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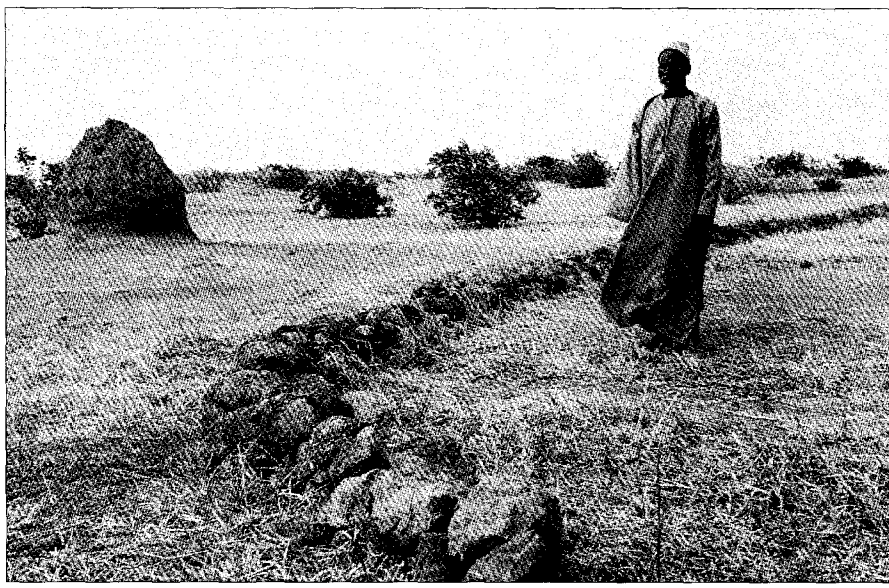
Sustainable Agriculture

Combining Human and Ecological Needs with Economic Development

Sustainable agriculture (SA) is an economically feasible approach that maintains the viability of soil, water, and air while promoting social equity and community well-being. Combining sustainable farming practices with incentives for economic growth is necessary for food security and poverty reduction in the developing world. This note discusses what these practices are along with ways to engage the local people in the process. Farm operators and local institutions must participate in any technology developments, or agricultural innovations will not be used.

High- And Low-Input Agriculture

Where the "green revolution" has been successful, it has been with high-external-input-agriculture (HEIA). Where agriculture has depended mainly on the use of local resources—and where agro-chemicals, improved varieties and modern equipment are either too expensive or not available—it can be characterized as low-external-input-agriculture (LEIA). LEIA is found in most regions with rainfed agriculture, but especially in so-called diverse, complex, risk-prone, and remote regions, and where farmers have been isolated or neglected. Both types of agriculture face serious ecological and economic problems. For HEIA, the problems relate to excessive and unbalanced use of agro-chemicals, salinization from irrigation, and loss of plant diversity, which can in the long run harm humans, animals, and the soil. Increasingly, HEIA areas are experiencing a decrease in the effectiveness of these external inputs because of biological factors and also because of a loss in profitability as input subsidies are being withdrawn. By contrast, in LEIA areas, the problems are related to loss of protective bio-mass and soil fertility. This makes farming even more vulnerable to climatic risks and decreases the productivity of the natural resource base. (Reijntjes and others 1992. This Note draws heavily on this source.)



Rodale Institute

Low-rainfall or marginal farming areas are often especially suitable to sustainable agriculture techniques.

Alternative Approach

SA is a new paradigm for agricultural production under both high- and low-input systems. This alternative approach is variously referred to by such names as biological, natural, organic, integrated, low-external-input-sustainable-agriculture, or simply sustainable agriculture. Biological, natural, or organic usually refers to practices that significantly reduce or eliminate the use of inorganic fertilizers and synthetic pesticides. The integrated, low-external-input, or sustainable approach seeks to optimize the use of organic and inorganic inputs. Hereafter, "sustainable agriculture" (SA) will be used to cover development approaches that focus on optimal use of local resources and, where necessary and feasible, use of modern external inputs.

SA practices are often perceived as being associated with reduced technology inputs. However, the opposite is the often the case. Sustainable agriculture can be a

An SA project in Benin dramatically increased maize yields.

In 1986, the International Institute of Tropical Agriculture (IITA) and Beninais scientists started on- farm research in Benin on methods to restore soil fertility and — at the same time — to encourage farmers to participate in the experimentation process, as a means to develop practical technologies. One such technology, the cultivation of a ground cover or live mulch, *Mucuna* pruriens var. utilis, enriches the soil with nitrogen.

Farmers accepted *Mucuna* after seeing how effective it was in combating two of their main farming problems: restoring soil fertility so that maize yields improved and halting the rampant speargrass by covering the ground and preventing the weed from receiving adequate sunlight. The farmers' contributions over four years of *Mucuna* research gave them a stake in the results, motivating them to encourage others to use it as a result of their experience.

The results for farmers who had chosen *Mucuna* were dramatic. They recorded, on average, a tenfold increase in maize yield (from 200 to 2,000 kilograms per hectare.)

Source: IITA Annual Report 1991, p. 36

knowledge-intensive production system and may use the most advanced equipment, plant varieties, and management approaches, just as in high-input systems. But while the goal of profitable and productive agriculture is paramount the achievement of SA, it requires a focus on safe and clean water supply in bays, streams, and wells, a desirable habitat for fish and wildlife, a viable rural economy, and a safe food supply. Agriculture can no longer limit itself to a few narrow goals and treat undesirable side effects as constraints (O'Connell 1992).

SA should be seen as a development approach and a participatory process rather than a hard set of techniques and criteria. Ideally, farmers and other development actors, extension workers, researchers, policymakers, bankers, and others need to work together on a equal and participatory basis.

Basic Goals

Scientific understanding of SA is still in its infancy. However, the insights and experience gained thus far through agro-ecological research and indigenous agriculture suggest some basic goals that can guide the process of SA. The ecological goals can be grouped as follows:

- Securing favorable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biological life
- Optimizing plant nutrient availability and nutrient flow through the soil profile
- Minimizing losses due to plant and animal pests and diseases by means of prevention and biologically safe treatment
- Exploiting complementary and synergy in the use of genetic resources, both in the genome of plants themselves and through the management of functional diversity in the farming system

Many promising SA techniques are being used effectively by low-input farmers. While some involve traditional practices, others have been improved by farmers or scientists. These techniques fall into roughly three categories.

SA Techniques

Soil and nutrient management—Techniques for managing the soil and its nutrients include:

- Manure handling. Improved collection, composting, storage and transport of dung and urine can reduce nutrient losses. The quality and quantity of manure depends on the animal species, the protein and energy content of feed and the choice of bedding material and housing for livestock.
- Composting. An important technique for recycling organic waste. Compost is a slow release organic fertilizer which stimulates soil life and improves soil structure. Other important techniques of organic waste management are biogas production and composting of night soil.
- Cover cropping. Cover crops can be managed in various ways to enhance soil fertility, i.e., replacing fallow vegetation with cover crops, alley cropping, integration of trees into cropland, relay fallowing by sowing bush legumes among the food crops, live mulching, shaded cover crops, and use of azolla and blue-green algae in flooded rice systems.
- Use of inorganic fertilizer. Applying inorganic fertilizers in balanced combination with organic fertilizers can greatly enhance soil productivity.

Managing flows of solar radiation, air, and water—Techniques or factors that can help in this area include:

- Mulching creates a shallow layer at the soil-air interface with properties that enhance the original soil surface layer through influences on temperature, light penetration, and moisture retention.
- Windbreaks improve the microclimate or decrease wind erosion. Windbreaks can be formed by living hedges, trees, or physical structures and are positioned around fields, gardens, or farm compounds.
- Water harvesting includes a wide variety of techniques to catch water and promote percolation rather than runoff. Water harvesting is of great importance in rainfed agriculture to conserve the available water and/or guide excess water safely from the field.
- Strip cropping, where the crop is sown in narrow, tilled rows along contours. The strips of land between the rows, which are left untilled in natural grasses, slow the flow of rainwater down the slope and promote percolation.
- Permeable contour-line barriers, in which ridges of stone, stalks, branches, trunks or other organic material, as well as the planting of hedges, grasses

or shrubs along contour lines at regular intervals can promote percolation and improved soil structure.
- Small ponds or dams are traditionally used in many parts of the world to store water for livestock and domestic purposes.

Pest and disease management—Aside from the techniques of intercropping (growing two or more crops at the same time in the same field) and the use of traps, other techniques include:
- Use of trap and decoy crops. Pests can be attracted by certain plants. When these are sown in the neighboring field, insects will gather on them and can be more easily controlled.
- Biological control. In biological control, pests are suppressed by predators, virus, or fungi that may be natural to the area or specifically introduced for pest/weed control.
- Use of pesticides. At times, the use of pesticides may still be required. They can sometimes be prepared from local plants or other materials (e.g., neem, urine, ashes, minerals). Where these plants or the knowledge of how to use them correctly are not available, the use of synthetic pesticides may be necessary.

Choosing, conserving, and improving genetic resources—Many species that are cultivated or collected are not known to formal science or have been underestimated in their potential.

Also, using in-situ conservation (collecting, evaluating, safeguarding, improving, multiplying, and distributing indigenous genetic resources in their place of origin) can improve local genetic resources in the long run.

Participatory Technology Development

Research is often seen as the monopoly of scientists. However, through farmer experimentation and farmer-to-farmer communication, most agricultural innovations continue to evolve. Participatory technology development (PTD) is an approach that combines the research capacities of farmers and other professions in a process of joint experimentation to improve the farmer's situation. PTD essentially is a process of purposeful and creative interaction between local communities and outside facilitators, in order to understand the main characteristics and dynamics of that particular agro-ecological system, to define priority problems, and to experiment locally with a variety of technological options. The options are based on ideas and experiences derived from both indigenous knowledge and formal science.

Experiences working with farms to promote PTD suggest the following steps:

Getting started—Taking a PTD approach requires studying existing information, building a relationship with farmers and networks of farmers, participatory diagnosis of problems, and a joint analysis of needs based on the farming situation..

Identifying options—This involves identifying indigenous technical knowledge as well as scientific knowledge. Topics for further development need to be screened and selected according to criteria for optimal use of local resources and sustainable systems of production.

Organizing the experiments—The design and planning of experiments should be based on farmers' criteria and measuring techniques, with suggestions from outsiders for improved methodologies. Experimental groups need to be developed, and farmer-experimenters need to be trained.

Implementation—Carrying out experiments by farmers is done together with monitoring and evaluation of results.

Sharing results—Results can be shared with local and scientific networks to scrutinize and interpret, and to encourage further testing to adapt results for particular circumstances.

Sustaining and consolidating PTD—This involves creating favorable conditions for participation of farmers' organizations and local institutions. Establishment of infrastructure and educational facilities is needed to strengthen local experimental capacities and local management of the process of innovation.

PTD gives a consistent framework for methods and techniques covering the whole process of technology development at the village level. PTD is labor-intensive in the initial stages, and PTD practitioners need to remain open to farmers' needs and their practical knowledge of agriculture.

Conclusions

SA is being promoted by NGOs in Africa, Asia, and Latin America. The CGIAR sys-

World Bank Projects in China, Mali, and India incorporate SA goals.

In the Bank's current China Loess Plateau project, the objective is to increase agricultural production and income in nine tributary watersheds of the Yellow River and reduce soil losses with various conservation practices. These practices include terracing on slopes between 5 and 25 degrees, expanding forest cover from 14 per cent to 28 percent of the land area, and the construction of sediment control dams.

The objective of the Mali Natural Resource Management project is to introduce a land use system which seeks to reverse natural resource degradation in 150 farm communities. The nature of resource-enhancing investments are being defined by local committees and include such practices as stone contours, water harvesting and improved forest and wildlife habitat management.

The India Watershed Plains project seeks to contribute to the reversal of ecological degradation in a variety of agro-ecological zones in the rainfed and dryland areas in the states of Gujarat, Orissa,and Rajasthan. The area covers 265,000 ha. The project will introduce replicable soil conservation practices such as planting of vetiver grass and reforestation.

Source: World Bank documents.

tem and the National Agricultural Research Systems (NARS) as well as the Food and Agriculture Organization of the United Nations (FAO), and others are paying increasing attention to the development of site-specific and ecologically sound agriculture. Improvements can be made with relatively low levels of external inputs. In many cases substantial problems have to be overcome before successes at the farm level can be achieved:

Restoration—In areas where over-cultivation has led to a degradation of vegetative cover and soil resources, as is the case in large parts of Africa, a transition period may be necessary during which considerable levels of external inputs may be needed to restore, regenerate, and enhance the local resources.

Incentives—Most production activities have an immediate market response when products are sold. Returns for improved soil and nutrient management are generally a few years in the future, however. To correct this gap, appropriate government incentives should be explored. When looking at net returns to farmers, "integrated pest management" techniques often look quite good, but the focus must shift from gross output to what the farmer has in his or her pocket at the end of the growing season.

Filling the technology gap—Since research for SA is recent, there is a gap in existing technologies. In many cases, SA technologies require more labor than under the traditional approach. Labor-reducing technologies may therefore be one of the first priorities. Longitudinal and quantitative studies on the effects of different approaches are urgently required.

Training and retraining:—Most researchers and extension staff in the world have been trained in agronomic concepts that assume the presence of external inputs, and suggest a top-down approach of transfer of technology. Training in the principles of sustainable agriculture and participatory technology development is a prerequisite for effective promotion of SA.

Participation of farmers and communities is a key part of developing or adopting techniques for sustainable agriculture.

Agricultural policy adjustment—In many cases the system of land ownership, policies, and research planning are not geared toward the needs of SA. Possibilities to enhance this approach to farming requires an update of current tenure, research and policy positions.

Institutional concentration and networking—NGOs, government agencies, extension agents, research scientists, and international research organizations each have to play their role. Their efforts need coordination and overall leadership.

For SA to succeed, an approach for agricultural development is required that builds on the available bio-physical and human resources. No blueprint is recommended here; the approach should be specific to the ecological, cultural, and institutional situation. The basic ecological principles outlined above can be followed and a methodology for participatory technology development is available. In many cases, the incentives for enhancing SA require a conducive policy and institutional coordination. Creativity and flexibility for field staff and researchers are important requirements for this approach in order to develop the site-specific solutions.

Recommended Additional Reading

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Reijntjes, Coen, Bertus Haverkort, and Ann Waters-Bayer. 1992. *Farming for the Future—An Introduction to Low-External-Input Agriculture*. New York: MacMillen.

Agriculture Technology Notes provide up-to-date information on selected agricultural topics to World Bank professionals. Further information about sustainable agriculture can be obtained from Paul O'Connell (x87238) or Willem Zijp (x32456). To obtain copies of this or other Notes, or to inquire about Agriculture Technology Notes, please call (202) 473-9406. Other Notes in this series are: "Reform of Seed Regulations," "Information Technology and Rural Development," "Simple Animal Health Techniques," "Competitive Research Grant Systems," "Provision of Mineral Supplements," "Integrated Pest Management," "Privatization of Animal Health Services," "World Fisheries," "National Seed Systems," "Participatory Rural Assessment," "Integrated Soil Management for the Tropics," and "Biotechnology." Layout and design by Peter Wiant.