all three activities are the focus of the new concept of conservation. Only by balancing economic production with conservation can we achieve the goals of either enterprise.

Conservation projects are development projects. The answer to the question, Does conservation relegate the poor to poverty, is very simple: No. On the contrary, it is development without conservation that perpetuates poverty. It is destruction of natural resources without a vision toward the future that keeps the poor always with us.

The key to economic progress for the rural poor and to the maintenance of environmental health both lie in the conservation of natural resources. After lingering too long in the preservation paradigm of outmoded conservation, we now understand this point. Our goal as the new conservationists must now be to transform the world’s decisionmakers into participants in the same new paradigm.

Reference

CLOSING SESSION
World Bank Experience in Renewable Resource Management: Implications for Lending and Evaluation Work

Alfredo Sfeir-Younis

Introduction

The subject of Renewable Resource Management (RRM) has acquired a new status in development planning and implementation. For many developing countries: renewable resources provide a major foundation of economic development and daily livelihood -- particularly for the poor; renewable resources are becoming increasingly scarce and therefore needing effective management; materializing the potential benefits from further use entails complex decisions encompassing social, ethical, economic, and ecological considerations; and attaining sustainability in the development process -- a key objective of today's development agenda -- requires these resources to be treated in policy and strategy formulation as "capital goods" rather than simply "consumption goods."

This paper contends that RRM should be one of the most important components of any World Bank involvement in the development process, and the central theme of every development assistance program.

There are three underlying messages in this paper. First, the study of RRM -- in the context of sustainable development -- has to go beyond a single preoccupation for the optimal allocation and use of natural capital. Specifically, to attain sustainability requires taking into account a large number of interactions among all forms of capital participating in the development process (for example, human, natural, institutional, cultural, physical, and financial). In this respect this paper shows how recent evaluation work provides a new framework to address sustainability concerns, through merging RRM considerations with those of the development process in general.

Second, there is a hierarchy among those forms of capital. Hierarchy is defined here in a loose and narrow sense; that is, there are some forms of capital that seem to be more relevant in determining development performance. In this respect evaluation work since 1985 shows that human and institutional capital are the most important forms of capital to attain the objectives of RRM policies and strategies. These two forms of capital are intimately related given that institutions cannot exist outside the domain of those who form and participate in them. Evaluation work also notes that the ex-ante assessment of both, the quantity and quality of human and institutional capital, has been inadequate and that, as a result, development performance has suffered.

Third, the new framework is useful to evaluate development performance at both the country and project levels. At the country level evaluation work has shown that the interaction among these forms of capital can be analyzed and addressed within the context of public expenditures and investment review or country strategy formulation. At the project level evaluation work has shown that several aspects of sustainability and equity can be addressed more comprehensively (for example, importance of property rights, effectiveness in resource management practices).

This paper relies heavily on a number of project completion and audit reports, impact evaluation studies, special evaluation studies, and annual reviews of evaluation results (as listed in the references). While those reports contain many examples and case study material, this paper makes reference to only a few of them (for example, forestry).

* The author was a Principal Evaluation Officer in the Operations Evaluation Department (OED) of the World Bank and currently is with the Environment Department.
This paper is narrow in scope and its generalizations must be taken with caution. Several methodological and practical limitations should be noted. First, the emphasis on RRM is recent and many completed operations -- thus, evaluation reports -- have very limited information and analysis. Second, "cause-effect relationships" associated with Bank-financed interventions are difficult to isolate due to the multidimensional and multisectoral character of RRM issues (for example, macro policy and changes in use rates of renewable resources). Third, modern valuation methods -- that is, the assignment of monetary values to benefits and costs through, for example, contingent valuation, option values, travel cost estimates, and replacement cost -- to be used in project or policy formulation and appraisal seldom have been applied. Finally, lack of adequate information has constrained the evaluation process from carrying out an in-depth analysis of the consequences of development strategies and policies on the environment. This is due mainly to the unsatisfactory performance of monitoring and evaluation arrangements.

The main findings of two Operations Evaluation Department (OED) reports on the subject of sustainability and the implications for designing RRM policies and strategies are discussed in the next section of this paper. Later sections summarize findings in the area of environment and poverty alleviation; discuss the Bank experience with forestry management and implementation; summarize the experience in fisheries and livestock; outline the principal findings and lessons relating to the effects of macroeconomic policies on the allocation, use, and management of renewable resources. The paper concludes with suggesting some implications for Bank lending and listing a few elements of an evaluation agenda for the 1990s.

Sustainable Development

Sustainable development has become a central objective of RRM. The meaning of the term, however, continues to fuel a large number of discussions and the controversy may last for a time.

An OED study on sustainability, issued in 1985, defined sustainability of development operations as their ability to maintain an adequate level of net benefits (for example, economic, social, environmental) after the investment phase is completed. At the time that evaluation study was issued, there was a growing concern about the rapid depletion and disappearance of the development effort soon after project completion. Somehow, the fact that a donor agency would diminish its presence from an operation, the effort would often vanish.

Following the 1985 study, OED carried out another detailed study, which included the review of nearly 600 completed operations in all sectors of the economy. By studying what operational staff and evaluation officers have said about sustainability, the assessment revealed that sustainability depends on whether an operation or an investment or policy program is able to achieve an appropriate balance among the major forms of capital: human, natural, cultural, institutional, physical, and financial. For example, it was found that if a project expands the supply of financial and physical infrastructure (such as irrigation works, or school buildings), it will have little chance of being sustainable unless there is enough human and institutional capital (knowledgeable people, organized so that they can operate and manage it efficiently) to use the new facilities to advantage.

The study showed that in complementing the assessment of development performance, sustainability analysis has taken into account the characteristics of institutions and of social and cultural factors, which, experience shows, are very important determinants of sustainability in operations. Moreover, this kind of sustainability analysis has focused on the costs and benefits of a project over the long-term, and has addressed the effects on the project of other projects in the country's portfolio. Explicit consideration of these "portfolio effects" was one recommendation of the study.
Determinants of Sustainability

The review of experience in projects judged to be sustainable highlights the role played by the following six elements.

Institutional Development

Most of the sustainable operations put a major emphasis on developing the institutional capacity required to sustain benefit flows after their completion. Experience also shows the importance, for the sustainability of individual operations, of the general level of education and institutional development in a country at large. Prospects for sustainability are better, too, in projects where the Bank has been able to ensure that the goals and intended means of achieving them are compatible with the attitudes and cultural values of their intended beneficiaries.

Macroeconomic Policies

Good projects may fail if they have to operate in inhospitable policy environments. Most of the evaluation reports on sustainable projects mention that the macroeconomic policies of the borrowing countries were conducive to their profitability and efficient operation.

Management

Most sustainable operations have had adequate management structures, and good managers. Audits indicate that management is a critical factor influencing sustainability in most sectors of the economy, particularly in development finance institutions and industrial and energy projects.

Resource Mobilization for Recurrent Costs

The sustainability of most operations depends heavily on their access to enough financial resources to maintain the efficiency and productivity of the physical capital they create. At the time they were evaluated, all the sustainable operations had efficient mechanisms for covering their recurrent costs.

Commitment

A large number of audits have shown the importance of beneficiaries' participation to the sustainability of projects. Another, broader, dimension is a commitment by government to carry out the institutional and policy reforms needed to encourage sustainable growth. The importance of this latter commitment cannot be overemphasized, particularly as projects become increasingly sensitive to changes in the macroeconomic environment, both domestic and international.

Strategy

Most of the sustainable operations formed part of a clearly defined national development strategy. Without such a strategy, a country's portfolio of investments tends to respond to short-term imperatives, and as a result, projects are much less likely to be sustainable. Only with a clearly
defined long-term strategy is there a sufficient chance of securing the financial resources needed and of creating the skills and management expertise needed to sustain the operations.

Importance of Public Expenditure and Investment Reviews

Given the importance of these portfolio effects, public expenditure and investment reviews should play a central role in planning for sustainability. Assisting with these reviews provides the right milieu for the Bank to discuss with governments priorities regarding the allocation of scarce financial, human, and institutional resources across all sectors of the economy. Public investment reviews should consider sustainability issues systematically, assessing the distribution of benefits and costs over time, as well as the alternative forms of financing, for the whole portfolio of investments. Investment and expenditure reviews should continue to focus on the financing of recurrent costs and the establishment of an adequate approach to resource mobilization for that purpose.

Project Sustainability in the Context of Macroeconomic Adjustment

Though no study has been done to quantify the extent to which adjustment programs have directly affected the sustainability of individual projects, the evidence from project evaluation work shows clearly that macroeconomic variables (such as pricing, tariff policies, public finances, and the level of institutional development) are important determinants of project sustainability in most sectors.

In a recent review of development performance of adjustment operations (that is, Structural Adjustment Loans [SALs] and Sectoral Adjustment Loans [SECALs]) several conclusions were arrived at regarding macroeconomic policy effects on sustainability. The report states that: "adjustment operations, which are designed to have economic effects, may also affect the environment through the reallocation of resources that they engender. This effect may be positive or negative... increasingly, Bank- and IDA-supported adjustment programs are addressing environmental issues. Although none of the operations included in this review contains such component, more recent SALs and SECALs that are still under implementation pursue a variety of approaches to protect the environment... environmental objectives have also become prominent features in sector lending to new Bank members in Central and Eastern Europe..." (World Bank 1992 p. 209).

Two additional points should be stressed. First, Bank lending in support of adjustment programs strengthens macroeconomic incentives and should thus lead to a more efficient allocation of resources, and by improving the climate for savings and investment it should enhance the borrowing country’s capacity to mobilize financial resources. It also helps to strengthen the institutional framework for policy analysis and for investment planning and evaluation. All of this should help to make development efforts more sustainable. Second, however, adjustment programs contain measures (for example, measures to reduce public spending) that have often aggravated the funding problems of projects designed before the adjustment process got underway.

Under current circumstances, the public sector finance aspect of RRM requires more attention than it has received in the past. At the project level, fiscal implications and linkages are often not carefully analyzed. There is seldom explicit consideration of the links between the financial structure of projects and the country’s cost recovery and macroeconomic policies.
Managing Natural Resources, Strengthening Institutions

For the pursuit of sustainability at the country level, proper management of natural resources and institutional development are major necessary conditions.

Management of Natural Resources

Bank-financed operations have made significant contributions to sustainable development, by enabling countries to transform natural resources that are, in some cases, relatively abundant into economic goods. Bank-financed investments have helped to raise the carrying capacity of cities by improving land, water, and air, and by providing complementary physical and institutional capital. Other contributions to sustainable development—amounting to several billion dollars thus far—have come through irrigation projects and projects for the management of land, forest, and energy resources.

Where natural resources are mismanaged, growth and equity-related goals are often compromised over the long-term. The results of evaluation reports, however, also show that in the pursuit of sustainable development, forms of capital other than natural resources must also be taken into account. Thus, there is no point in adopting or financing an environmentally sound resource management strategy unless managers are available to manage it, adequate incentives are in place, and the development process is rooted in the society’s values and beliefs.

Institutional Development

The Bank’s experience, as evaluated by OED, has shown the great extent to which the sustainability of development efforts depends on the type and performance of institutions. It also has shown that while components aimed at strengthening institutions feature in a high proportion of Bank-financed operations, and the approaches used in them are very diverse, many of these components have not had lasting positive effects. Imperfect though the measures of such achievements are, the record calls for even greater attention to the institutional aspects of operations.

In view of the fact that the sustainability of development depends heavily on a country’s capacity to manage its economy, assistance for public sector management is a necessary condition for successful RRM. An OED study of freestanding technical assistance in support of public sector management in Africa (concentrating on twenty operations, in seven countries) shows that the technical expertise provided by these operations was often very successful in achieving specific, short-term goals. But in most cases the operations either failed or only partly succeeded in developing viable national institutions. Positive results were found only in the case of the introduction of specific systems and procedures (for example, for debt management, budgeting procedures, or statistical data bases). The projects rarely created lasting changes, and most of them failed to build up the basic self-reliance or institutional viability of the recipient entities involved.

For the Bank to encourage institutional development successfully through technical assistance, experience suggests the need for a high level of commitment and mutual interest on the part of the donor and the borrower; project design that capitalizes on existing opportunities and exploits the comparative advantage of different donors in a complementary fashion, within the context of an identified, country-specific, institutional development strategy; and a thorough basis in Bank sector work.
Attention to legal issues is also important in institutional development. An inadequate recognition of the role of law in institutional development may have contributed to the failure of some institutional development efforts in the past.

These findings suggest three preliminary recommendations. First, the Bank should continue to increase its ability to assist borrower countries in managing their natural resources, and to establish comprehensive national environmental or resource management strategies. The environmental dimension of Bank lending should be more central to the design of country strategies and to sector work.

Second, the Bank should continue its efforts to help countries incorporate environmental concerns into macroeconomic policy. Whenever appropriate, environmental concerns must become an integral consideration in the design of adjustment lending programs (public expenditure and investment issues will be essential components). In this regard, the Bank’s Environment Department should continue to play a leading role.

Third, the Bank’s research and policy programs should continue to receive increasing support to find ways of incorporating environmental and natural resource considerations into national accounting systems. Some policies that appear sound within the existing system of national accounting, because of their contribution to national income, may have a disastrous impact on the environment.

Equity: Environment and Poverty Alleviation

This section reviews the relationship between natural resources and poverty alleviation, examines some of the constraints associated with capital formation, and suggests how an adequate management of natural resources can become an effective way for the poor to escape from poverty. An important finding is that, in regions with significant levels of poverty, major social and distributional changes have taken place through the use and conservation of renewable resources. Another finding is that even though many low-income people live in poor or fragile environments (that is, areas where water, land, air, and other resources are either depleted or are of very low quality), the relationship between poverty and the environment is not always well understood by decisionmakers.

Approaches

Several approaches have been applied in development programs to deal with the tradeoffs between allocation (for example, economic efficiency, and output per unit of land), use of natural resources (such as environment), and poverty alleviation. Despite the diversity of situations encountered across projects and countries, several trends appear to be relatively common.

First, most of the effort appears to be "extensive" rather than "intensive"; that is, greater financing has been justified on the grounds of broader, spatial coverage rather than in response to specific environmental problems or demographic tendencies (for example, population pressures) prevailing in a given area. Often the driving force has been a productivity increase (output per hectare), with little regard to its sustainability (as in soil erosion control, and sediment management). Several agricultural development projects have attributed to the decline in land productivity and lack of commercial inputs (such as fertilizer), including credit; rather than focusing on the adoption of sustainable cultural practices, soil erosion control, and protection of land and water resources. In this situation, the poor are typically the first to suffer, because they are located in areas with the lowest quality or most fragile lands.
Second, in most completed operations there appears to have been little understanding of how fast (or slow) the pace of "environmental adjustment" should be, and what the sequence of components should be to maximize implementation effectiveness in areas inhabited by the poor. For example, the Bank has financed projects that attempt to benefit the poor through the expansion of infrastructure and services (for example, rural roads, markets, and health posts) without a careful assessment of the local institution's absorption capacity. Two outcomes have resulted from this approach: environmental degradation has increased as infrastructure facilitated access to natural resources; and the productivity of the physical and financial investments have been lowered, due, in most instances, to inadequate levels of human capital and low institutional performance. In addition, the Bank has frequently overestimated the institutional absorptive capacity of many countries, with the result that, soon after approval, projects began to face a series of constraints initially reflected in time and cost overruns, and later, in reduced economic and social returns. Good examples of Bank-financed operations in "frontier areas" are: rural development projects in Northeast Brazil, land settlement operations in Asia and Africa, and livestock development projects. Here, investment in infrastructure preceded development of institutions and human capital, both central determinants of project performance. Opening access through road construction into environmentally fragile areas has resulted in a marked demographic imbalance, and in a constant pressure by different groups to deplete the natural resource in question (for example, land and forest).

Third, several of the projects reviewed were located in agricultural frontier areas where little was known about the quality of the natural resource base, or the extent to which the practices advocated by the Bank were likely to be sustainable. Therefore, projects designed with the dual purpose of benefiting the poor and enhancing the environment have frequently been unsatisfactory. As indicated above insufficient knowledge about the natural resource base has also been a problem in many nonfrontier projects.

Fourth, successful operations demonstrate that the poor can effectively accumulate natural resources, even though they are less able to accumulate other forms of capital. Two examples are to be noted: social forestry and aquaculture. In both cases not only farmers with land have been able to benefit, but thousands of landless people as well. As a recent audit of two social forestry projects in India finds, trees have become a unique form of asset accumulation, and perhaps one of the only ways for the poor to have an "insurance policy" against future downturns in income. The same phenomenon has occurred in the case of aquaculture -- low-income and landless people have greatly benefited from using land and water that otherwise would not be employed for agricultural purposes. In areas of rice cultivation, several experiments have shown that farmers can undertake both agriculture and aquaculture.

Project Components and Instruments

A broad array of project components and instruments for poverty alleviation have been incorporated in Bank-financed projects. While in general, these have differed little from those used in nonpoverty operations, two important aspects should be noted: the very frequent use of land-related instruments (for example, land tenure, land demarcation, assignment of property rights, and land redistribution); and the nature and degree to which some of the environmental interventions have been targeted on the poor. The following types of instruments have been used by borrowing countries: subsidies for irrigation water (for example, low or nonexisting water charges, and cost recovery mechanisms), agricultural services (such as, free extension, research, and training), inputs (subsidized fertilizer, farm machinery, and land leveling services), heavily subsidized credit schemes, price supports, technology adoption (as in improved seeds and agricultural practices), and cattle exchange programs.
Existing evaluation material is not sufficiently comprehensive to permit assessment of the effectiveness of all of these instruments, although some important trends can be noted. To start several of these instruments have not benefited the poor in a significant way. Even in irrigation projects where governments have decided to provide water free of charge, the fact that all local farmers have access meant that richer farmers tended to benefit the most. A farmer’s ability to benefit from irrigation depends, among other things, on the farm unit's location within the irrigation system (that is, those nearer the water source will have greater access) and their wealth and ownership endowments and rights at the beginning of the project. These structural factors appear to be more important than the input subsidy in question. A similar pattern was found both with respect to the free provision of agricultural services and the application of price supports.

Even though most poverty and environment projects have used land-related measures, these have faced a number of limitations, insofar as helping the poor and enhancing the natural environment are concerned. The main reasons for this are lack of good quality land, the difficulty for both the countries and the Bank to succeed in altering land rights and tenure arrangements in the short-term (which requires strong government commitment). OED’s study on Nepal showed that acquiring property rights to land, while perhaps a necessary prerequisite, is not a sufficient condition for increasing land productivity or attaining sustainability. Despite these constraints, in many cases, land-related instruments may be the only way to benefit the rural poor and landless.

Whenever performance of natural resource management programs have been less than satisfactory, this is often related to the fact that the instruments frequently have been applied as discrete and independent actions. Area-based development projects, which show the lowest performance rating, have often failed because all instruments have been assumed to be of equal importance, and used at the same time. However, experience with more successful operations demonstrates that the sequencing of these measures is as important as their selection, because different types of interventions yield results at different points in time. Depending on the sequencing, outcomes can and will vary from what was initially intended. In practice, it is often the capacity of existing institutions, as an instrument of intervention, that determines the sequencing of instruments, rather than the merits of these measures per se.

Managing the Forests

The world is witnessing major changes in forestry development policy as well as in the development paradigm. The Bank policy statement issued in 1978, which led to such a shift in paradigm, recently has been updated by a new policy that places a major emphasis on “forestry management.” The concept of management encompasses practically all aspects of the development process: people, natural resources, institutions, and sector-related matters.

A key element in the paradigm shift is the explicit recognition that sustainability of forestry development goes far beyond the management of the natural resource proper. The role of beneficiaries, as the subject of economic development, has been recognized as central to any sustainable forestry development strategy. Community and nongovernmental organizations (NGOs) participation now are well recognized ingredients in managing forestry development. This recognition has had profound effects on the ways the Bank and borrowing countries conceive forestry projects, set up institutional arrangements for implementation effectiveness, and define the objectives of forestry development.

The Bank has lent more than US$2 billion for forestry, a figure that only includes lending for freestanding forestry projects. Several millions also have been invested in forestry components in
agricultural and rural development, energy, or other sector projects. In response to the 1978 policy paper, the Bank switched its emphasis away from financing industrial forestry projects almost exclusively to financing social or rural development and environmental forestry projects. The pre-1978 interest in financing industries had a lot to do with the perceived role of forests, the idea that forestry resources were relatively abundant and ready to be exploited, and was the approach to development at the time. This approach was not unique to forestry.

Several important facts, relevant to RRM, stand out from the assessment of Bank experience. First, the overall performance of completed projects is largely satisfactory, although the lending program faces a number of problems. This is not surprising, given that forestry projects take a rather long time to mature and that institutions in the sector are taking an even longer time to develop.

Second, the problems are mostly sectoral or national in nature, reflecting the strong intersectoral linkages that the forestry sector faces but that are often ignored. These problems are strongest in the area of macroeconomic incentives (for example, pricing policies, credit), and how they affect land-use patterns. Many of the sectoral issues are institutional, financial, and organizational, all central to RRM strategies. The solutions to those issues tend, in many cases, to go beyond the boundaries of a single project or even the forestry sector.

Third, the move toward new style forestry projects has made the Bank’s lending program more complex. One of these is in the area of institutional arrangements, where traditional modes of development organization, which strongly favor traditional sectoral boundaries, has proven to no longer be convenient or efficient. Complexity also has increased as a result of the involvement of a very large number of beneficiaries and the addition of a much broader set of development objectives (for example, growth, equity, sustainability) in the sector. Despite these changes, the basic lending parameters have nonetheless remained the same.

Fourth, rural development or social forestry projects and environmental forestry projects have proven difficult to formulate and implement. Projects of this kind tend to accentuate intrinsic sociopolitical and institutional weaknesses and as such, they compromise sustainability in the long-term. Some projects, for example, have increased the pressure to change traditional systems of property rights. Experience demonstrates that it would take a long time to change those systems in a sustainable way.

An in-depth analysis of important project components (for example, forest management, watershed management, and rehabilitation) shows that some of them show unsatisfactory performance regardless of the type of forestry project in question. This is the case of forestry management and monitoring and evaluation. The unsatisfactory performance of the forestry management components is explained by the increasing complexities of the task, the lack of adequate definitions of the activities involved, the difficulties in assigning responsibilities in an institutional and organizational sense, and the inability of forestry management schemes to address important intersectoral linkages.

In addition RRM instruments of interventions are seldom well defined, and when they are defined, the capacity of the instruments to yield the expected results has been very limited by comparison to the scope of the development objectives involved. Unclear definition of means and ends (such as poverty alleviation and energy conservation in social forestry projects, where forestry has represented only one instrument), lack of commitment to implementation, and poor supervision have all contributed to unsatisfactory performance.

With regard to issues related to the environment and environmental aspects of forestry development, several findings should be noted. In industrial forestry projects environmental concerns are primarily related to the management of existing forest resources, implementation of management plans, demarcation of land, and assignment of rights and obligations to those using or leasing the resource. A related issue is forest clearing and its environmental effects. Evaluation reports have particularly noted the damage to forest ecosystems due to the use of heavy machinery, road construction, and the felling of green trees.
In rural development and social forestry projects a principal goal of RRM has been to address regional or national fuelwood crises by augmenting forest resources for subsistence purposes. The most important problem associated with those efforts is the loss of soil productivity, as deforestation increases the rate at which erosion occurs and decreases chances for long-term agricultural sustainability, due to the burning of agricultural residues and animal dung by households as a substitute for wood. Distributional questions associated with the fuelwood crisis have been central to RRM strategies as lower-income people in general, and women in particular, are the groups most adversely affected.

In environmental forestry projects the preoccupation has been mainly with erosion and sedimentation control, decreased soil depletion, enhanced water and pasture management, and improved agricultural practices. The effectiveness of these RRM interventions has tended to be low, mainly due to their multipurpose, multidimensional nature.

Current evaluation work has concluded that new forms of lending may be needed to address the environmental imperatives facing borrowing countries and to expand the supply of forest products and to manage properly the existing forest resources. Experience suggests that operations in the 1990s should be of a "program" type, rather than discrete project operations. But the success of sector loans will depend on the following: sector policy, comprehensive forest management components, a favorable economic package of policies, a major infusion of human capital development, and a clear recognition of the interplay between forest, people, and culture.

Renewable Resource Management in Livestock and Fisheries

One of the central RRM issues facing a large number of livestock projects is reducing overgrazing. To this end they have sought to improve grazing management on either pasture or rangeland. Two general approaches have been followed. The first sought to intensify management through the establishment of improved pasture and use of feeds or agricultural waste, in both cases as substitutes for overgrazed natural pasture. The second attempted to establish semi-intensive management and regulation of grazing or stocking numbers in a still somewhat extensive system. This also entailed efforts to substitute a sedentary system -- through the allocation of title, leaseholding, or user rights - for communal, migratory systems that were thought to contain no appropriate incentives for resource conservation. RRM instruments used included new or improved technological packages, credit, extension services, processing facilities, improved market outlets, additional infrastructure, establishment of ranches and user groups or pastoralist associations to manage grazing, upgrading of stock (cattle exchange program), beneficiaries training, and animal health services.

Several factors have limited the effectiveness of an RRM instrument. The most important has been the lack of reinforcement from the macroeconomic environment, lack of attention to pertinent socioeconomic factors (for example, user-rights conflicts), inability to quickly adopt new management and grazing practices, inadequate forms of organization for development implementation, and human resource deficiencies. Evaluation reports show that there are two other issues central to RRM in the livestock sector: privatization of grazing resources to avoid the "tragedy of the commons," and competition between livestock development and wildlife. Overall experience with privatization has been mixed and, when successful, it represented only a necessary condition for success. The tradeoffs between livestock development and wildlife result from growing competition for land, traditional migration patterns of wildlife relative to the location of development projects, and lack of strategic planning on a regional and national basis.
Central to an RRM strategy in fisheries development has been to prevent a decline in the catch per unit of effort. But, overall, very few completed projects have included resource management concerns. This is not surprising, however, because the Bank's Fishery Sector Policy Paper, which placed greater emphasis than previously on fisheries management, was not issued until December 1982.\textsuperscript{11} The apparent decline in the "catch per unit of effort" was due either to the expansion of fishing effort or equipment replacements, both important aims of Bank-financed fisheries projects at the time. Unfortunately, attainment of these goals has resulted in higher rates of resource depletion,\textsuperscript{12} as the number and type of vessels and equipment used were not in balance with the fish stock available. In some cases overfishing also resulted from poor design or the inability to predict the effectiveness (in terms of catch) of replacement technology.

Information is essential to the effectiveness of an RRM strategy. However, several fisheries operations were identified and designed without adequate information regarding fish stocks. In capture fisheries, resource surveys were often not carried out prior to decisions regarding technological improvements and likely sustainability. The data typically used to assess sustainability in these operations (that is, harvest levels for several previous years) have proven to be poor predictors of the ability of the resource base to sustain itself at a given level of physical investment. Management components of these projects, moreover, generally failed to compensate for these shortcomings. In the design of inland fisheries, lack of information (for example, inadequate analysis of hydrology, water quality, and soils) has also contributed to adverse environmental impacts. Evaluation reports in some aquaculture projects show that unsuitable soil structure caused continuous subsidence of pond slope embankments, while increasing water levels in adjoining lakes led to flooding of the project sites. In the same projects, lower than anticipated yields were traced to high salinity levels and predation by migratory birds. Cumulative water pollution also has been cited as a critical problem.

There has been neither a clear nor a systematic selection and appraisal of RRM intervention measures in these projects. Two such measures were biological assessments or surveys of the resource base, and laws or regulations to control unplanned expansion of fishing. In most cases these measures failed to yield the expected results. Experience demonstrates that some projects were instrumental in the enactment of laws or regulations aimed at conservation and resource management, but that enforcement was poor. Furthermore, in order to adequately regulate fishing efforts, laws were just one of the necessary conditions; other reforms were needed in order to attain project conservation goals. In those instances in which resource assessment activities, including analysis of pollution and its effects on fish stocks, were incorporated into Bank-financed projects, they generally took the form of studies or small research components that were clearly secondary to other project components. These efforts were typically not completed, or were finished too late to have an impact on project design and execution.

Resource Management and Macroeconomic Policy Formulation

An increasing number of evaluation reports recognize that development performance is closely linked with macro policies and management. Several reviews have pointed out that well-designed projects perform unsatisfactorily in unfavorable macro environments. Those linkages often are referred to as "externalities" or external factors influencing project performance and these now are believed to be more significant than anticipated. Since 1985, OED has paid particular attention to the impacts of macro policies on the allocation, use, and management of renewable natural resources in the rural sector. The Renewable Resource Management Study\textsuperscript{13} represented the first step, where the assessment of performance was based on various aspects of the Bank's activities -- completed
projects, country economic studies, and economic and sector work (ESW) -- providing new insights as to how policy interventions affect the ability of countries to effectively manage their renewable resources to achieve sustainable development. A key finding of OED’s evaluations is that those interventions are not neutral with regard to the access to and the use and management of natural resources. While the linkages between policies and natural resources are sometimes complex and some of their impacts difficult to trace, policy instruments (for example, public expenditure and investment allocations, pricing and trade policies, investment codes and assignment of rights, legislation, taxation, and effective protection), affect the allocation and management of natural resources in several ways -- for example, changes in land use, rent seeking behavior, and spatial distribution of economic activities.

Renewable Resource Management: Phase I

Phase I of the Renewable Resource Management Study involved twelve country desk studies and reviewed 335 PCRs and PPARs of operations approved over a period of twenty years (1960-80). This assessment reached several conclusions that have been confirmed by the second-phase country case studies in Nepal and Bolivia. One such finding was that "Bank’s thinking on natural resource management has not led to major changes in the design of a project since 1961. However, in ESW, as distinct from projects, the general approach has changed substantially in a number of countries." The Phase I country’s case studies revealed a wide divergence in the nature and handling of resource management issues that affect economic development. At one extreme was Malaysia where, in spite of population pressures, the use of resources has been relatively adequate and sustainable. At the other extreme were countries like Nepal and Niger, where social institutions and government policies -- or the lack thereof -- have led to population pressures and degradation of natural resources severe enough to threaten future development prospects.

In the late 1960s, sustainability and equity issues were not generally raised by the Bank, or other donors, when renewable resource use was discussed. The underlying rationale was that most countries had a vast stock of underexploited land, water, and forest resources that should be brought into production as quickly as possible to accelerate economic development. However, specific questions were raised as to whether the proposed use of the resources involved was sustainable. In some cases, alarm over the rate of resource degradation was raised. More recently, the extensive clearing of tropical forests in countries such as Brazil, Costa Rica, Indonesia, and the Philippines has generated vocal concerns. Yet, adaptation of lending practices has lagged.

According to the Renewable Resource Management Study, the impact of ESW on Bank operations, with respect to sustainable resource management, has been limited. There are several reasons for this. First, while the associated policy recommendations were commendable on paper, they were frequently not realistic in practice. For a variety of reasons, governments found it difficult to strengthen public administration, change the system of land tenure, or introduce water charges with the view to increasing efficiency or improving sustainability. Second, in most cases, ESW did not provide a comprehensive overview of developments in the country, which could have an impact on renewable resource use. The primary emphasis in ESW has been on projects that promoted growth and economic efficiency. ESW provided little guidance on how questions of location, intersectoral tradeoffs, and conflicts in resource use should be considered in a wider, long-term context, and how these questions should influence the selection and design of projects. Third, at times, the Bank appeared to have been largely unaware of major changes affecting resource management within specific project areas, or at the country level. Thus, ESW did not provide borrowers and Bank staff with a strategic intersectoral framework for policy formulation and the development of action plans.
Based on these findings, Phase I of the Renewable Resource Management Study recommended that Bank economic and sector work should:

- Examine the national and, in some cases, the international dimensions of resource issues, the intersectoral linkages, tradeoffs and conflicts, and their relationship to macro policies.
- Assess what governments, NGOs, and external aid agencies were doing to address the relevant issues.
- Identify and evaluate a set of policy options to build on what is already being done.
- Frankly discuss institutional constraints.
- Suggest how the information base necessary to improve policies for natural resource management on a broad scale could be strengthened.

Management of Natural Resources in Nepal

OED reviewed the extent of Bank contributions and the means it selected to assist Nepal in the management, allocation, and use of its renewable resources. The approach to natural resource management in Nepal illustrates the importance of understanding the links between macroeconomic policies and natural resource management. The study concluded that the linkages between development and the management of natural resources are sufficiently strong to suggest that environmental concerns must be incorporated into decisionmaking at all levels. Also the study demonstrates that six important forms of capital participate in the development process -- human, natural, institutional, cultural, physical, and financial; and concludes that sustainable development means attaining a balance across the various forms of capital, over space and time. In Nepal several factors prevent that balance from being achieved, but primarily it is because most forms of capital are limited. Expansion of infrastructure related projects -- through the financing of physical investments in roads, telecommunication, and irrigation -- was pursued more aggressively in the past than that of human capital and institutional development, or the conservation of renewable resources. However, as renewable resources are depleted, the possibility of devising viable strategies and options diminishes.

The Nepal study noted that it is neither advisable nor acceptable to take only a partial view of natural resource degradation, relegating concerns to either the project or sector alone. At the national level, concepts like "sources of growth" or "comparative advantage" -- which often define the nature and extent of donors' interventions, and the instruments chosen for development -- must incorporate environmental concerns. Central to the proper design of donors' interventions is the assignment of proper economic values to such resources as land, water and forests; in most cases these natural resources are significantly undervalued. The study concluded that resource management problems are, and should be, a profound concern of macroeconomic and sectoral policies, and that the Bank can make a major contribution in this area.

The study stated three main operational recommendations that may be useful in improving RRM policies and strategies. First, to organize a Consultative Group Meeting for the agricultural sector which would seek the participation of all donors and relevant NGOs. The key questions that could be addressed are: what do we know about the natural resources problems; what are the most effective instruments to deal with the problems; what are the roles of different donors in conceptualizing, studying, implementing, and evaluating Nepal's resource management problems; and what kind of strategy should be developed, both for the short and long run? Second, to recognize that natural resource management is a key ingredient in Nepal's development, and that the design and implementation of instruments, such as adjustment operations and public expenditure reviews, should
take this resource management dimension into account. Due to the continuous undervaluation of natural resources, economic prices, and opportunity cost, which guide the development process in Nepal, decisionmakers must explicitly consider the external effects of policies over space and time. And finally, to enhance existing efforts to consolidate the new macroeconomic framework and adjustment policy strategies. At present, macroeconomic policies and sector policies often are conceived separately, increasing the risk of contradiction in fundamental ways. As a result, these policies have had little effect on the rate at which Nepal's natural resources have been degraded.

*Growth and Sustainability*

Although not always explicitly recognized in project appraisal and evaluation reports, in some instances, the tradeoffs between growth and sustainability often have been significant. In other words, in order to attain an acceptable level of environmental improvement, conflicts related to resource allocation resulting from market forces needed to be resolved (that is, externalities).

Experience shows that the development effort at the project and sector levels is not sustained if growth and capital accumulation do not take place. Experience with rural development,

experience shows that the development effort at the project and sector levels is not sustained if growth and capital accumulation do not take place. Experience with rural development, land settlement and colonization projects, and with social forestry clearly shows that beneficiaries are reluctant to actively participate and sustain the development effort where these projects do not enhance their ability to create and accumulate assets. This can be the result of an increase in the use rate of a natural resource itself (for example, forests and water) or the accumulation of other assets (as in physical infrastructure and money).

At the macro level the same principle applies. There renewable resource management activities demand a substantial amount of resources that need to be made available over long periods of time. In most borrowing countries, these development resources are not always available. The design and implementation of most natural resource management-oriented operations demand substantial financial resources to attain their goals for operation and maintenance, abatement, and conservation. The need for asset accumulation is also important from an efficiency point of view. In practice whenever target populations do not benefit, they frequently lose interest in participating in development projects, and there is a tendency to overexploit the natural resource base, thus hindering the attainment of resource management and conservation goals.

In most completed operations the sources of growth were associated largely or exclusively with physical (expansion of roads and highways) and financial assets (credit). Improving institutions, enhancing human development, and considering cultural values and attitudes were less prominent, although, achieving sustainable development depends heavily on basic buildup in these areas as well. Operations evaluated in the rural sector of Brazil, the Nepal case study, and the early findings of the Bolivia case study confirm that the most serious constraint to sustainable RRM in many countries is the continuing underinvestment in human capital (as in education, training, and participation) and in institutional development (for example, strengthening government organizations, improving operational effectiveness, and so on), a conclusion that calls for a realignment of national and sectoral priorities. In some cases, like Nepal, a sizeable proportion of Bank lending was allocated to operations (such as roads and telecommunications), which were perceived as having a very low demand for institutional response and human capital. However, as development progressed, these operations began to perform unsatisfactorily.
Implications for Bank Lending

Since the late 1980s, most Bank operational regions have designed strategies to deal with different aspects of natural resources management in borrowing countries. Economic and sector reports progressively incorporate environmental concerns, and the lending program reflects these trends. The following conclusions and recommendations should assist in the definition of future priorities.

- The ability of countries to achieve sustainable development goals will depend to a significant degree on how well natural resource management concerns are integrated into policy formulation at the sector and macro levels. This is particularly true for countries characterized by severe population pressures, a disproportionately large number of people under the poverty line, and fragile ecosystems (for example, of Sub-Saharan Africa). Several development instruments (including structural adjustment, public expenditure and investment reviews, national environmental action plans, sector work, and policy dialogue), could be more effectively utilized in this connection.

- Most completed operations have involved extensive resource utilization in the absence of a framework to carry out economic and social reforms that will directly benefit the poor in ecologically sensitive areas. If natural resource-based programs are to succeed, policy, institutional, and other reforms should be designed and implemented. Loan conditionality has proven to be no substitute for reform, policy implementation, government commitment, political support, or knowledge.

- The traditional framework for the provision of agriculture sector services (including all its subsectors) has to be improved if "green issues" are to be given due consideration. The recent emphasis on green issues has created, for example, a demand for a more sustainability oriented focus in the provision of agriculture extension, and research and training services. The Bank can make a substantial contribution in this regard.

- The Bank frequently has overestimated the level of readiness of borrower institutions to implement programs for poverty alleviation and/or environmental improvement in rural areas. This has led to insufficient attention to institutional and human aspects. To remedy this, the Bank should approach natural resource management in a way that clearly recognizes the need to strengthen local and national institutions to permit more active and effective participation by those potentially affected by Bank projects. Also the Bank should encourage the participation of NGOs and seek to help replicate experiences that have proven successful. This is especially important because Bank experience reveals that popular participation often has been an important means of avoiding (or correcting) adverse external effects.

- Some of the governments' instruments designed to benefit the rural poor have benefited richer families, and exacerbated rent-seeking behavior that has intensified the process of renewable resource depletion.

- Many decisions regarding the use and management of natural resources have been made without sufficient information. This situation needs to be corrected as soon as possible. In this regard the Bank should support the development of information gathering systems in borrowing countries and should increase its ability to network with other specialized regional and international development agencies.

Several evaluation reports have suggested changes in lending policies and instruments, although such changes have not been defined in a comprehensive way. One aspect of the suggested changes has to do with the policy content of Bank-financed operations. The attainment of RRM objectives and goals requires acting on several fronts. One area of particular interest and importance is that of "incentives" -- market and nonmarket incentives to enable economic and social forces to
make choices that incorporate the full social value of the renewable resources involved. In the absence of such incentive structure, the development process will most probably result in higher rates of resource depletion, some of which, may be irreversible. This process will have negative consequences for the present and future generations.

However, the changes and adjustments that are needed in the area of incentives and institutions (for example, role of the private and public sector, laws and regulations, and community participation) may be costly for some developing countries, particularly in the short-term. Thus, an adjustment instrument may be needed -- that is, environmental adjustment operation (EAO), to minimize the cost associated with the transition to a new set of incentives that would move the economy to a sustainable development path. These operations would include, in addition to the changes in prices and other incentives, provisions for organizational and institutional reforms in the public sector, a clearly targeted development of human capital, important elements of technical assistance and training, guidelines for reinvestment levels to replenish the stock depletion of natural capital (that is, a public expenditure and investment consideration), adjustment in fiscal and other macro policies, and a clear delineation of strategies and actions to manage or protect those natural resources that are considered public goods for the benefit of this and future generations. These operations also may be used to guide countries' natural resources and environmental policy formulation as well as to determine the best use and allocation of Global Environmental Facility (GEF) funds and other available resources (for example, debt-for-nature swaps). A clearer definition of adjustment related instruments would necessitate further research and studies. The proposition of environmental adjustment operations is not really new. There are several projects that have many elements of those stated above.

Several evaluation studies have shown that a successful RRM requires major investments in human capital. In many instances, success will depend on the extent to which beneficiaries adopt new technologies, transcend traditional modes of exploitation, and engage in sustainable production activities. The ability to materialize these changes depends on the availability and quality of human capital. The "human dimension" of most RRM strategies has not been given the full status that it deserves, and much more needs to be done. New education, training, and technical assistance programs should be identified and implemented. These programs need to be tailored into a well-defined sustainable development strategy and have to be integrated into the overall RRM strategy. Again, this proposition is not new; several technical assistance projects are being put together to address these concerns.

Elements of an Evaluation Agenda for the 1990s

Any new element in the evaluation agenda has to be integrated into the whole decisionmaking process that takes place during the project cycle. For example, there will be no more returns to the application of more advance valuation methods if these were not applied during the preparation and appraisal stages. In addition to effectively improve the analytical depth of evaluation studies it would require that a major effort is launched to improve the effectiveness of monitoring and evaluation units. Today there are very few, if any, comprehensive benchmark surveys to be used in RRM evaluations and there is no adequate information base to follow changes in the natural resource systems affected by Bank operations.

At this juncture several aspects of Bank operational activities should be evaluated: the first stage of GEF actions, the Tropical Forestry Action Plan (which, in part, has already been evaluated), the National Environmental Action Plans, and the role of Public Expenditure and Evaluation Reviews
in attaining RRM objectives. Their evaluation will shed light on the countries’ capacities to incorporate RRM concerns into sectoral and macroeconomic policy formulation and strategies.

Finally, the evaluation of SALs and SECALs should also be extended to see the extent to which macroeconomic policies and reforms have negatively affected natural resources. This task is going to take time, but the recent OED’s second SAL and SECAL review represents an important point of departure.

References


Endnotes

1. Substitution and complementarity are two examples of those interactions.

2. Because irrigation and water management is addressed in a separate plenary session this paper does not cover those subjects.

3. Most sections (but not all) have been taken directly from OED’s evaluation material. The sources are identified in the references.


6. The term "environmental adjustment" is used here to denote specific changes needed in the economic incentive structure (that is, market and nonmarket incentives), policies, and institutional reforms to achieve a desired environmental and poverty related improvement. In several completed operations, the adjustments tend to go beyond the initial period of project implementation.

7. This is particularly the case with regard to local and state development agencies. A comparative analysis of organizational arrangements between the POLONORDESTE and the Carajas projects in Brazil supports this contention.

8. "Frontier areas" are defined as those geographic modes where major changes in land use are taking place, for example, conversion of natural forest into agriculture.

9. It is important to note that although pricing of water is an important determinant of water allocation among project beneficiaries, there are several other factors (for example, physical and institutional) that need to be taken into account.

10. Land reform, land tenure, land titling, and land adjudication have seldom been implemented in the time frame specified at appraisal. The development performance of these land-related instruments depends critically on government commitment and political and social viability of the proposed reforms.
II. The Fishery Sector Policy Paper defined important management aspects of fisheries development, assessed the potential for future development, and outlined the elements of the Bank's lending strategy in this subsector. In addition it encouraged investments and institutional development in "artisanal fisheries" to ensure benefits to lower-income groups.

12. "Depletion" is defined here as an increase in the use rate, in physical terms, of the fishery resource. It is important to note that every time the fishing effort has been replaced (for example, new boats and gear), the effects were substantial, as technology and overall efficiency increased. See for example, Panama Fisheries Projects I and II. The decline in catch per unit of effort was explicitly discussed in The Philippines Fisheries Projects I and II.


14. This section is based on OED, Natural Resources Management in Nepal: 25 Years of Experience. February 1992. Nepal was chosen because the links between poverty, economic incentives, institutional weaknesses in government, and the destruction of land, water resources, and forests are more starkly visible than in countries in which environmental damage is not (or not yet) as severe.

Implications of the Earth Summit for Sustainable Agriculture and World Bank Activities

Mohamed El-Ashry*

The Conference

The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro this past June, recognized the danger to human survival and the impediment to economic development from the degradation and depletion of our valuable natural resources. It was an event unprecedented in scale, scope, and expectations. The consensus reached by the world community in Rio is that the economic, demographic, and political forces underlying existing and potential global environmental degradation cannot be redirected unless we bring environmental considerations into the mainstream of economic decisionmaking. UNCED has launched a process toward a new environment and development ethic and a global plan of action for sustainable development.

The Earth Summit was the most representative world conference ever convened as well as the largest gathering of world leaders ever held. One hundred and twenty heads of state and government were in attendance. Many delegates viewed the conference as a "triumph" of global cooperation, recognizing that the results reflect the give and take necessary to achieve consensus. Others found it "deeply disappointing" in the lack of specific commitments and timetables for policy change and enhanced financial assistance. Considering the realities of multilateral global diplomacy, the agreements reached at the Earth Summit represent a remarkable achievement, even if they fall short of what is needed to ensure sustainable development in the near future.

UNCED was primarily about integrating environment and development and about increasing cooperation between North and South on these issues. That meant reaching agreement on the reciprocal responsibilities of industrialized countries and developing countries in making societies and economies environmentally sustainable.

Agenda 21 was the main operational product of UNCED -- a comprehensive blueprint for sustainable development to guide national and international environment and development actions into the 21st century. The agenda covers over 100 program areas for integrating environment and development to be supported by new and additional financial resources, improved access to environmentally sound technology, and strengthened institutional capacity in developing countries. Early chapters cover the social and economic aspects of sustainable development, including strategies for poverty reduction, health, and population. The bulk of the document addresses specific environmental problems -- from soil, atmosphere, forests, and oceans to consumption, waste disposal, science, and technology.

The Bank and Agenda 21

The document obviously includes a tremendous amount of detail, but in many of the areas much remains to be done in improving our understanding of the relationships involved, for example, the world's climatic system and the influence of economic activity on it. However, I believe that the

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importance of Agenda 21 is not in its detail, but in the fact that this document and its endorsement is an explicit recognition by the nations of the world of the central importance of maintaining the earth's environmental systems and of the complex relationships -- physical, economic, social, and political -- which are involved in doing so. For reasons I will indicate below, I believe that the Bank will have a central role to play in the UNCED follow-up. This is because of the Bank's unique position and mandate that enable it to take, and follow through on, a holistic approach to the issues raised in Agenda 21, through its influence on policies as well as specific investment-based actions.

In this regard the World Development Report 1992 was an important and well received first step in providing an appropriate, operational framework for action. For example the Bank has long emphasized the importance of the overall policy framework in a country in influencing the development process within it. The same applies at a global scale. If the overall trade and economic policy environment is inappropriate it will prove unnecessarily difficult to promote the modification of agricultural and other practices in order to achieve sustainability.

The Bank and others have long pointed out the welfare losses caused, for example, by current agricultural policies that result in excessive production in industrial countries and reduce world prices for the commodities involved. Environmentally the costs are also large, in the form of the pollution resulting from heavy use of chemicals to increase production in the industrial countries, while in the developing countries, low export prices reduce the potential earnings from land and reduce the incentives to use resource conserving technologies. In this regard the current General Agreement on Tariffs and Trade (GATT) negotiations and outline agreement, although not perfect, provide an important first step in developing an appropriate framework for sustainable development. And the Bank's emphasis on the benefits of open trading arrangements will continue to be important if environmental as well as developmental goals are to be met.

An Integrated Approach

Much of the discussion in this symposium has been on different aspects of the challenge to agriculture in general, and the Bank's in particular, of the increased emphasis on sustainability. This also has been reflected in the recent Agricultural Sector Review Paper. Therefore, I will not try to cover the whole range of issues, but wish to particularly emphasize the need for an integrated approach to the management of our natural resources. Land and water degradation, declining agricultural productivity, unsustainable land uses, rural poverty, and hunger are interrelated. They can be addressed best by actions across the entire range of land resources -- the land itself; soils, water, and biota; the uses of land resources as inputs to the development process; and government policies as they affect land resources. In the past, problems like soil erosion, deforestation, or declining agricultural productivity have been treated as separate problems requiring separate sectoral responses by specialized institutions. As a result interaction among different, but interrelated sectors, has largely been ignored. As examples of what I have in mind, I would like to briefly discuss three issues, which illustrate some of the further changes in emphasis, that we must pursue. These relate to irrigation and drainage, the approach toward semiarid and other marginal lands, and research and extension.
Irrigation and Drainage

Already many parts of the world are facing water scarcity, serious environmental problems resulting from agricultural practices, and agricultural production systems that are clearly not sustainable. Waterlogging and salinity plague many irrigation projects and reduce crop yields. Intense competition is taking place for scarce water, particularly in arid and semiarid regions. Urban and industrial needs promise to take precedence over agricultural uses and new demands for augmentation of water flow to restore damaged aquatic systems will compete with existing diversions for irrigation. Major adjustments will have to take place in agricultural, environmental, and macroeconomic policy on both national and international levels to cope with these situations.

While the need for new agricultural irrigation and drainage projects will continue, the world can no longer, and I believe will not, ignore the type of environmental and economic damage that has been associated with these projects in the past. The future will see a shift toward environmentally and economically sustainable agriculture with environmental considerations being built into new irrigation and drainage projects as well as retrofitted into older schemes. Many of these older irrigation projects require rehabilitation because the lack of proper drainage and maintenance has contributed to waterlogging, salinization, and reduced yields. Implementing this shift will pose challenges, particularly to environmental and agricultural institutions.

The way ahead in terms of making this shift toward more sustainable systems is through a more comprehensive approach to water management. The Bank is making a significant step forward in its approach to this issue in its new Water Policy Paper, which is now in its final stages of preparation and reflects these concerns and needs.

At the highest levels of government, recognition should be given that water and water-dependent ecosystems must be managed as valuable natural resources to meet multiple uses rather than just inputs to a specific sectoral activity. At the operational level, greater emphasis will be needed in a number of areas: (a) expansion of drainage to rehabilitate salinized and waterlogged irrigation projects; (b) implementation of best management practices to improve water-use efficiency and to minimize pollution; and (c) transition, in some areas of highly intensive use, to low-input, more sustainable agricultural systems for economic and environmental efficiency. Use of proper economic instruments and elimination of environmentally damaging subsidies are also essential elements of this comprehensive approach. This will require close cooperation between irrigation and drainage experts, environmental specialists, and fiscal policymakers in order to meet the world's demand for food and other agricultural products in an environmentally sustainable fashion.

Semiarid Regions

One area of special attention at Rio was that of the semiarid regions and of "desertification," reflecting in part the concerns of African countries, but a problem which is by no means confined to that continent. Agriculturally the only thing common to all the semiarid lands of the world is sparse and variable rainfall; everything else varies so much that it is impractical to think of global solutions. There are general principles and guidelines, but no widely applicable system for sustaining soil quality in highly populated semiarid croplands. Plans to improve agricultural productivity and to halt, or slow down, the effects of soil degradation can hopefully be formulated by sorting out what is possible and what is practical, what the land capability will allow, and what options are feasible under prevailing social and economic conditions. Agricultural production can only be sustained on a long-term basis, however, if the integrity and productivity of the land and water resources on which it is based are not degraded.
It is becoming increasingly accepted that land degradation cannot be tackled purely by agricultural means. Most of these areas, besides being resource poor and agriculturally marginal, are economically and politically marginal also; certainly on a global scale and usually also at the national level. They are remote from the potential markets for their products and from the centers of political power. In addition to the need for better focused efforts in technological innovation, there is also an almost universal need for improvement to the physical and commercial infrastructure linking these regions to their potential markets. This is important in increasing both the reliability of market outlets and the level of prices, which are essential if market incentives at the local level are to provide some reason for efforts at resource conservation and improvement.

However, even with such improvements and the adoption of better technology, there is little prospect of these areas being able to support much more than their present population at above subsistence levels of living toward which we must aspire in our work. Thus, an increasing share of the population must be supported in nonagricultural activity. As a result the development of sustainable agriculture in these areas will occur only in the context of a process of development that stresses non-agricultural elements as well. This is the type of holistic, cross-sectoral approach, which the Bank is really in a position to assist our borrowing countries to articulate and develop. The Food and Agriculture Organization (FAO) and the other United Nations (UN) agencies only have mandates covering part of the need, and bilaterals, individually, usually feel somewhat constrained in becoming closely involved with such a wide sweep of development policy. It is here also that we come back to the importance of progress in improving the overall international trading system which will assist in increasing the potential for nonagricultural activity in these regions.

Agricultural Research

The Bank has long provided the Secretariat and substantial support for the Consultative Group on International Agricultural Research (CGIAR) system. This has been a principal vehicle for upgrading basic research on tropical food crops. The limitations of the system’s initial structure, having individual centers focus on specific crops over all climatic zones has long been recognized. As most of you know, the system is now in the process of increasing the focus of individual centers on issues of sustainable production systems in their regions. This is linked to an effort to upgrade their capacity to undertake work in the field as opposed to at the research station, and to strengthen the relationships with the national agricultural research systems in their regions.

However, given the cultural divide, which frequently separates the researcher from the farmer in the field, even best efforts by the international centers will only scratch the surface of the issue of adequately reflecting the researchable priorities as seen at the farm level back to the researcher. Now that in many of our borrowing countries, reasonably adequate extension structures are in place, it seems to me that the next step is to begin to place greater emphasis in their programs on developing and transmitting “messages” back from the farmer, rather than on those to be transmitted to him or her, as in the past. As the field level operatives have developed experience with farmers, the potential for doing this should be increasing anyway, and greater emphasis on in-service training in this area would seem to be a logical next step, including both work with individual farmers and other groups.

In this regard, nongovernmental organizations (NGOs) can also play an important role in testing new sustainable agricultural technologies. They are often better placed to identify community needs and to assist in strengthening institutions at the grass-roots level than public bureaucracies. We should encourage research centers and others to establish better linkages with NGOs, as part of their outreach.
In summary, I believe these examples illustrate three main points. First, we must be concerned about the impact of the changes induced by development on the environment. Environmental concerns will increasingly guide future actions in development and the Bank is uniquely placed to combine these concerns. We must constantly examine our development thinking so that it can respond to changing needs and conditions and we must assist borrowing countries in doing the same. Second, developing sustainable agricultural systems is not just something that can be achieved through agricultural projects, and thus just the domain of the agriculturists. It must be an element of a country's whole development strategy. In that regard, national environmental action plans (NEAPs) can be a useful, integrating tool. Third, much of what has been increasingly advanced in recent years, in agriculture and related activities, on both policy and technology development fronts, is in line with Agenda 21. What is now needed is proper implementation of these policies at the national and international levels, and of those sustainable technologies on the ground, if UNCED and Agenda 21 are to achieve even a proportion of their goals. We at the World Bank are in a good position to help make it happen.
The World Bank’s Water Policy: Executive Summary*

Background

One of the most important areas of World Bank lending over the past three decades has been water resources. Through its support for sector work and investments in irrigation, water supply, sanitation, flood control, and hydropower, the Bank has contributed to the development of many countries, and has helped to provide essential services to many cities. Yet, as pointed out in Operations Evaluations Department (OED) reports, the water investments supported by the Bank have often encountered implementation, operational, and social problems. Underlying these problems is a vicious cycle of poor quality and unreliable water services resulting in consumers’ unwillingness to pay, which in turn leads to inadequate operating funds and a further deterioration in services. Moreover, the Bank and governments have not taken sufficient account of environmental concerns in the management of water resources.

The difficulties encountered by Bank-supported projects reflect a larger set of problems faced in water resources management, highlighted in the 1992 World Development Report. Water is increasingly a scarce resource requiring careful economic and environmental management. The situation is made more critical by rapid population growth and urbanization in developing countries. The demand for water for human and industrial use has escalated, leading to competition for water used by irrigated agriculture. At the same time, the engineering and environmental costs of new water supplies are much higher than for sources already tapped. New challenges call for a new approach. In the past, governments have often misallocated and wasted water, as well as permitted damage to the environment owing to institutional weaknesses, market failures, distorted policies, and misguided investments. Three problems in particular need to be addressed:

- Fragmented public investment programming and sector management, that have failed to take account of the interdependencies among agencies, jurisdictions, and sectors.
- Excessive reliance on over-extended government agencies that have neglected the need for economic pricing, financial accountability, and user participation and have not provided services effectively to the poor.
- Public investments and regulations that have neglected water quality, health, and environmental concerns.

To achieve more effective management of water resources, a balanced set of policies and institutional reforms should be sought that will both harness the efficiency of market forces and strengthen the capacities of governments to carry out their essential roles.

Framework for Water Resources Management

The proposed new approach to the management of water resources builds on the lessons of experience. At its core is the adoption of a comprehensive policy framework and the treatment of

* This is a summary of the World Bank’s Water Resources Management Policy written by a team that included K. William Easter, Gershon Feder, Guy Le Moigne and A.M. Duda.
water as an economic good, combined with decentralized management and delivery structures, greater reliance on pricing, and fuller participation by stakeholders. The proposed approach is consistent with the Dublin Statement (1992) from the International Conference on Water and the Environment, as well as with Agenda 21 from the 1992 United Nations Conference on Environment and Development.

Comprehensive Framework

The adoption of a comprehensive framework for the analysis of policies and options would help guide water resources management decisions in countries where significant water resource management problems exist, or are emerging, concerning water scarcity, service efficiency, water allocation, or environmental damage. The complexity of the analysis would vary according to the country’s capacity and circumstances, but often, relatively simple frameworks can clarify priority issues. The framework would facilitate the consideration of relationships between the ecosystem and socioeconomic activities in river basins. The analysis should take account of social, environmental, and economic objectives; evaluate the status of water resources within each basin; and assess the level and composition of projected demand. Special attention should be given to the views of all the various stakeholders. The results of the analyses at a river basin level would become part of the national strategy for water resources management. The analytical framework would provide the underpinnings for public policy formulation regarding regulations, incentives, public investment plans, and environmental protection -- and the interlinkages among them. It would establish the parameters, ground rules, and price signals for decentralized implementation by government agencies and the private sector. Decentralization of the delivery of water services and adoption of pricing that induces efficient water use are key elements of sound water resources management. But for decentralized management to be effective, a supportive legal framework and adequate regulatory capacity will be required, as well as a system of water charges to endow water entities with operational and financial autonomy for efficient and sustainable service delivery.

Country Focus

The comprehensive analytical framework outlined above will need to be tailored to individual country situations and constraints. Many of the countries with limited renewable water resources are in the Middle East, North Africa, Central Asia, and Sub-Saharan Africa where populations are growing fastest. Elsewhere, water scarcity may be less of a problem at the national level, but is nevertheless severe in many watersheds such as in northern China, western and southern India, and western South America, and in large parts of Pakistan and Mexico. For some countries, such as those in Eastern Europe, pollution is the largest problem affecting water resources. In much of Africa, implementation capacity is a critical issue exacerbated by the frequency of prolonged droughts. In some countries water resource management is not yet a significant problem. These regional and country differences will shape the design of country strategies and programs.
Implications

Country differences notwithstanding, water resources management that follows the principles of comprehensive analysis, opportunity cost pricing, decentralization, participation, and environmental protection outlined in this paper will yield greater coherence in policies and investments across sectors, promote conservation, and improve the efficiency of water allocation. The objective is to achieve, over time, the following improvements:

* For Industry -- extensive water conservation and protection of groundwater sources. Industrialized country experience suggests that pollution control also leads to large reductions in the quantity of water used per unit of industrial output.

* For Water Supply and Sanitation -- more efficient and accessible to water service delivery and sewage collection, treatment, and disposal with the ultimate goal of achieving universal coverage. This will be achieved by extending existing supplies through water conservation and reuse, and using other sustainable methods. Greater involvement of the private sector, nongovernmental organizations (NGOs), and user groups will be required, as will cost recovery to ensure financial viability while applying graduated fees to assist the poor.

* For Irrigation and Hydropower -- modernized irrigation practices, greater attention to cost recovery, drainage and salinity control, measures to reduce pollution from agricultural inputs, improvements in operation and maintenance of existing systems, and investments in small-scale irrigation, and various water-harvesting methods. This calls for the development of institutions and technologies that respond to farmers' needs for higher-quality services, including greater participation of community groups and users associations, while reinforcing efficient demand management. Particular attention will be given to the needs of small farmers, who comprise the majority of the agricultural community. Greater priority should be given to energy demand management, small-scale and renewable energy alternatives, watershed conservation, and to retrofitting and enhancing dam facilities.

* For the Environment and Poverty Alleviation -- more rigorous attention to avoiding resettlement, enhancing biodiversity, and protecting ecosystems in the design and implementation of water projects. Water and energy supplies gained through conservation and efficiency improvements can be used in the place of developing new supplies to extend service to the poor and to maintain water-dependent ecosystems. Low-cost and environmentally benign methods for developing new water supplies for agriculture, rural drinking water, and industry will be pursued. The water supply needs for rivers, wetlands, and fisheries will be considered in reservoir operations and water allocation decisions.

Bank Policy

The Bank's overarching objective is to reduce poverty by supporting country efforts to promote equitable, efficient, and sustainable development. This entails support for the provision of potable water and sanitation facilities, flood control and water for productive activities in an economically viable, environmentally sustainable, and socially equitable manner. The new approach is designed to help countries achieve these objectives more effectively while sustaining the water environment, and the Bank will support member governments to that end. The Bank will give priority to countries where water is scarce or where there are serious water allocation, service efficiency, or environmental problems. In these countries, through its economic and sector work, lending, and participation in international initiatives the Bank will seek to promote: policy reforms, institutional adaptation and
capacity building, environmental protection and restoration, and, when requested, cooperation in the management of international watercourses. Because of the crucial interdependencies among water and other sectors, the Bank will incorporate water resources policy and management issues in its country policy dialogues and in the formulation of country assistance strategies where water issues are deemed to be of significance.

**Comprehensive Analytical Framework**

The Bank will encourage and, when requested, assist countries selectively to develop a systematic analytical framework for water resources management that is suitable for a country's needs, resources, and capacities. The framework would be designed so that public water management options can be evaluated and compared in the context of a national water strategy that incorporates the interdependencies in water and land use. It would enable coherent consistent policies and regulations across sectors. To facilitate the introduction of such a framework, the Bank is ready to support capacity building through training, demonstrating participatory techniques, and assisting in the conduct of water resource assessments. The Bank will also promote the creation, enhancement, and use of hydrologic, hydrogeologic, water quality, and environmental databases for both groundwater and surface water, as well as help governments to make effective use of this information in decisionmaking.

**Institutional and Regulatory Systems**

The reform of water resources management policies will have implications for the institutions dealing with water resources. The Bank will assist governments to establish a strong legal and regulatory framework for dealing with the pricing, monopoly organizations, environmental protection, and other aspects of water management. Similarly, the Bank will support the adaptation of institutional structures at the national and regional levels to coordinate the formulation and implementation of policies for improved water management and public investment programs. In many countries, institutional reform will focus on river basins as the appropriate units for analysis and coordinated management. Such coordinating arrangements are of particular importance in countries with federal structures, in which provincial or state governments have primary authority over the management of water resources in their jurisdictions. In such countries, before committing funds to support operations that have important interstate effects, the Bank will require legislation or other appropriate arrangements to establish effective coordination and agreed water allocation procedures. The Bank also will use water resources sector loans to achieve coordination of water resources activities across sectors.

**Incentives**

Many of the problems encountered in the provision of water services are due to the lack of incentives both for performance by providers, and for efficiency by users. A key component of the reforms to be supported by the Bank is thus greater reliance on incentives for efficiency and financial discipline. The Bank will highlight the importance of pricing and financial accountability by using estimated opportunity costs as a guide in setting water charges. In practice, immediate adoption of opportunity
cost pricing may be politically difficult. Thus, given the low level of current cost recovery and the importance for the sustainability of operations, pricing to ensure financial autonomy will be a good starting point.

Water Conserving Technology

An important element in any strategy to conserve water is incentives for adopting technologies and management approaches that increase the efficiency of water use, allocation, and distribution. Such technologies and management approaches will make it easier to conserve water, to increase the efficiency of water use and conveyance, and to reuse wastewater. As water scarcity and waste disposal problems become more acute, adopting and improving water conservation practices, wastewater reuse systems, and overall pollution-reduction approaches will become increasingly important.

Poverty Alleviation

Inadequate water services have a particularly adverse impact on the poor, facilitating the spread of disease, especially in crowded low income areas. Thus, special efforts will be directed to meeting the water needs of the poor. Moreover, better hygiene and the health benefits from clean water should be emphasized so that the advantages of improved water supply can be fully realized. Where public finance is scarce, it is often possible to mobilize significant additional resources from within local communities. Attention should be paid to ascertaining from the poor the level of services they want. Research and experience suggest that, when provided with reliable service, the poor are willing to pay for it. Indeed, in the face of unreliable service, the poor may pay more for less — typically from street vendors. By providing water entities with a financial stake in serving the poor, the provision of services to them is likely both to improve and to be sustainable. "Social fees," whereby the better-off cross-subsidize the poor, as well as budgetary transfers to subsidize connections, can be used. However, caution is required. The assignment of noncommercial objectives to a public enterprise may undermine the achievement of its service objectives, possibly initiating a new round of the vicious cycle of unsatisfactory service and low collections. Policies, which affect or change water rights should be carefully evaluated to ensure that they do not harm the poor, as water rights are often crucial for income generation. Where necessary, adjustments should be accompanied by compensatory measures.

Decentralization

Because of their limited financial and administrative resources, governments need to be selective in the responsibilities they assume regarding water resources. The principle is that nothing should be done at a higher level of government that can be done satisfactorily at a lower level. Thus, where the local or private capabilities exist, and where an appropriate regulatory system can be established, the Bank will support central government efforts to decentralize responsibilities to local governments and to transfer service delivery functions to the private sector, to financially autonomous public corporations, and to community organizations such as water user associations. The privatization of public water service agencies or their transformation into financially autonomous entities and the use
of management contracts for service delivery will be encouraged. Arrangements for performance accountability and for putting in place an appropriate regulatory framework to set and enforce environmental protection standards and to prevent inefficient monopoly pricing will be incorporated into Bank-supported activities. These steps should improve incentives for cost recovery, service provision, and give the users a sense of ownership and participation. In countries where provincial or municipal capabilities are inadequate to manage a complex water resources system, the Bank will support training and capacity building to improve local management capacities so that decentralization can eventually be implemented.

**Participation**

Participation is a process by which stakeholders influence policy formulation, design alternatives, investment choices, and management decisions affecting their communities. With increased participation in water resources management, project selection, service delivery, and cost recovery will likely improve. Therefore, the Bank will encourage the participation of beneficiaries and affected parties in the planning, design, implementation, and management of the projects it supports. In the context of Environmental Assessments, the Bank requires consultation with affected people and local NGOs, and will also promote the participation of concerned people -- including the poor, indigenous people, women, and disadvantaged groups -- in the water-related operations it supports. The Bank will encourage governments to follow these principles more broadly in their investment programs and other activities related to water resources.

**Environmental Protection**

Preservation of the environment and the resource base are essential for sustainable development. The protection, enhancement, and restoration of water quality and the abatement of water pollution will therefore be a focus of Bank-supported operations, particularly given the importance of providing safe drinking water, which is so critical to improve human health. Accordingly, the Bank will increase its support of government efforts to improve and expand sanitation and wastewater collection and treatment. Similarly, the Bank will promote the use of efficiency pricing and the polluter pays principle in the imposition of pollution charges to encourage water conservation and reduce pollution. In the case of industrial waste, mining runoff, and wastewater discharges a balanced strategy involving economic incentives, effective legislation, and regulatory systems, and guidelines for levels of pollution control will be relied upon to reduce effluents at the source -- especially toxic substances -- and to stimulate reuse. On pollution originating from agricultural activities, the Bank will support activities to restore and protect surface and subsurface waters degraded by agricultural pollutants, and to minimize soil erosion. The Bank will assist governments in developing strategies and cost-effective mechanisms for the ecologically sustainable management, protection, and restoration of recharge areas and water-dependent ecosystems, such as wetlands, riverain floodplain areas, estuaries, and coastal zones. Investments that involve resettlement should be avoided or minimized and where resettlement is necessary former incomes and living standards should be restored or improved. Given the increasing importance of groundwater, especially in arid and semiarid areas, the Bank will pay attention to the linkages between ground and surface water in the management of river basins and will support the establishment of governmental programs and policies, including land-use policies, to restore and protect groundwater quality and preserve groundwater recharge areas.
Skills Upgrading

In tandem with the promotion of a comprehensive framework and with institutional and policy reforms, skills upgrading will be needed by country policy analysts, planners, managers, and technicians. Accordingly, where water resources management issues are significant, the Bank will support the training needed for dealing with cross-sectoral analysis, with legal, regulatory, and privatization issues, and with river basin management, flood and drought planning, environmental protection, project formulation and evaluation, demand forecasting, and participatory management. The Economic Development Institute of the World Bank will be an important element in this training effort, through a special initiative to support the implementation of the new policy.

Design of Country Programs

Countries differ in their water requirements and endowments, their poverty profiles, their institutional capacities, and the problems they face from environmental degradation. Thus, the specific design of relevant reforms, and the time frame for implementation, will need to be developed and evaluated on a case-by-case basis. Nonetheless, the introduction of the recommended reforms will typically entail difficult political choices, and commitments by governments will therefore be essential. Given the present status of water resources management and institutions in many countries, the implementation of the necessary changes will take time. Accordingly,

- In countries with significant water management problems, the Bank will assist governments through sector work, technical assistance, environmental action plans, and in collaboration with other international and national agencies, in identifying and formulating priority policy and institutional reforms and investments, and in determining their appropriate sequencing. These priorities -- and the degree of government commitment to them -- will be highlighted in the country assistance strategy, and will guide the sectoral lending program.

- The priority reforms and activities to be addressed in analytic work and referred to in the country assistance strategy will deal with issues such as the appropriate (a) incentive framework and pricing, (b) service delivery to the poor, (c) public investment priorities, (d) environmental restoration and protection, (e) water resources assessment and data requirements, (f) comprehensive analytical framework, and (g) legislation, institutional structures, and capacities. Assessing the degree of government commitment to implementing the requisite reforms will be an important part of the analysis.

- Progress in implementing the identified priorities will be monitored through normal Bank interactions with the country. If the absence of adequate progress on priority actions is judged to lead to serious resource misuse and to hamper the viability of water-related investments, Bank lending in this area will be limited to provision of potable water to the poor households and operations that are designed to conserve water and protect its quality without additionally drawing on a country's water resources. Such operations include sanitation, waste treatment, water reuse and recycling, abatement of water pollution, drainage, and distribution system rehabilitation. These investments will be assessed on their individual merits.

- Individual water lending operations should discuss the linkage to priorities for reform, investment, and Bank support, as well as the likely impact of the overall water-related program. The analysis of operations will include an assessment of the implications for other water-using subsectors within the relevant regional setting, most likely a river basin. Relevant
pricing issues, cost recovery, and financial autonomy and sustainability will receive particular attention. The rationale for institutional arrangements for implementation, particularly the division of responsibilities between government and nongovernmental or financially autonomous entities, will be provided. Bank existing directives already require the assessment of environmental impacts of projects, as well as river systemwide environmental assessments for significant water-related projects, and full consultation with affected people and local organizations.

International Watercourses

Existing guidelines describe Bank policy on the financing of projects on international waterways. But the Bank will play a more proactive role, together with other international organizations, in helping countries to improve the management of shared international watercourse systems, for example, by supporting the analysis of the development opportunities foregone because of international water disputes. Through technical, financial, and legal assistance, the Bank, if requested, will help governments to establish or strengthen institutions, such as river basin organizations, to address transnational water management activities. Furthermore, the Bank will support studies and consultations to review available organizational arrangements and help to develop alternative solutions. In initial contacts with riparians, the Bank will avoid setting preconditions, but will rather explore the most appropriate form of assistance. The Bank will be sensitive at all times to the interests of other riparian parties, as it is essential to treat all parties in an evenhanded manner. The focus will be on those international watercourses in which the Bank's assistance would be likely to have a substantial effect. In addition, the Bank will continue to finance the incremental cost of actions by riparian states to protect international water resources and river basins in the framework of the Global Environment Facility (GEF). The Bank will promote the acquisition of knowledge concerning internationally shared groundwater, to provide a basis for establishing guidelines governing the Bank's activities in this area.

Implementation

To implement the water resources management policy the Bank will undertake a range of activities, including preparation of guidelines and best practices papers, staff and country training programs, capacity building, and the development of coordination mechanisms for the water resources sector. More specifically, in collaboration with the United Nations Development Programme (UNDP), a guide on capacity building is being proposed for countries interested in formulating water sector strategies. Guides are also being prepared on establishing water resource information systems, on best practices in setting up coordinating mechanisms, on generalized economics models for river basin analysis, and on best management practices for Water Users Associations. Regional units are preparing regional water strategies, which incorporate the recommendations of this water policy within the specific circumstances of their areas. An analysis of available and required Bank staff in the area of water resource management has been conducted and training programs, workshops, and seminars are being prepared to upgrade staff skills. Pilot projects will be used to implement some of the newer aspects of the water policy such as decentralization and opportunity cost pricing. Finally, a review of the implementation of the new water policy will be undertaken in two years.
Challenge to Bank Agricultural Staff

Michel Petit*

To conclude this symposium, I would like to challenge the Bank's agricultural staff to reverse what I call the "benign neglect" of agriculture within our institution. If we accept what Mr. Serageldin told us yesterday, namely, that "the challenge of the future is in your hands," then it is up to us, the agricultural staff of the Bank, to convince Bank managers (a) that agriculture needs attention, (b) that the Bank can make a difference, and (c) that we know what needs to be done. To organize my thoughts in this direction, I would like to divide my presentation into two main parts. First, I will illustrate why it is that this challenge is difficult, in order to ensure that we all know what we are up against, and second, I intend to suggest five directions we might take in order to meet this challenge.

Why Is the Challenge Difficult?

First, I would like to argue that the challenge is difficult on two fronts, both because of the prospects for the sector in many developing countries, and because of prevalent attitudes within the Bank. These two points are, of course, interrelated but it is useful to distinguish among them and to treat them in succession.

The Outlook in Developing Countries

In general, there are two observations that generally hold true regarding agriculture in developing countries. The first is the prevalence of an urban bias affecting policymaking in those countries. This expression, invented by Michael Lipton almost twenty years ago, indicates that in the political economy of many developing countries, urban interests and concerns receive a disproportionate share of attention and a disproportionate weight in national policies. It is almost certain, therefore, that urban bias discriminates against rural areas.

A recent piece written by Alberto Valdes and Maurice Schiff, entitled The Plundering of Agriculture, offers a quantitative estimate of the consequences of this urban bias. Indeed, the figures are staggering. These authors selected eighteen countries, in such a way that they would present a range of situations, including countries that discriminate very little against agriculture, such as Portugal and the Republic of Korea. They estimated that the average aggregate impact of all policies (macroeconomic, trade, industrial policies, as well as agricultural policies) was a transfer of resources away from the sector amounting to 46 percent of agricultural gross domestic product (GDP). From this result, as well as others like it, we should not be surprised that in many of these countries, the existence of rural poverty is not really a major concern among policymakers.

On the international front, there is a growing complacency in food production that has developed, partly as a consequence of the success of the so-called "Green Revolution", and partly because of the existence of agricultural surpluses in many developed countries that heavily protect and subsidize their agriculture. Prices on international commodity markets have been depressed, and it is

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unlikely, barring a major catastrophe, that they will rebound in the next few years. As a result, there is a general disbelief in the possibility of a food crisis.

The reality, of course, is much less certain. Many of you are familiar with the recent work by Pierre Crosson and Jock Anderson on resources and global food prospects (World Bank Technical Paper Number 184) indicating that in the next thirty or forty years, sufficient increases in grain production in developing countries will be difficult to achieve because sources of growth relied on in the past (such as expansion of area and of irrigation technology, as well as the rapid increase in the use of chemical inputs) will no longer result in the same levels of growth as were possible in past decades. Thus, there are good reasons to work toward ensuring that the capacity to increase agricultural production will be maintained. Complicating this challenge is the fact that in many rural areas, environmental problems tend to be ignored.

The circumstances of former socialist countries deserve special attention at this point. We all believe that the devolution of state farms, agroprocessing plants, and input supply industries to the private sector is desirable. We also believe that market liberalization is desirable. But these trends are fraught with many difficulties. Issues of land ownership carry much symbolism and a high level of political content, factors that hamper the proper and efficient transfer of farms and related production units to the private sector. For agencies such as the World Bank, which offer support to those countries, the sequence of these reforms is not obvious. There are many legitimate concerns regarding the macroeconomic situation, particularly the need for stabilization. Often these concerns dominate and overwhelm the others. Even in the event more specific issues can be addressed, the need to reform the financial sector or public enterprises, the establishment of safety nets, the problem of environmental degradation, or even the rehabilitation of the energy sector tend to take precedence over agricultural issues.

**Prevalent Attitudes within the Bank**

Given this situation, it is not surprising that we, the agriculturists, face the challenge of merely capturing the attention of decisionmakers at the highest level in most of our borrowing countries. This problem is confounded by the prevalent attitudes that exist within the Bank itself. This is at the bottom of what I call the "benign neglect" of agriculture by Bank managers.

On the whole there is a general, but rather bland, consensus on the importance of agriculture in countries eligible for credits from the International Development Association (IDA). That is what I refer to by calling the neglect benign. It is nonetheless neglect because what is needed is a very proactive stand by senior World Bank officials to obviate the urban bias that discriminates against agriculture. The distortions that plague the agricultural sector must be emphasized, and we must promote the elimination of these distortions. Most senior Bank officials do not feel much in the way of urgency to redress this widespread bias against agriculture. Perhaps partly because the borrowing countries themselves fail to develop a strategy for the development of the agricultural sector, the Bank also lacks a clear strategy for Bank lending to the sector in most countries.

One may actually get the impression that the agricultural sector serves as a "filler" in Bank country-assistance programs. In too many cases when a project slot has become available, any project that happens to be ready is sent to the Board for approval. Hans Binswanger refers to this condition as "projectitis," a malady that is hard to diagnose with certainty, but would appear to be widespread especially where agricultural projects are concerned. The circumstances appear even worse when one considers that the actual track record, or project performance, of agricultural projects is not very good. At any rate, we have witnessed a decline in the relative importance of agriculture in the total
volume of lending by the Bank and, more seriously, a decline in the quality of projects reported at or following completion.

This reported decline in quality may be due, at least in part, to a greater awareness of the limitations of what we are able to do. We may be more critical and have more severe demands in our evaluation procedure today than in the past. We certainly have more ambitious objectives for our projects now than in the past. To put it in simple terms, we want dramatic development impact but, because our somewhat unrealistic objectives are not fulfilled, we decide that the project is not satisfactory. But whatever the interpretation of this decline, the fact that projects in the agricultural sector have one of the worst records of any sector in the Bank should be a cause of concern for us. This concern has indeed led to very serious questions being raised within the Bank, mainly by senior managers who recently have asked whether or not the decline in the volume of lending has been sufficiently reflected in the number of staff working in agriculture and whether or not we have the proper skill mix, both between the agricultural sector and the other sectors in the Bank, as well as within the sector. Given this situation, what can be done? What should we, Bank agriculturists, do? What should you, Bank operations agricultural staff, do?

**Directions to Face Up to the Challenge**

In order to meet the challenge confronting our sector in the Bank today, there are five areas that require our attention and our effort. The first direction we must take is toward **improving the content of investment projects**. I know very well the burden of the processes and procedures that are imposed by our institution. But as the recent report on effective implementation (the Wapenhans Task Force Report) has pointed out, the quality of a project at its inception is an important factor in determining the project’s performance. Actually, I believe that the Wapenhans report has not given sufficient attention to the content of the project as a determinant of quality, in spite of the many Operations Evaluation Department (OED) results and other reviews and studies, which tell us that the content of a project is critical in determining its success or failure.

When I refer to content, I mean the definition of a favorable policy environment, ensuring that the project relies on good institutions or attempts effective promotion of institutional development, and that the explicit or implicit technical package embodied in the project is sound. The technical package must enhance productivity while ensuring proper husbandry of the natural resources that are used. In other words, production growth has to be sustainable. All of these elements of a project must exist, for if they are missing, the chances of success in achieving the project objectives are poor. Thus, my recommendation to you is to pay more attention to the content of your projects in spite of the constraints that hinder you from doing so.

Let me illustrate this point with a specific example. As you know, the Bank supports the development and promotion of technical change in agriculture through many instruments. We provide grants to the international agricultural research centers belonging to the CGIAR, we lend money to borrowing governments to support their national agricultural research systems, we have lending operations supporting agricultural extension and other technology development and diffusion efforts, we influence the incentives faced by farmers through our policy dialogue, and we have an impact on the domain of feasible choices that farmers face through the investments that we support in infrastructure, marketing, processing, and so on. All of these activities have an impact on the process of technology generation and diffusion. I do not believe, however, that we are very effective at exploiting the potential synergies and complementarities among those various instruments. The
challenge for all of us is to find ways to develop those synergies, thereby improving the quality of our projects.

The second area of effort we must undertake is to be prepared to modify our projects in the course of implementation in order to improve their performance. This is equivalent to the recommendation for flexibility as put forward by the Wapenhans Task Force. Incidentally, this does not mean that we should shy away from difficult objectives that may have less chance of success, such as the empowerment of the poor or of women. On the contrary, it is more often the pursuit of the very complex objectives that lead to our having a genuine impact on development. And these issues must not be treated as add-ons. They should be incorporated in the very design of our projects. We must attempt to identify, and then find a way to monitor, our objectives, so that if we find somewhere during the implementation of the project that a strategy or method is not working well, the design of the project and the choice of procedure can be modified. This is asking a great deal, especially because the project should be "owned" by our client, the borrower, and we should confine our role to one of adviser, not manager.

Third, we must learn from both the successes and failures of the Bank, a notion that is fully consistent with my previous comments advocating flexibility. I wish to stress that this learning should be Bank-wide, across regions. This means that we must find new ways by which the operational and central departments will collaborate. AGR’s incentive to do so is that our work can be made more relevant to, and effective in influencing, Bank operations. The incentive for you to seek closer collaboration with us should be that you will increase your chances of doing a better job. In addition, I believe that collaboration can lead to wider recognition within the Bank and, as a result, to greater support from Bank managers.

Fourth, we need to develop a coherent and up-to-date sector strategy, as recommended in the sector review paper prepared for the Board. This sector strategy should be a key component of our policy dialogue with borrowing countries. The challenge for us is to reach beyond Bank managers and client officials in our own sector, and to convince both Bank managers and government officials at the highest levels that they need to give greater weight to agriculture in such diverse offices as the Ministries of Finance or the Ministries of Planning. For this purpose, we believe that public expenditure reviews, including detailed judgments regarding institutions and the technical packages that are promoted by public investment programs, are indispensable in this process.

This implies that the skill mix needed in our sector staff should be diverse, and capable of making difficult professional judgements in various disciplines. Linkages with macroeconomic policies are critical, particularly if we accept the findings of the Schiff and Valdes study, which illustrates all too well how discriminatory against agriculture are the many policies regarding macroeconomic, trade, and industrial issues in developing countries. Correcting these distortions will be possible only by diversifying the team character to include both technical and social science disciplines.

Finally, we must stress the importance of natural resource management in everything we do. This includes especially forests, water, soil, fisheries, and aquaculture, as well as livestock. For the past several years, we have been developing two major policy papers regarding both forests and water resources. These papers provide general but clear directions as to how the Bank should proceed with its lending operations in these subsectors. In the case of soils, fisheries, and livestock, however, the internal debate within the Bank has not progressed nearly as much. But it is clear that for all of these natural resources, each project intervention should be conceived as a component of a holistic and comprehensive intersectoral approach. Our approach must be directed toward the policy environment, in order to ensure that this environment is conducive to proper management of the resources.
In addition to addressing the policy environment, technological packages must be available and promoted in our projects. User participation must be encouraged through the empowerment of beneficiaries, and some programs may have to rely, in certain instances, on common property (as distinguished from free-access-property institutions, see the discussion by Pinstrup-Andersen in this volume). Therefore, even though there is wide scope for creativity, since each project must be adapted to the local situation, which itself varies tremendously within and across countries, the general features that I have outlined provide a clear direction for our activities.

Finally, let me conclude by asserting that we are likely to know without ambiguity whether or not we are succeeding in convincing Bank managers that our activities deserve their support. This will be reflected in the amount of resources, which these managers make available to us, both in terms of budget and lending opportunities. In addition, if the managers are convinced of the importance of agricultural issues, their conviction will be reflected in the policy dialogues that they conduct. It is my conviction that if we move in the five directions I have briefly presented above, we will go a long way toward reversing the benign neglect from which we have recently suffered.
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