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Intensified Systems of Farming in the Tropics and Subtropics

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Foreword

The human population will continue to grow for the next several decades, and most of this population growth will occur in the developing world. It is well established that the demand for food from the rural sector will increase, and world's poor, who are concentrated in rural areas, will seek to increase their production from ever more scarce land and water resources.

This paper has involved the collaboration of staff from several departments in the World Bank and many others throughout the world, and is part of a growing repertoire of cases where agricultural production systems are intensified without depleting the natural resource base. The cases contribute to our experience of policy environments, institutions, and practices which are integrated to meet the demand for food, to reduce poverty, and to utilize resources in an environmentally, socially, and financially sustainable way. They illustrate the importance of production systems which are capable of continually adaptating to changing social, economic, and environmental conditions. Additionally, each case demonstrates the importance of reliable infra structure to the transition of farms from subsistence−level to more intensive systems of farming.

This paper contributes to increasing the awareness of the possibilities and opportunities for sustainably intensifying agricultural production systems.

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Abstract

A review of eight intensified systems of land use on unirrigated farms in developing countries is used as a basis to propose three complementary sets of conditions necessary for farming systems to be sustainable in the long run. These three sets of conditions or "domains" are public sector policies and investments; private farmers, their families, and institutions; and scientific principles, natural resource endowments, and ecological systems.

The eight farming systems represent a wide range of geographic and resource features and contrasting sociological conditions in Africa; south, east, and west Asia; and Latin America. They include the reduction of the proportion of fallow land in Turkey, dairy development in Uruguay, associated cropping on small farms in Colombia and Nigeria, the opening up of the *Cerrados* region of Brazil; and the development of minimum tillage and direct drilling practices on large−scale soybean farms, soybean growing by small−scale farmers on black cotton soils in central India; and two examples of perennial crop development on estates and smallholdings in Kenya (tea) and Malaysia (oil palm).

In all cases the role and policies of governments have been of crucial importance, particularly in the following respects:

Creating transport infrastructure, such as railway and road systems;

Facilitating and promoting active markets for farm products and, for some seasonal crops, establishing floor prices;

Minimizing direct involvement in product marketing; and

Maintaining realistic foreign exchange rates.

Farmers have responded rapidly to market opportunities when they have been confident that they can sell all their product surplus to family requirements. Price predictability appears to have been more important than the level of farm gate prices. Falling prices have generally induced intensification of production. Social customs affect considerably the sequence and degree of change in farming practices. Centrally organized group farming among small−scale oil palm growers in Malaysia has been successful, but in the other cases, the intensification of farming systems has been the result of many separate decisions by individual farmers. Major improvements in resource use have occurred, but in the cases of India, Nigeria, and Turkey, communal decisions and action on landscape planning will be necessary to sustain the changes already made.

All the cases show the importance of scientific research, but with the exception of tea in Kenya and oil palms in Malaysia, research efforts have been sporadic, seldom well−balanced, and usually not documented in the international scientific press. Plant breeding and selection has often been successful, but poorly supported by studies of soil and water management and hydrology. Soil studies have generally been weak regarding soil organic matter and biological activity in the rooting zone of crops and pasture plants. All the cases illustrate the importance of leguminous species in the farming system, but in general these species have not been adequately studied. Much research has been weak on socioeconomic variables, and consequently the results and possibilities for improved use of natural resources have been poorly understood by policymakers.

Preface

The purpose of this inquiry is to see whether intensified systems of rainfed farming have some characteristics or features in common that are not harmful to the environment. This is not a review of World Bank operations, although the Bank had promoted or encouraged policy changes that had enabled several of the systems to be intensified.

I spent ten to twenty days in each of eleven countries where I had been advised of the existence of one or more rainfed farming systems that:

Had been notably intensified and widely adopted during the last ten to thirty years;

Appeared not to threaten the local environment, although they did, of course modify the natural ecology;

Were claimed to be generally viable financially and environmentally; however, it is not asserted that any system is sustainable unless it continues to evolve.

Further criteria for selection are summarized in the introductory chapter. In this first chapter I also outline my ideas, based on field observations, of necessary conditions for "sustainability." I extend the concept of sustainability to embrace three distinct domains: the natural sciences or "facts of life," the family's or firm's point of view and the public sector. There must be at least a moderate degree of consistency among these three domains for a system to have the possibility of being sustainable. One troubling consequence of this approach is that any apparently sustainable system may well become unsustainable if there is a change in one domain that is inconsistent with the developments in one or of both the other domains. Chapter 2 provides an overview of the findings from the eight cases and suggests lessons that may be broadly applicable.

Of the eight examples of intensified farming systems covered in this review, the one from Nigeria is only at an early stage of dissemination, but it is included as an interesting example of a promising set of adjustments to a traditional system of associated cropping on small−scale farms in the forest zone that has not yet been widely adopted. It illustrates some of the complexities involved in intensifying a traditional system of farming.

I was not persuaded that the changes in farming systems I was shown in Central Visayas, Philippines; the Loess Plateau, China; and the Eastern Lowlands, Bolivia, were sustainable as practiced at present. However, each of these cases is well worth revisiting as further changes are introduced and more convincing experience is evident.

A secondary, but also important, purpose of this paper is to draw attention to the great volume of information available in numerous papers, many of which have not been published in international professional journals, and consequently are not known outside the respective countries. Where these are cited in the bibliography, the issuing institution is included, and its mailing address is provided in the list of abbreviations.

Chapters 3 to 10 of this discussion paper provide an outline of each system, emphasizing the technical, institutional, and social variables. No evidence is offered on the financial or economic viability of each system, because the evidence of rapid adoption by farmers confirms that they have been financially attractive except in the Nigeria case (chapter 6). Indeed, it is interesting to observe that intensification has usually increased as world market prices have declined, presumably because farmers wish to maintain or improve the net farm family incomes and standard of living despite falling market prices. Each case warrants more detailed in−depth research, for which I hope the corresponding chapters will provide an overall orientation, and the bibliography a useful introduction to the relevant literature.

I prepared this study during my eighteen−month period in the Senior Staff Resources Program attached to AGRDR. My operational expenses were financed jointly by AGR, ENV, EDI and some operations divisions where I was able to assist in a country operation during my field work for this study.

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This review is based on interviews with many farmers, scientists, and senior managers of public and private institutions. Many of these people have written on subjects related to the intensification of farming and sustainable agriculture in their countries, and some of their important contributions listed in the bibliography at the end of this publication provided valuable material for this review.

I would particularly like to acknowledge the invaluable help provided by my main collaborators in the eight countries covered, as follows:

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1— Introduction

This is a review of eight intensified farming systems most of which have proven effective in exploiting the natural resources upon which they are based, not degrading them, but sometimes restoring them. Each case brings out the interactions and complementarity among sound scientific and practical knowledge, market factors, social and political contexts, and public policies and investments. Seven of these systems are apparently viable under current circumstances, but are they "sustainable"?

Sustainability is a term that has come into widespread use, particularly during the past decade. Its use has been so extensive and it has been applied to so many distinct circumstances that it has come to be interpreted in many different ways (Dixon and Fallon, 1989; Munasinghe, 1993a; Pezzy 1989). Some people have applied it to an unchanging system of production or to a lifestyle that can be perpetuated indefinitely. Such a static interpretation is inappropriate for farming systems. For a system of natural resource management to be sustainable, it must be able to withstand sharp climatic fluctuations and evolve steadily in response to social changes and the costs and availability of inputs of land, labor, and knowledge. The names and addresses of organizations concerned with sustainable agriculture have been listed in Reijntjes, Haverkort, and Waters−Bayes (1992, pp 232235). In a recent issue of Finance and Development , a useful review of the present state of thinking on sustainable development was provided by a sociologist (Cernea 1993), an ecologist (Rees 1993), and an economist (Munasinghe 1993b), while Steer and Lutz (1993) considered how sustainable development might be measured and Serageldin (1993) combined the specialists' views into a triangular model representing social, economic, and ecological objectives.

One of the first points to be considered is what is to be sustainable, and for whose benefit. As Norgaard (1988) pointed out, some people will emphasize the maintenance of ecological systems, while others will press for sustaining the level of consumption and for improving the level of employment. Governments cannot alleviate poverty except by seeing that the net added value created for each unit (for example, day of work) is increased substantially. In the primary and secondary sectors this generally requires using both renewable and nonrenewable resources. For services and academic output this is less obvious.

While populations continue to increase, as they are likely to do in the developing countries for many decades to come, the availability of nonrenewable resources per person will clearly decline. Another issue of increasing importance is the need to dispose of waste products safely and to prevent production and marketing processes from contaminating the environment. Sometimes this relationship has been condensed to a balance between "sources" of inputs and "sinks" for the disposal of unwanted outputs. Between these two extremes complex physical and biological processes are at work. This review uses the term farming system to encompass the whole cycle, from the sources of resources all the way through to the final consumer and sinks for wastes.

Sustainability here refers in the first place to a farming system's physical, chemical, and biological elements and how these interact over space and time. The World Commission on Environment and Development (WCED 1987, p.8) considered that:

Humanity has the ability to make development sustainable − to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits − not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth. The Commission believes that widespread poverty is no longer inevitable. Poverty is not only an evil in itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfill their aspirations for a better life. A world in which poverty is endemic will always be prone to ecological and other catastrophes.

Daly (1987) considers that present generations can only provide future generations with a "resource dowry," and how future generations use it to produce happiness or misery is their own affair. This legacy must surely also include all the information and knowledge earlier generations have accumulated, as well as the physical resources.

The accumulated knowledge resource will no doubt lead to changes in technology and the development of substitutes in response to the new needs of future generations. This has been termed the "possibilistic" or "technological optimistic" view, which assures us that market−induced responses will arise that will solve problems that are as yet unknown. This view overlooks the undoubted problems of imperfect access to knowledge, rent−seeking behavior, and greed of individuals. A positive advantage of this view, however, is that it reminds us that the combination of resources that will be essential to future generations will almost certainly be different from what we now consider to be essential.

Another common subject of debate is how far into the future we should worry about. For an individual the distance of the time horizon depends upon that person's wealth and security. We will all die one day, but the poor will almost surely die younger. The time horizon of governments and elected representatives of the people should be much longer than the individual's, although in practice this is often not the case. Norgaard and Dixon (1986) present an argument for combining economic and "co−evolutionary" methodologies when designing development projects. Their approach draws attention to concurrent changes in physical and social systems. This view is also helpful in accommodating the imponderables and uncertainties we face today when deciding which farming systems are likely to be sustainable and which are not. The authors emphasize the continuing changes that should and can be made as new knowledge and experience is acquired. This evolutionary development will be most effective if the initial technical and social systems are both broadly based and diverse, as this provides many opportunities to learn from experience.

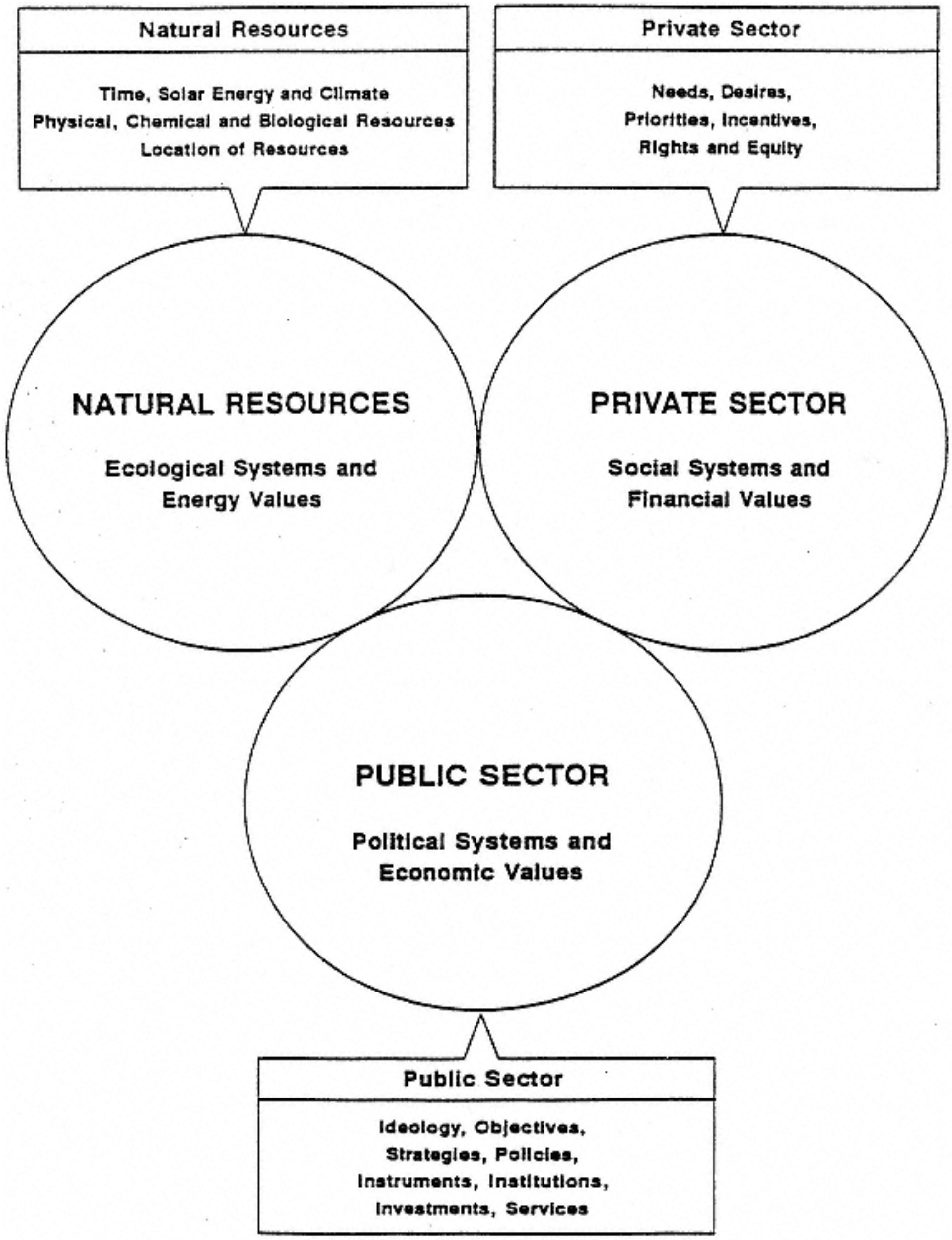

Figure 1−1.
Factors in a Sustainable Farming System
Source: *J.A. Nicholas Wallis.*

Building upon Norgaard and Dixon's approach, Figure 1−1 illustrates that in addition to the physical and social systems or "domains," there is a third public sector domain made up of political systems and economic, rather than financial, valuations. It is how these three broad domains interact that determines whether or not a system has the possibility of being truly sustainable. All the cases discussed in the later chapters illustrate that sudden changes in farm productivity may occur when the three domains come into reasonable compatibility, including the subjects listed in the boxes in Figure 1.1. It is, of course, equally true that an apparently sound and sustainable system may not continue to be sustainable if a major change occurs in any of the three domains, for instance, if public policy leads to a seriously misaligned exchange rate.

In their review of economics, the environment, and sustainable development, Pearce and Warford (1993) outline a general theory of poverty and the environment within which they advocate two broad strategies for the sound development of the agricultural sector, namely:

Raise agricultural productivity in the most resilient and potentially productive areas, thereby improving the well−being of 250 million of the most impoverished poor, and reducing the pressure exerted on marginal lands by populations who would otherwise be displaced from resilient areas.

Decrease the fragility of marginal areas through policy responses to introduce schemes of water conservation, agricultural extension, afforestation, and agroforestry. As with resilient areas, the policy mix must consist of investment, incentives schemes, infrastructure, credit, extension, and institution building, in many cases including the establishment or reinforcement of resource rights through land and resource tenure.

This review of intensified farming systems shows that some conditions have to be met for any system of farming to be sustainable. These are summarized in Figure 1−2. It is essential that the public sector ensures a reasonable degree of peace and stability to provide a general feeling of **security** in rural areas. The public sector also has a special responsibility to promote education and research, disseminate **information,** and provide means of **communication.** Services are often most effectively carried out by private sector entities, but as all these cases illustrate, the public sector usually has to take the important first steps.

The main driving force for agricultural intensification is a **demand** for farm products. Before farmers will actually intensify their operations, they need to have reliable commercial **information** and ready **access** to markets for their products, and also for any essential farm inputs. Within the ecological system, an essential feature of a satisfactory intensified farming system is that marketable output is increased per unit of input. The most appropriate measure of **productivity** is not always yield per unit of area or animal, but may be per unit of labor, energy, or water input, depending upon which is the most limiting factor. **Stability** and reliability of output from season to season is an important condition, and the concept of sustainability as applied to farming systems also needs to encompass the capacity to withstand and recover from major shocks, which may be from natural events such as droughts or floods, or from sharp fluctuations in commodity prices. **Resilience** is, therefore, an important characteristic in reducing a farming system's vulnerability. The final highly desirable, although possibly not essential, characteristic of a sustainable farming system is that it is **flexible** and readily adapted to produce new outputs in response to unforeseen market demands.

Figure 1−2.
Some Conditions Necessary for a Sustainable Farming System
Source: *J.A. Nicholas Wallis.*

A farming system may meet these criteria and appear to be sustainable, but some other considerations are also involved, such as biological diversity. The system's very success may lead to its extension into areas of great biological **diversity.** This can raise a broad range of issues for which there are as yet no clear solutions. Only informed guesses are available concerning the possible value of life forms that have not yet been identified and how they interact to form an ecosystem. Prudence and responsibility to future generations, as well as ethical considerations, must lead us to maintain diversity within systems and to retain extensive, untouched areas of high biological diversity.

Diversity is also an important feature of socioeconomic systems, since this increases the probability of knowledge accumulation through the process of trial and error by millions of individuals and many entities. This is an essential part of Norgaard and Dixon's (1986) co−evolutionary strategy that should reduce the importance of the question as to how far into the future we must peer.

Autonomy and **solidarity** are other characteristics that researchers have suggested are essential for sustainable farming systems. Autonomy requires that each farmer be free to make independent decisions and innovations, but for some aspects of natural resource management, such as water and soil management in a watershed, some degree of coherence or solidarity among groups of farmers is essential, otherwise all will suffer from the effects of resource degradation. This is particularly clear in the examples from India, Nigeria, and Turkey.

Equity in **access** to, although not necessarily ownership of, resources is the final feature of a truly sustainable system. Not only is this desirable for ethical reasons, it is also an essential part of socioeconomic diversity that is most likely to help farming systems adapt continuously in the light of experience, new knowledge, and changes in the sociopolitical context. In the absence of a reasonable degree of equity in the distribution of assets and access to services, social unrest is eventually likely to disrupt any system of farming, even if it is technically sustainable.

The eight farming systems discussed in this review are examples of some of the wide range of circumstances found around the world. All the cases are of rainfed farming, because irrigated agriculture is relatively well documented. Cases initially considered were from areas receiving at least 700 millimeters of rainfall per year. The case from Turkey was included later as it illustrates a particularly interesting example of successful fallow reduction under quite dry conditions (around 400 millimeters of rainfall per year). The cases cover a range of countries with contrasting physical and economic conditions, and include low−income, lower−middle income, and upper−middle income countries (Table 1−1). Six cases were drawn from tropical regions, while Uruguay and Turkey represent contrasting conditions outside the tropics. The set of cases also covers a wide range of farm sizes, for example:

Small−scale farm operations: Colombia, India, Kenya, Nigeria, Turkey

Medium−scale farm operations: Brazil, Malaysia, Uruguay

Large−scale farm operations: Brazil, Kenya, Malaysia, Uruguay

The cases also illustrate several distinct types of farming systems:

Associated crops: Colombia, Nigeria

Seasonal crops: Brazil, India, Turkey

Perennial crops: Kenya, Malaysia

Livestock and pastures: Uruguay

Other interesting contrasts are in rainfall, altitude, and soil characteristics:

Annual rainfall:	Low (under 1,000 millimeters per year): Turkey Medium: Brazil, India, Uruguay High (over 2,000 millimeters per year): Colombia,Kenya, Malaysia, Nigeria
Altitude:	Low (under 1,000 meters): Malaysia, Nigeria, Uruguay Medium: Brazil, India, Turkey High (over 2,000 meters): Colombia, Kenya
Soils:	Volcanic: Colombia, Kenya Nonvolcanic

Neutral to alkaline: India, Turkey, Uruguay

Acidic: Brazil, Malaysia, Nigeria

The description of each of the natural resource management systems reviewed in the following chapters explains how they have evolved. Sometimes they have developed in response to macroeconomic and market changes, often changes in physical and social infrastructure have been important, but in all the cases a necessary condition for change has been that the underlying physical, chemical, and biological systems have been understood and respected by the farmers.

In each of the following chapters, following a brief background review, an outline is provided of the climatic and natural resource conditions. The next sections deal with the changes that have taken place in market demand and supply of inputs, and with public and private institutions that have evolved and investments that have taken place to influence the market. The main part of each review describes and comments upon the many factors affecting the viability of each system, grouped around the headings of plant and livestock genetic base and diversity, the management of soil moisture and nutrient status, and other characteristics of the farming system. The final section comments on prospects for the future and suggests some lessons for other countries in which conditions are similar.

Table 1−1. Development Indicators for the Agricultural Sector

	Low income economies			**Lower−middle income economies**		**Upper−middle income economies**		
INDICATORS	**India**	**Nigeria**	**Kenya**	**Colombia**	**Turkey**	**Brazil**	**Malaysia**	**Uruguay**
GNP per capita (US$ per year)	310	320	330	1,290	1,950	2,770	2,800	3,300
Population mid−1991 (millions)	866.5	99.0	25.0	32.8	57.3	151.4	18.2	3.1
Area (thousands of square Km)	3,288	924	580	1,139	779	8,512	330	177
GDP average annual growth rate (%)								
197080	3.4	4.6	6.4	5.4	5.9	8.1	7.9	3.0
198091	5.4	1.9	4.2	3.7	5.0	2.5	5.7	0.6
Agriculture average annual growth rate (%)								
197080	1.8	(0.1)	4.8	4.6	3.4	4.2	n.d.	0.8
198091	3.2	3.5	3.2	3.2	3.0	2.6	3.7	0.2
GDP (millions US$) distribution								
1970	52,949	12,546	1,453	7,199	11,400	35,456	4,200	1,940

1991	221,925	34,124	7,125	41,692	95,763	414,061	46,980	9,479
GDP distribution (%)								
Agriculture								
1970	45	41	33	25	30	12	29	19
1991	31	37	27	17	18	10	n.d.	10
Industry								
1970	22	14	20	28	27	38	25	37
1991	27	38	22	35	34	39	n.d.	32
Manufacture								
1970	15	4	12	21	17	29	12	n.d.
1991	18	n.d.	12	20	24	26	n.d.	25
Services etc.								
1970	33	45	47	47	43	49	46	44
1991	41	26	51	48	49	51	n.d.	58
Value added in agriculture (millions current US$)								
1970	23,916	4,787	484	1,806	3,383	4,388	1,198	378
1991	71,103	12,271	1,895	7,258	17,090	42,288	n.d.	926
Cereal imports (thousands of tons)								
1980	424	1,828	387	1,068	6	6,740	1,336	45
1991	58	763	330	780	638	6,332	3,014	83
Food aid in cereals (thousands of tons)								
1979/80	344	n.d.	86	3	16	3	n.d.	7
1990/91	217	n.d.	63	1	4	16	4	20
Fertilizer (annual grams per hectare of cultivated land)								
1979/80	313	36	169	603	451	755	912	633
1990/91	743	124	477	1,112	676	525	1,950	551
Average food production, annual growth per capita								
197991 (197981 = 100) (%)	1.6	1.5	0.5	0.6	(0.2)	1.7	4.1	0.8

Fish products: % of daily protein supply								
1970	1.6	2.7	1.5	1.7	1.9	3.6	13.7	0.8
1990	1.6	3.5	2.9	1.4	2.3	2.6	13.8	1.1

n.d. = no data

Source: *World Bank, (1993).*

2— Overview

At the end of each of chapters 3 to 10 there is a commentary on the respective farming system. In chapter 10 the commentary also compares and contrasts experience in the development of two important perennial crops: tea in Kenya (chapter 9) and oil palms in Malaysia (chapter 10). In this chapter some more general lessons are drawn, each from two or more of the farming systems reviewed in the following eight chapters. These overall comments are grouped broadly according to the three domains proposed in chapter 1, with some closing remarks on environmental considerations and integration of science with sector policies.

The Public Sector

The role of government and public policy has been crucial to all the farming systems outlined in chapters 3 to 10. In all cases little intensification of farming took place before a reasonable degree of law and order had been established in rural districts. Transport infrastructure has been essential in all the cases, particularly for perishable products (milk in Uruguay, green leaf tea in Kenya) and for commodities for which foreign markets are important (soybeans in Brazil and India, tea in Kenya, and oil palms in Malaysia).

Social infrastructure (education and health) is clearly important, but showing how it directly contributes to successful farm intensification is difficult. However, the remarkable and rapid improvements in Uruguay's dairy industry could probably not have taken place before the country had sufficient well−educated people to manage the intensified dairy farms. Functional literacy for a least one member of each farm family may be an acceptable minimum precondition for significant improvements in farm management. This was the situation in Kenya at the outset of the successful smallholder tea development program in the 1950s.

The assurance of a market, even with falling world prices, is essential to encourage farmers to try new crops and innovations in crop, pasture, and livestock management. In India, farmers have the assurance that all the soybeans they produce will be bought, if not by the many commercial oil millers, then by one of the government−supported cooperative oil mills. The cooperatives bid at auctions against traders, but must buy at an annually set official floor price. In Turkey, the official agency that had dealt only with cereals was authorized to buy pulses as part of the fallow reduction program. This provided an assured floor price, although the agency seldom procures as much as 20 percent of production.

One common feature in all the cases mentioned in chapters 3 to 10 is that in no case did the government monopolize the marketing of farm outputs. In Uruguay, a statutory cooperative had the monopoly for all pasteurized milk sold in the capital city for almost fifty years, until 1984. However, the removal of its monopoly status was one of the policy changes that contributed to the remarkable development of the country's dairy sector in recent years.

Several of the abrupt changes in farming systems and the degree of intensification of their management are clearly related to changes in public policy. In Turkey, the policy of opening up markets and promoting exports from the early 1980s laid the essential groundwork for the fallow reduction program.

The elimination of credit subsidies in Brazil suddenly made farm machinery much more expensive, and thus farmers immediately became more interested in direct drilling, which requires much less investment in farm machinery.

In Nigeria, the government continues to subsidize the price of fertilizers substantially, but they are not readily available in most rural areas. This is one of the reasons why farmers are not adopting the improvements to the associated cropping system in the forest zone (chapter 6) as rapidly as had been expected. In India fertilizers are still subsidized, but to a declining extent. They are, however, generally available.

Natural Resources

The evidence of the last seventy years, as the following chapters show, is that the public sector can play an important role in the discovery and dissemination of new knowledge. In general, however, progress has been sporadic, and often research has not been sustained for long enough to reveal all the conditions that farmers face in practice. The selection of research topics has often lagged behind farmers' real needs (for example, direct drilling in Brazil), and the quality of research has been uneven. In only a few instances have national scientists submitted their research papers to international, refereed professional journals, therefore the work has lacked scrutiny, while at the same time other researchers, and policymakers often within the same country, remain unaware of useful information derived from excellent research. The bibliography that follows chapter 10 lists many interesting, but generally unknown, papers. A list of abbreviations and addresses follows the bibliography to help readers locate the documents.

The two perennial crops (tea and oil palms) considered in chapters 9 and 10 are found on both estate−scale and small−scale plantations. Each has an industry−financed research institute, and some of the estates also have their own research units. Scientists from these institutes regularly publish their results in international journals, and almost all the results are scale−neutral, that is, equally useful for estate managers or small−scale farmers. With the assurance of industry funding comes greater accountability for the direction of research, which is thus more likely to address the issues of most pressing interest to producers and processors.

The organization and funding of research for food crops, such as pulses in Turkey and maize, beans, and potatoes in Colombia, is much more difficult than for industrial−scale crops such as tea and oil palms. Defining a subgroup of producers willing and able to finance research is difficult, which is why it is usually done entirely in the public sector. Colombia is in the process of converting most of this sort of research to contractors, and the experience will be studied with interest by research policy planners throughout the world.

In all fields of agriculture, the earliest subject for study has been the selection and breeding of more useful and productive species. For tens of thousands of year this was done by millions of individual farmers, and led to the range of crops, pastures, and domestic livestock we know today. A little more than 100 years ago, as scientists began to understand the principles of genetics and inheritance, they built up a scientific basis for deliberate breeding programs and achieved great progress, particularly during the past 50 years. This led to varieties of plants and breeds of livestock that were highly productive under the

conditions in which they were selected. However, often they were not able to perform reliably under the wide range of conditions and climates that are characteristic of rainfed agriculture throughout the world.

The scientific basis for the understanding of soil chemistry and physics had been laid down before the foundations of scientific breeding had been established. However, the development and application of the former area of knowledge has been uneven, and in most countries has commanded less attention than plant and livestock improvement. By the 1920s several of the countries covered in this review, for example, India, Turkey, and Uruguay, had built up valuable bodies of knowledge about soils, but farmers and policymakers paid little attention to this information. Indeed, Howard and Wad's (1931) pioneering work in India on compost and soil organic matter is only now gaining the attention it deserves.

With the exception of the long−term studies led by Pereira in Kenya (1962) of the hydrology of upland forested areas and tea plantations in Kenya, hydrology is still barely considered in most countries. As outlined in chapter 8 on India, the serious drop in groundwater levels concurrent with the rapid spread of soybeans on the black cotton soils of Madhya Pradesh is probably only an indirect effect of the new crop. The increased wealth generated by soybeans provided farmers with sufficient funds to sink uncontrolled wells for producing irrigation water for a second crop after the end of the monsoon rains. However, this important issue has attracted little systematic study, which is urgently required.

Soil scientists have shown that relatively simple treatments can lead to huge tracts of country being suitable for crops. For example, applying a few tons of dolomitic limestone and some micronutrients per hectare of the Brazilian *Cerrados* makes the soils suitable for many crops. Major progress has followed the breeding and selection of pasture grasses, soybeans, and maize varieties specifically for the conditions encountered in the *Cerrados.* Meanwhile, in Malaysia work is in progress to breed oil palms that have bunches of fruit that are easier to harvest; in Colombia, disease resistant beans have been fundamental to the improved productivity of associated cropping in Antioquia; and in the forest zone of Nigeria, the availability of mosaic−resistant strains of cassava is an important element of the promising modifications to the spacing, density, and timing of associated crops.

The large−scale propagation and distribution of improved planting material has often been a limiting factor, although there have been notable successes, such as with disease−resistant cassava in West Africa and tea clones in Kenya. In these two instances individual farmers have been shown how to raise their own plants, initially from vegetative material provided by research or farm extension agencies. The dissemination of improved varieties has been far more difficult with legumes. Commercial seed companies are seldom interested in entering the legume seed business because of the difficulty of protecting their rights and the numerous species involved. In Turkey, considerably improved varieties of chickpeas and lentils are now available, but these are not getting out to farmers as quickly as new varieties of wheat or barley. Similarly in India, issues of quality control, viability, and widespread distribution are limiting the successful use of the much improved varieties of soybeans and of the *Rhizobium* seed inoculant that is needed when soybeans are first sown in a new area.

Legumes can have a key place in many farming systems, as is clear from their role in the pastures of Uruguay, the formerly fallow land of Turkey, the *Cerrados* of Brazil, and the black cotton soils of India. They provide essential ground cover in young oil palm plantations in Malaysia, and climbing beans yield

much of the cash income of farmers in the Antioquia highlands of Colombia. However, legumes are usually missing from the cropping associations in Nigeria's forest zone because of serious insect infestations that are common in the second year in which a legume species is grown in the same location. Cowpeas would be suitable if insect−resistant varieties were available. There is a widespread need for disease and insect resistance in all legumes used in farming. Success is this area is possible, however, as it has been accomplished with some of the edible beans in Colombia and some soybeans in Brazil and India.

Additional nitrogen in some form is necessary for all the intensified systems of farming discussed in the following chapters. For soybeans, experience in India is different from that in Brazil. In Brazil, farmers use a nitrogenous fertilizer immediately after clearing *Cerrados* vegetation, but it may be omitted in subsequent years once a good culture of *Rhizobium* has been established in the soil, but in India nitrogen fertilizer is recommended each year. Phosphorus fertilizers are important in all the systems, but especially to establish and maintain legume pastures in Uruguay. This is a matter for considerable concern in the long run as phosphate deposits are a nonrenewable resource, and are not as abundant as other essential elements. Potassium fertilizer is recommended in several systems, although the evidence from well−managed field trials is often not convincing. The return to the fields of empty fruit bunches of oil palm in Malaysia and of tea prunings in Kenya considerably reduces the need for additional potassium.

In the farming systems covered in this review there have been no reports of pollution of water sources or groundwater supplies by nitrates or phosphatic products. However, more field work is required, particularly in Kenya, where tea receives heavy applications of a compound fertilizer once a year.

Much of the soil science and agronomic research underlying the systems discussed in the following chapters is weak regarding the role of organic matter on the surface and within the rooting range of the crop and pasture species. Yet it is within this neglected area that much of the biological activity and processes take place. The rapidly expanding technique of direct drilling in Brazil is mainly at the initiative of individual farmers. The practice seems to have many advantages realized by protecting the soil organic matter, and presumably the level of biological activity. This is an area that requires a multidisciplinary research effort throughout the world, and may be applicable under many other circumstances.

The depletion of soil organic matter leads inexorably to the loss of soil aggregate structure, lower water infiltration rates, and serious erosion. This was a major problem in Malaysia's rubber industry until farmers started using legumes for ground cover, and more recently has been serious in the *Cerrados* of Brazil following several years of cultivation of seasonal crops, mainly soybeans. The introduction of direct drilling, including growing winter crops to provide organic matter to cover or mulch the ground surface, shows promise for halting the degradation of cultivated *Cerrados*. Elsewhere more work is still needed on retaining or restoring soil organic matter. For example, the harvesting of pulses in Turkey and soybeans in India generally involves removing the whole plants from the field for threshing, often by hand. The waste material is then used for cattle fodder. In India, cattle manure is usually returned to the field, but in Turkey it may be used for fuel.

Social Systems

Countries' social structures and customs and the extent to which farmers are confident that they will secure access to markets and retain access to particular parcels of land together have a vital influence on farming systems and standards. This is particularly clear from the examples from India, Nigeria, and Turkey. In each of these countries farmers may own several pieces of unfenced land on several sides of the village. In Nigeria and Turkey each year the community agrees to leave some contiguous areas or sectors fallow and to sow their crops on another block. In this way only a few herders are sufficient to keep livestock off the fields growing crops. Under these circumstances it is not feasible for one farmer to decide to cease fallowing, as the whole community must first agree. In Turkey, and particularly in India, the issue is how to plan and manage land and water communally. For example, to change from cultivating up and down slopes to laying out operations along the contour, all neighbors must agree. On the flat or slightly undulating black cotton soils of central India, one farmer alone cannot establish furrows to remove excess water during the monsoon season, because this will aggravate the flooding on the neighbors' fields. Researchers have shown how drainage could be improved, but their methods cannot be implemented unless several farmers, and possibly the whole community, agree and cooperate, because this sort of landscape planning has to be based on a broad consensus followed by common actions.

Substantial changes are needed in communities' understanding, values, and often power structures before changes in landscape use can be put into effect. In England and several other European countries this took many decades of debate, and sometimes of strife, during the nineteenth century. Turkey and India have made great progress, but under the conditions of central Anatolia and the black cotton soils of central India, substantial social changes are probably essential before further intensification of farming is possible. In Nigeria the technical recommendations for improving traditional systems of associated cropping are unlikely to be widely adopted until considerable changes have occurred in the perceptions and priorities of farm families.

Environmental Considerations

Every system of farming changes the original natural environment. In Turkey the initial conversion was 10,000 years ago, while in Brazil and Malaysia the clearing of native vegetation has been recent. The test of whether a system is sustainable must consider how to maximize the productivity of the land already in use in a way in which it may continue to be used indefinitely. This will reduce the rate at which wild lands and forests are converted to farm land. Brazil has not yet reached this stage, but apparently Malaysia has.

Malaysia is also interesting because the oil palm development initially led to serious water pollution by effluent from the oil mills. None of the other systems reviewed in these chapters had any such immediate negative impact on the environment. However, appropriate legislation and enforcement and good research and development work in Malaysia has solved the problem. The waste is now a source of several byproducts, and the residue is returned to the plantations and is increasing the yield of palm oil and substantially improving the soil's organic matter content. The change in the method of pruning Kenyan tea has had a similar effect on organic matter, since all prunings are now left to decompose in the field and are not removed for fuel. In Uruguay, much of the pasture improvement for dairy farming has been on land seriously degraded by continuous cropping for many decades. Not only has erosion been halted, but soil

organic matter is also gradually being raised as a result of improved, more intensive pasture and livestock management.

Integrated Approaches to the Intensification of Farming Systems

Several of the cases of successful intensification outlined in the following chapters illustrate how countries can make rapid advances when the knowledge from soil science and biological sciences is combined. For example, the 1950 mission to Uruguay by the Food and Agriculture Organization of the United Nations led directly to progress in pasture management through the application of phosphatic fertilizers and the sowing of seeds of improved legumes treated with *Rhizobium* cultures. Several scientists in Uruguay were already aware of most of the elements of this combination, but it was the transfer of practical experience from New Zealand that captured the attention of scientists and cattle farmers and led to widespread adoption of the combined treatments on ranches and dairy farms.

Turkey's fallow reduction program was triggered by a meeting of scientists and policymakers in 1981, who reviewed research results and the experience gained from the Corum Cankiri Rural Development Project. This project, which had been funded in part by a loan from the World Bank, included a pilot component to test whether legumes for grain (pulses) could be grown during the traditional fallow year between wheat or barley crops. Some soil scientists had suggested that this might be possible, except in the driest regions, as early as the 1920s, and again in the 1960s, but it was clearly the 1981 meeting that stimulated a series of policy decisions and actions that quickly led to a nationwide program to promote legume production in place of the traditional year of fallow.

3—
Turkey:
Fallow Reduction in Anatolia

The location of Turkey, which covers about 780,000 square kilometers, has been of strategic importance for thousands of years. Not only is it at the crossroads of Asia and Europe, but it also includes the centers of origin of several of the world's most important crops: wheat, barley, and several grain legumes. It was in this region that settled farming begun as the hunter−gatherers learnt they could retain seeds from wild plants and sow them to produce food crops that were more convenient to harvest. Archeologists have found carbonized wheat kernels dating back to 6,700 B.C. in Turkey, and an ancient Hittite relief shows gifts of wheat being carried to King Araras in 800 B.C. (Durutan, Yilmaz, and Kiziltan 1988).

Wheat and barley are grown throughout Turkey, with a high proportion being produced on the central Anatolian Plateau, where the annual rainfall ranges around 400 millimeters, mainly in the winter and spring. In this region, where irrigation is not available, the traditional cropping sequence has been one season of small grains (wheat or barley), followed by a "weedy" fallow for around fourteen months. Bare soil fallows were encouraged from the early 1970s after many years of field research had shown the effectiveness of the elimination of weed growth and the maintenance of a soil mulch on the availability of moisture for the following cereal crop. The increased availability of tractors in this period made this practice feasible. On a national basis, fallow land accounted for more than one−third of the arable area until 1981.

Wheat is a key component of the national diet. According to the State Planning Organization (DPT 1993), per capita annual utilization is as high as 274 kilograms, while the corresponding amount for pulses is about 25 kilograms. The central importance of wheat to the national food supply has guided agricultural policy, particularly since the formation of the Turkish Republic in 1923. As early as 1925, a series of six seeds improvement and experiment stations was established in Adapazari, Ankara, Erzurum, Eskisehir, Istanbul, and Samsun. At the Istanbul and Adapazari stations the main focus was on plant selection, and subsequently on breeding. Researchers at the Ankara station also studied agronomic practices, while a separate organization was establish at Eskisehir—the Dry Farming Station—whose activities included plant improvement, crop rotation, and soil tillage experiments.

Early trials soon showed the importance of winter hardiness and the advantages of sowing small grains early in the autumn. Winter hardiness was therefore an important criterion in the early selection work from local plant populations and imported material. It was also an important consideration in the breeding programs that started in 1929, from which the first uniform lines were released in 1944. By 1969, nineteen bread wheat and eight durum wheat cultivars had been developed at the seeds improvement stations (Mizrak and others 1986).

Between 1935 and 1960 the area of cropland (sown and fallow) doubled from 11.6 million hectares to 23.3 million hectares. Much of this increase occurred following World War II, when the Marshall Plan financed the importation of a large number of tractors. Subsequently, the amount of cropped land increased gradually to 25 million hectares in 1973, of which about 36 percent was fallow each year. By this time agriculturists had generally realized that seasonal crops were being grown in many unsuitable areas where erosion and soil fertility declines were evident. The dilemma was thus how to discourage the cultivation of erodible soils where degradation was already evident while increasing national food production, particularly of wheat. The first attempt to reduce the proportion of fallow took place on a pilot scale in the late 1970s in a World Bank−supported rural development project in the northern area (Corum−Cankiri). The project, which included replacing unimproved legume varieties, using fertilizers, encouraging mechanization, and supporting credit, was very successful. Farmers readily took to legume production as an alternative to fallow, and within five years had largely adopted a legume−wheat rotation system.

Evidence from twenty years of rotation trials at Eskisehir that started in the 1930s had shown that substituting legumes for fallow has the least adverse effect on the succeeding wheat yield, and that the effect of the previous soil use (for fallow or cropping) becomes less pronounced as the annual precipitation rises above 400 millimeters.

This gave rise to the possibility that the proportion of land in fallow each year might be reduced, thereby reducing the total area of cropland while increasing the area sown to crops each season and withdrawing from the cultivation of the most marginal land. Two crucial questions remained to be answered to avoid any possibility of lowering national wheat production:

Under what ecological conditions could fallow be safely eliminated without reducing wheat yields?

What are the most suitable crop rotations that will not depress the yields of wheat?

The National Program for the Utilization of Fallow Areas, known by its Turkish abbreviation NAD, grew out of a symposium organized by the Turkish Scientific and Technological Research Organization on the subject, held in Ankara in September 1981, and attended by research scientists from Turkish universities and institutes, as well as by agricultural extension staff. Kalayci (1981) and Yesilsoy (1981) presented reviews of research results since the 1920s, and the participants discussed the practical experiences drawn from the Corum−Cankiri project at length (Duratan and others 1990). The recommendations of the symposium's participants were conveyed to the minister of agriculture. This led to instructions to research institutes to prepare relevant research proposals, and a committee was set up that completed preparation of a research and extension project for the NAD in February 1982.

In the following year the General Directorate of Agricultural Affairs of the Ministry of Agriculture and Rural Affairs (MARA) completed plans for training NAD extension staff, providing inputs and credits, and marketing the expected increase in pulse output. Turkish research scientists followed with interest research and field experience in western and south Australia, where extensive work was in progress on fallow reduction and alternative crop and pasture rotations. These contacts were facilitated by the International Centre for Agricultural Research in Dry Areas through several specialized workshops, and by a conference on dryland farming held at the Texas Agricultural Experiment Station in 1988.

Since the 1920s, Turkish agriculturists have accumulated a gradual, but fragmented, knowledge of the characteristics of indigenous species (wheat, barley, lentils, chickpeas, and forage legumes) and an increased understanding of the biological, moisture, and nutrient cycles (particularly of nitrogen) that occur during fallow periods. They reported almost all this research work only in Turkish at national conferences and in papers and institutes' annual reports. Thus, the international scientific community was unaware of most of it, and hardly any of the scientific papers benefited from the peer review process required for publication in internationally respected scientific journals.

Little successful integration of scientific knowledge with public policymaking occurred until the TUBITAK 1981 symposium that laid out the basis for the National Fallow Reduction Program. The impetus for this meeting grew out of the field success of the World Bank−supported Corum−Cankiri Rural Development Project that had been launched a few years earlier. The symposium took place at a time of major political and structural adjustment in Turkey. The context was favorable, since public security had improved and export promotion was in favor, rather than only import substitution. However, the maintenance of self−sufficiency in wheat production remained of highest priority.

Since 1980/81 reducing the area in fallow from a third to a fifth of the total area cultivated each year has more than doubled Turkish pulse production (+125 percent), while still allowing a steady increase in wheat (+20 percent) and barley (+35 percent) production during the decade in which the reduction in fallow area took place (Table 3−1). The 1991 census also indicated that the total area cultivated each year had decreased significantly, although the apparent reduction of 6 million hectares probably exaggerated this trend because of earlier overestimation of the area cultivated.

Table 3−1. National Production of Small Grains and Pulses, Selected Pairs of Years

	Wheat		*Barley*		*Pulses*	
Two−year averages	*Thousands of tons*	*Index*	*Thousands of tons*	*Index*	*Thousands of tons*	*Index*
1980/81	16,750	100	5,600	100	839	100
1985/86	18,000	107	6,750	121	1,679	200
1990/91	20,200	120	7,550	135	1,890	225

Source: *DIE (1992a and b), MARA (1992).*

The reduction in the practice of fallowing meant that the land more suitable for cultivation, for example, less than 8 percent slope, could be used more intensively, while the steeper, more fragile land could be returned to grazing or forest. However, no specific evidence indicates the extent to which this has actually occurred.

The intensification in land use has been possible without much additional investment in machinery or new labor, because in most villages the existing resources were far from fully utilized when the program began. Considerable underemployment was one reason for the earlier substantial migration from Turkish villages to Germany and neighboring countries in search of work. Recently some people have returned to their villages after an absence of up to twenty years.

The share of agriculture in total Turkish GDP declined from 34 percent in 1965 to about 15 percent in 1992, mainly as a result of rapid industrialization (Table 1−1). Agriculture remains an important sector, however, providing about 15 percent of civilian employment, and also generating around 15 percent of export earnings, and showing a positive trade balance (Table 3−2).

Table 3−2. Imports and Exports by Main Sectors, 1985 and 1992 (US$ millions)

	1985			*1992*		
Sector	*Imports*	*Exports*	*Difference*	*Imports*	*Exports*	*Difference*
Agriculture and livestock	375.3	1,719.4	+1,344.1	1,178	2,203	+1,025
Mining and quarrying	3,626.3	243.8	−3,382.5	3,055	264	−2,791
Industrial products	7,341.8	5,994.8	−1,347.0	18,638	12,251	−6,387
Total	11,343.4	7,958.0	−3,385.4	22,871	14,718	−8,153

Source: *1985: Undersecretariat for Treasury and Foreign Trade quoted in MARA (1991).*
1992: HDTM (1993).

Turkey has been one of the few countries in the Middle East that has been virtually self−sufficient in food production; however, as Table 3−2 shows, the value of agricultural imports as a percentage of the value of agricultural exports rose from 22 percent to 54 percent between 1985 and 1992. Cereals and oilseeds accounted for 45 percent of the value of agricultural imports in 1992 (HDTM 1993).

Local Conditions and Natural Resources

The central Anatolian Plateau is around 1,000 meters above sea level and has a semi−arid Mediterranean climate. Most of the low total rainfall occurs in winter (33 percent) and spring (36 percent), with much less rain in the autumn (17 percent) and summer (14 percent), when the potential

evapotranspiration is much higher, and exceeds rainfall for at least seven months a year. Year−to−year variations in total rainfall and in the distribution of rainfall between months are considerable (Durutan and others 1991). Variability and unreliability increase with decreasing average annual rainfall, with the most limiting conditions being mainly in the Great Konya Basin. This basin is enclosed by uplands from which several rivers flow to an extensive (10,000 square kilometer) plain at an altitude of 1,000 meters. As part of a soil fertility study of the area between 1964 and 1968 by the Department of Tropical Soil Science of the Agricultural University of Wageningen, the Netherlands, Janssen (1972) developed a tentative scheme to establish coherence between average annual precipitation, desired rotation, and the application of nitrogen fertilizer to the wheat crop, as shown in Table 3−3.

Guler and Karaca (1988) describe how these ideas were further developed to define climatic and soils criteria to determine the boundaries between areas that should be kept with a fallow period in the rotation, and those in which the land could be cropped annually. Based on the climatological research by Aydeniz they quoted, fallowing was unlikely to be necessary except in southeastern Anatolia and the southwestern transitional zone (see map of Turkey). Based on Yesilsoy's (1981) work, they concluded that fallowing may be practiced in areas where the soil is deeper than 90 centimeters, but that fallowing is not effective where the soil is shallower than 90 centimeters, even if the area is in a zone where fallowing is currently practiced.

Table 3−3. The Relationship between Annual Precipitation, Rotation, and Nitrogen Fertilizer in the Great Konya Basin

Annual precipitation (mm)	Rotation	Nitrogen filter
less than 200	No wheat cultivation possible	not applicable
200 to 259	2 years fallow, 1 year wheat	None
260 to 349	1 year fallow, 1 year wheat	Depends on soil nitorgen
350 to 450	1 year fallow, 1 year wheat	Small dressings desirable
More than 450	Permanent cultivation	Nitrogen dressing replaces fallow year

Source: *Janssen (1972).*

The soils of the central Anatolian Plateau belong to the Great Brown Earth Group (Cambic Inceptisols). About 56 percent of the central drylands are classifiedmas clay or clay−loam soils, and the remainder is mostly (40 percent) loam soil. Typically the soil is about 1 meter deep overlying calcareous parent material. The soils are poor in organic matter and phosphorus, but well supplied with lime and potassium (Durutan and others 1989). These soils usually have a rather poor moisture infiltration rate and a slow downward rate of moisture movement, but a relatively rapid upward movement in the top 15 to 20 centimeters of soil if there is strong evaporation from the surface soil.

Within 120 centimeters of soil depth, the maximum amount of moisture storage capacity available to plants is around 300 millimeters.

Anatolian farmers live in villages, and typically have 5 to 10 hectares each divided among ten to fifteen plots distributed around the village on land of varying slope and potential. Where farmers have followed the traditional wheat:fallow or wheat:second crop:fallow rotation, the villages have maintained all their cropped or fallow land in blocks to facilitate the herding of livestock away from the land currently cropped. According to the *1980 Census of Agriculture: Household Surveys* for the sample drawn from the whole of Turkey the distribution of land was as shown in Table 3−4.

Of Turkey's total area of 780,000 square kilometers (78 million hectares), the MARA (1991) states that 28 million hectares, or 36 percent, is cultivated. Sown areas account for 79 percent of this total cultivated land, with the remaining 21 percent left to fallow. The total of 18 million hectares sown annually and fallow land according to DIE (1992b) was 7 million hectares less than the MARA's 1990 estimate; however, the proportion of fallow land to the total remains at 20 to 21 percent. This represents a sharp decline from 33 percent fallow in 1981. If one−third of the cropland had been in fallow during 1991, using figures from the 1991 census, about 2.4 million hectares less of annually sown crops would have been planted that year. This is a substantial change in land use, even though it represents only two−thirds of the area the MARA claimed was released from fallow in 1989.

Table 3−4. Farm Size Distribution, 1980

Farm size	*Thousands of hectares*	*Percentage of farmland*
Less than 2 hectares	1,102	30.3
2 to less than 5 hectares	1,165	31.9
5 to 20 hectares	1,159	31.7
Over 20 hectares	223	6.1
Total	3,649	100.0

Source: *DIE (1992b).*

The MARA's General Directorate of Production and Development (MARA 1992) estimated that in 1991, farmers used 1.3 million hectares of the land withdrawn from fallow for crops other than small grains. Thus, just over a million additional hectares of wheat and barley were sown on land that traditionally would have been left fallow (Table 3−3). In broad terms, therefore, the pattern of land use has changed from one−third under fallow to one−fifth under fallow each year. This has allowed the area under small grains to increase, and enabled a rapid expansion during the 1980s in the area and production of legumes and other crops. These structural adjustments have increased the number of productive workdays, and hence improved family incomes in the villages; have increased the supply of pulse grains and other crops for urban domestic consumption; and have produced a substantial surplus of pulses for export. The program of development has also promoted leguminous forage crops, such as spring vetch, Hungarian vetch, and sainfoin for hay on formerly fallow land. However, the shortage of livestock feed continues to be serious, and this may become the driving force for the further expansion of forage legumes into the remaining areas of fallow land.

Market Demand for Wheat and Pulses

Estimates of the domestic requirement for cereals and pulses vary quite widely. There may be some definitional problems between the per capita consumption for food and the total "disappearance" of food, feed, seed, and miscellaneous losses in trading and storage. Suy (1988) estimated that the annual consumption of pulses in Turkey was 6.7 kg per capita, but at about the same date the estimate of a panel of Turkish experts came to 14.3 kg. The State Planning Organization (DPT 1993, Table 3−7) provides a much higher figure for the domestic disappearance of wheat, other cereals, and pulses than earlier MARA (1992) estimates. Even at these higher levels of estimated domestic demand, it is evident from Table 3−6 that this was well covered by domestic production in 1991.

Table 3−5. Distribution of Village Area, 1991

Land distribution	*Thousands of hectares*
Sown annually	14,430
Fallow land	3,635
Forest	19,230
Horticultural crops	
Orchards and perennial crops	
Vegetables	2,337
Subtotal horticultural crops	592
	2,929
Permanent meadows and rangeland	12,373
Wasteland	
Unused agricultural land	
Uncropped land, settlement areas, stony and	2,164
rocky areas	11,337
Subtotal wasteland	13,501
Total village area	66,098

Source: *DIE (1992b).*

Both chickpeas and lentils are indigenous to Turkey, and according to Eser (1988), their cultivation began almost simultaneously with that of wheat and barley between 10,000 and 8,000 B.C. Research work in the 1940s, 1950s, and 1960s focused on selecting and breeding cultivars of those pulse crops that could be sown in the late autumn, and thus be suitable for replacing the traditional fallow period. Until the early 1970s, the production of lentils and chickpeas was fairly steady at 80,000 to 90,000 tons per year, and the area sown remained constant. Over the next few years, during which the Corum−Cankiri project began, the output of lentils in particular increased rapidly, and by 1977 the Turkish Grain and Opiates Board (TMO) had 70,000 tons of unsold lentils in stock. Once the fallow reduction program got moving in about 1983, the national output of pulses rapidly grew from 810,000 tons in 1980, to 1,457,000 tons by 1985, and more than 2 million tons in 1987 and 1988, before dropping back to just under 2 million tons annually for the next three years.

The price support and marketing of pulses from the NAD became important and as soon as its mandate was broadened to include pulses, the TMO carried out detailed studies of worldwide quantity and quality demand in 1986 and 1987. In 1989 and 1990 the TMO mounted pilot insect control programs in Erzurum and Yozgat to improve the quality of marketed pulses. By 1988 the proportion of cropland in fallow had fallen to 21 percent, and subsequently stabilized at around 20 percent. Agriculturists do not consider it advisable to reduce the proportion further, because a fallow break about every five years appears to be necessary to prevent the buildup of plant diseases, insect pests, nematodes, and weeds.

Table 3−6. Estimated Production and Domestic Disappearance of Cereals and Pulses, 1991

Crop	*Annual per capita domestic disappearance a / (kg)*	*Total annual requirements for the population (thousands of tons)*	*Production in 1991 (thousands of tons)*
Wheat	274	15,715	18,360
Other cereals (barley, maize, rice, rye)	167	9,546	10,748
Pulses (lentils, chickpeas, dry beans)	25	1,418	1,968

a / Includes food, feed, seed, and losses.

Source: *DPT (1993).*

The value of pulse exports increased rapidly from 1975, and by 1986 had reached US$171.4 million, or 10 percent of the value of total agricultural exports. The value of pulse exports peaked at

US$371.0 million in 1988 (16 percent of the value of total agricultural exports). Table 3−7 shows the volume of pulse exports from 1988 to 1992.

Table 3−7. Pulse Export Volume, 198892 (thousands of tons)

Year	*Red lentils*	*Green lentils*	*Chickpeas*	*Total*
1988	377	229	527	1,333
1989	114	77	179	370
1990	146	95	276	517
1991	90	52	366	508
1992	134	20	267	421

Source: *Turkish Grain and Opiates Board, personal communication (1993).*

During 198687, the TMO increased its purchase of pulses from 105,000 tons in 1986 to 503,000 tons in 1987. The following year the TMO reduced the amount procured to 220,000 tons. The year 1989 was particularly dry, and then disruptions that culminated in the Gulf War curtailed exports to Turkey's traditional markets in Iran and Iraq during 1990 and 1991. Even in 1987, the TMO purchased less than one−third of total production, and in 1988 it procured only 12 percent of national output. Private grain merchants handled all other trade and exports according to standards laid down and monitored by the TMO. In 1991 recorded exports of pulses were 508,000 tons and estimated domestic requirements were 1,418,000 tons, which accounts closely for the total estimated production of 1,968,000 tons (DPT, 1993). FAO (1991) has published substantially different estimates for the production and disposal of Turkish pulses.

In terms of pulse production, Turkey is behind Brazil, China, India, Mexico, and the former Soviet Union, but in terms of exports Turkey is a world leader. According to Huttman (1988), while Canada also rapidly increased its lentil production in the 1980s from 60,000 tons in 1982 to 250,000 tons in 1987, during 1987 Turkey produced 925,000 tons.

The fallow reduction program had brought in about 1.3 million hectares of formerly fallow land into noncereal production by 1992. Of that, 582,000 hectares were for lentils and 375,000 for chickpeas (Table 3−8). Thus, during 198991 the NAD program areas accounted, on average, for 84 percent of the national area of lentils and 29 percent of the chickpea area. Furthermore, an additional 1.1 million hectares of small grains were grown on land that had traditionally lain fallow, yet according to the *1991 General Agricultural Census* (DIE 1992b), the average yields for wheat (2.41 tons per hectare) and barley (2.26 tons per hectare) did not decline.

The reduction in the proportion of land under fallow in central Anatolia did not require additional workers or farm machinery, because all that was needed was already present and seasonally

underutilized in the region's many villages and small towns. Tractors in Turkey, including Anatolia, are seriously underutilized. A recent survey (personal communication with Kurtulus Tuncer, Cukurova University, Adana, 1993) reported an average of only 400 hours of use per tractor per year, 29 hectares of land per tractor, and 1.66 horsepower per hectare. Furthermore, in 1992 the Turkish tractor manufacturing and assembly industry was running at only 30 percent of its output potential of 100,000 units per year (personal communications with Alim Isik, Department of Agricultural Machinery, Cukurova University, Adana, 1993). The change in land utilization did, however, considerably increase the number of productive days of labor per family member.

Table 3−8. Lentil and Chickpea Production by Area, 198992

	Fallow Reduction Program Area *a* /		Rest of Turkey		All of Turkey *b* /	
	Lentils	Chickpeas	Lentils	Chickpeas	Lentils	Chickpeas
1989	808	170	74	626	882	796
Area (thousands of ha)						
Yield (Kg/ha)					590	858

Production (thousands of ton)					520	683
1990 Area (thousands of ha)	703	184	202	694	905	878
Yield (Kg/ha)					935	979
Production (thousands of ton)					846	860
1991 Area (thousands of ha)	629	383	121	492	750	875
Yield (Kg/ha)					693	983
Production (thousands of ton)					520	860
1992 Area (thousands of ha)	582	375	n.a.	n.a.	n.a.	n.a.

Sources: *a / Fallow Reduction Program, General Directorate for Production and Development, Ankara, Turkey; b /* National Statistics FAO (1991).

One area of difficulty has been the mechanical harvesting of pulse crops. However, Isik (personal communications 1993) claims that if combine harvesters are run at a slow speed and harvesting is before the pods start to shatter, existing combines can harvest lentils and chickpeas satisfactorily. Both farmers and plant breeders recognize, however, that the mechanical harvesting of pulses frequently leads to considerable (10 to 15 percent) crop loss. Breeding criteria include the search for erect growth, the lowest pods 15 centimeters from the ground, uniform ripening and no shattering.

Initially the availability, quality, and distribution of seeds of pulse crops and other noncereal crops was a limitation, but with the encouragement of the agricultural extension service this was resolved fairly quickly, mainly through farm−to−farm sales. The liberation of the seed trade from the public sector monopoly in 1985 had little effect on the legume seeds of greatest importance to the fallow reduction program because they are of little commercial interest to private seeds merchants. The production and distribution of the seed of forage legumes has been slow to develop; however, recently sales by the Agricultural Enterprise Corporation of seeds of Hungarian vetch have increased substantially, from 24,500 tons in 1989 to 125,235 tons in 1993.

Fertilizer utilization was remarkably steady from 1987 to 1992 at 4.5 to 5.0 million tons per year. The reduction in fallow land has not noticeably increased the demand for fertilizers, particularly where legumes are grown. Where sunflowers are grown, up to 70 kilograms per hectare of nitrogen and 40 kilograms per hectare of phosphorus (as P_2O_5) may be applied. The additional areas of small grains generally receive 70 kilograms of nitrogen and 60 kilograms of phosphorus (as P_2O_5) per hectare each season. The existing, mainly public service, delivery system for agrochemicals has continued to reach most parts of Anatolia, and private agrochemical firms are active closer to the market towns. In 1989 subsidies amounted to about 30 percent for urea, 41 percent for calcium ammonium nitrate and ammonium nitrate, and 55 percent for triple superphosphate.

As lentils and chickpeas are native to Anatolia, they usually show quite good nodulation, although the rhizobital are often present at rather low levels on chickpeas. In contrast with the need for a specific strain of *Rhizobium* when soybeans are introduced into any new area, agriculturists currently believe that adding rhizobia strains to lentil seeds in Turkey is unnecessary, but according to ICARDA (personal communication, 1993), may be useful with seeds of chickpeas.

Institutions and Investments

The involvement of public sector institutions has been a major factor in the implementation of the fallow reduction program (NAD). The leadership has been provided by the minister of agriculture and rural affairs through the General Directorate for Production and Development of the central government and the specialized departments of the provincial administrations (eventually more than twenty−nine provinces participated in the NAD). The responsibilities for the NAD were distributed across a wide number of central government, provincial government, and parastatal entities, broadly as follows:

Overall management of NAD	General Directorate for Production and Development
Plant improvement and agronomic research	Field Crops Improvement Center (TARM), Soil and Fertilizer Research Institute
Seed provision	
Wheat, barley, and legumes other than those listed below	General Directorate for State Farms, later the Agricultural Enterprise Corporation (TIGEM)
Hungarian vetch *(Vicia pannonica)* and sainfoin *(Onobrychis sativa):*	Agricultural Supply Corporation (TZDK) and TIGEM
Lentils *(Lens culinaris)* and chickpeas *(Cicer arietinum)*	Agricultural Credit Cooperative (TKK)
Provision of credit	Agricultural Bank of Turkey and TKK
Management of prices and procurement of supported crops	Turkish Grain and Opiates Board (TMO), Guneydogu Birtik (for red lentils)
Provision of technical advice	
Plant protection and animal health	General Director Protection and Control
Production and market advice	General Directorate for Production and Development, General Directorate for Organization and Support
Agricultural extension services	

Farmer Training and Extension Division of
the Provincial Directorates of Agriculture

The combination of these services has no doubt helped considerably in the NAD's rapid implementation. However, several studies have drawn attention to the need to improve the policies and management of each of these entities. The whole system seems cumbersome and expensive, but one must acknowledge that is has allowed the NAD to be implemented with remarkable success. The World Bank (1993b) recently completed a review of Turkish state−owned enterprises that analyzed the financial performance and viability of some 240 state economic enterprises and public economic institutions, and recommended that many of them be privatized.

Formal farmers' organizations or associations do not seem to have been important to the NAD, although village committees and local leadership have helped to promote the program and Guneydogu Birtik has been important for marketing red lentils.

The all−weather road system is well developed throughout most of the Anatolian Plateau, and most villages have access to electricity and the telephone network. The level of literacy among farm families has been sufficient to make use of printed extension material, which is supported by local and national educational radio programs. Health clinics are available in the larger villages and are linked to hospitals in the region's main towns. In general, the level of public investment in the physical and social infrastructure has been sufficient to enable implementation of the NAD.

Factors and Systems of Production

The Anatolian Plateau lies at the northwest margin of an area of remarkable biological diversity that extends through eastern and southeastern Turkey to Syria, western Israel, and the Lebanese plains and across to northern Iraq and western Iran. Plant breeders have recognized the importance of this area for many years, and recently received significant support from the Global Environment Fund, which is financing a subproject for *in−situ* Conservation of Genetic Diversity as

part of a project supported by a World Bank loan for the Eastern Anatolia Watershed Rehabilitation Project (World Bank 1993a).

Four of the main NAD crops have their primary centers of origin in this area, namely, wheat, barley, lentils, and chickpeas. The small grain crops have received a high degree of national and international attention since the 1920s, and selection and breeding have resulted in important advances in their performance. However, extensive research on pulses (food legumes) only began in 1975 in Turkey through the National Food Legumes Research Project.

Important criteria common to both the lentil and chickpea breeding and selection programs have been as follows:

- Drought and cold tolerance to permit autumn sowing,
- Yield of grain and flour,
- Large seed size to meet market preference,
- Erect growth habit to facilitate harvesting,
- Uniform maturation to facilitate harvesting,

Reduced pod shattering at maturity to facilitate harvesting,

Uniform cooking characteristics to improve market acceptance,

High protein content, high in methionine and cystine amino acids, and low in phenols to improve nutritional value.

In addition, for chickpeas resistance, or at least tolerance, to Ascochyta blight *(Ascochyta rabiei)* and to attack by *Bruchus* beetles are important selection criteria.

Researchers have made important progress with twelve new lentil varieties currently being registered (six green and six red), of which four have large seeds. Seven chickpea varieties have been registered, of which one is resistant and five are tolerant to Ascochyta blight. However, so far the average yields of pulses in the NAD area have changed little or not at all, possibly because of the inadequate dissemination of the improved varieties and the farmers' resistance to growing any but large−seeded varieties.

For thousands of years the generally believed reason for the effectiveness of fallows in semiarid conditions, such as in Anatolia, had been that moisture received into the soil in the fallow year would greatly improve the chances of a good harvest in the following year. Rotation trials to test this theory began at Eskisehir in western Anatolia in the 1930s and continued for a total of twenty years in two phases. The researchers arrived at two main conclusions (Kalayci 1981):

The effect of the previous land use (crop or fallow) becomes less pronounced as the annual precipitation exceeds 400 millimeters, and is hardly detectable in a year with 500 millimeters.

Leguminous crops cause less reduction of the following wheat crop than any alternative crop.

Later trials at Erzurum in eastern Anatolia showed that the most profitable cropping sequences included two years under sainfoin for hay (Tosun and others 1987), as this provided valuable fodder when it is most needed.

Janssen's (1972) soil studies during the 1960s in the dry Konya Basin confirmed that under local conditions, the contribution of stored moisture in fallowed land was essential to obtain even a modest yield of wheat. He proposed a tentative model to relate annual precipitation to the need for fallow and nitrogen fertilizer applications (Table 3−3). Many years later, Meyveci and Munsuz (1987) were able to show that just before wheat sowing time, the residual ammonium nitrogen in the zero to 120−centimeter soil layer following legume crops was at least as high as at the end of a fourteen−month fallow period.

At the initiation of the NAD, two−year rotation experiments were started on the Haymana Research Farm of the Field Crops Improvement Center, where the annual rainfall averages 350 millimeters. The first was on deeper soil and began in 1982, and the second, with an identical design but with smaller plots, was started in 1984 on nearby shallower soil. After the first six years Karaca and others (1991, p. 251) concluded that:

Winter−sown wheat crops like Hungarian vetch and lentil, and the spring−sown ones like chickpea and cumin caused some yield loss in succeeding wheat compared to wheat after fallow, but the yield reduction was limited and usually less than 10 percent. On the other hand, it was found that the water use efficiency of wheat following these crops was increased.

A study of the first ten years results of the 1982 trial and the 198892 results from the 1984 trial showed clearly that the conclusions of Karaca and others (1991) remain valid. It is striking that the yields from the plots on which wheat has been grown every year for ten years remain at 1.8 tons per hectare, showing no sign of any decline.

Table 3−9 summarizes the pooled average yields for the two trials up to 1992; however, a full statistical analysis of the data has not yet been carried out by staff of the Field Crops Improvement Center.

Why farmers find it attractive to replace fallow with winter sown, or even spring sown, legumes is obvious. In addition to providing more income, these crops also protect the soil surface from the impact of the rain from the occasional summer storms, and may thus improve the infiltration rate, and hence the moisture storage, for the following crop.

The two long−term trials have been useful in reconfirming the validity of the NAD's basic premise. They were not designed to assess financial returns or continuously to monitor changes in soil temperature and moisture and nutrient content; however, Meyveci and Munsuz (1987) and Meyveci (1988) reported on soil moisture and inorganic nitrogen forms under the various treatments for several seasons of the two−year rotation trails at Haymana. Apparently the investigators did not regularly survey soil microbiology, the incidence of pests and diseases, and the relative occurrence of weed species. In the first phase of these trials the weed density was regularly assessed as reported by Durutan and others (1991).

Table 3−9. Yield of Wheat for the 1982 and 1984 Trials at Haymana Research Farm up to 1992 (average tons per hectare per crop)

Crop	*Wheat yield*
Continuous wheat a /	1.8
Wheat following fallow a /	3.4
Wheat following winter sown legumes a /	
Hungarian vetch for hay	3.3
Lentils	3.0
Wheat following spring sown legumes b /	
Lentils	3.0
Chickpeas	2.8
Wheat following spring sown nonlegumes b /	
Cumin	3.1
Sunflower	2.7
Safflower	2.3

a / Wheat stubble burnt after wheat harvest.

b / Wheat stubble turned with a moldboard plough before winter to control weeds, followed by cultivation in the spring to prepare a seedbed.

Source: *Annual Reports of Haymana Research Farm.*

Durutan (personal communication, 1992) has reported on numerous experiments to determine alternative crop management systems for different economic conditions, soils, and availabilities of managerial skills. The crop management system is important not only for the crop replacing the fallow period, but also for the wheat crop, starting from soil tillage and continuing to harvest. The management elements comprise the seedbed preparation system; the seeding quantity and method, including date and rate; the fertilizer application method; the timing, rate, and type of fertilizer used; and integrated pest management, particularly weed control. Researchers have studied each of these management elements to improve the management advice to farmers to enable them to achieve acceptable and financially viable crop yields.

Although completeness of stand establishment is important for all crops, it is crucial for legumes. Good stand establishment requires good seedbed preparation. Therefore, management system studies have given high priority to soil tillage and seedbed preparation. Soil tillage is essential to increase water infiltration into the soil, reduce runoff, conserve the soil, reduce weed infestation, and achieve sustainable crop production. The Field Crops Research Institute emphasized this issue and carried out various experiments on seedbed preparation for winter vetch, wheat and spring lentil, wheat systems to provide farmers with a range of options that were adjusted to their ecological (climate, soil, topography) and socioeconomic conditions (farm size, labor availability, equipment park, access to markets, and so on) (Karaca and others 1989).

Weed control in legumes is a key component of the management system studied at the TARM. The major yield limiting factor in dryland areas is the moisture supply, therefore, economic and stable production can only be achieved through more efficient use of the limited soil moisture. Controlling weeds is one of the most effective means of increasing the amount of water available to the crops, and so of increasing the efficiency of water use. The success of the farming system depends on combining herbicides with various agronomic practices appropriate for the particular dryland areas. Agriculturists recognize that farmers can achieve the most dependable results in weed control, as well as in other areas of pest control, by combining various methods that supplement each other into a management system. Since the TARM adopted an integrated approach, investigators have tested various treatments in every component of the package to determine their effectiveness on overall weed control (Durutan and others 1989).

Commentary

The fallow reduction program in Turkey has been implemented very rapidly in a semi−arid region that many would not recognize as being capable of more intensified farming than had been practiced for thousands of years. This change has occurred as a result of deliberate public sector decisions and actions taken in the early 1980s. The most important of these was to promote a more open economy with an emphasis on increasing exports from all sectors. For the agricultural sector this included, for the first time, special attention to pulses. The public sector marketing system was modified to provide an assured outlet for pulses at annually determined floor prices. This provided the positive context for rapid expansion of the output of pulses and the active involvement of private traders who purchased most of the crop each year.

The necessary public physical investments (roads and port facilities) and a moderate level of social services (schools, health centers) were already in place throughout Anatolia by the 1980s. However, considerable new public expenditures were made for the fallow reduction program in services for farm advisory and research services starting with a pilot project in Corum−Cankiri.

The public sector initiative was promoted and given a scientific basis as a direct result of a symposium held in 1981. It is notable that this was attended by a broad range of scientists and extension workers, but there was little or no direct representation of farmers at this crucial meeting. It is quite unusual that it is possible to date so clearly the inception of a main change in farming practices. The 1981 symposium brought together over 50 years of research results and practical field experience and laid the scientific basis for the fallow reduction program, including defining the needs for further studies.

The farmers of the Anatolian Plateau were quick to adopt recommendations for fallow reduction once they were assured of a market for additional output of lentils and chickpeas; crops with which they were familiar already. The reduction in the proportion of fallow around each village required local community leadership and coordinated action by neighboring farmers to keep livestock off cropped areas. Community action has not yet extended to coordinated layout of fields to minimize soil erosion or to set aside steep land only for pasturing.

Total farm family productivity on the Anatolian Plateau could be improved further in many ways, although reduction in fallow is not advised in areas receiving less than 350 to 400 millimeters in annual precipitation. The following are some important areas of improvement:

Disseminating improved pulse and forage legume cultivars;

Managing water on a microcattachment basis, which would require closer community collaboration for water retention and soil conservation, possibly including water harvesting;

Breeding legumes for pest and disease resistance; particularly green lentil resistance to attack by *Bruchids*.

Improving the timing and methods of pulse harvesting, which is likely to require improved farm machinery;

Increasing attention to improving forage production and management;

Introducing oilseed crops in addition to sunflower and sesame.

The whole agricultural research establishment is being revised and strengthened through a World Bank−funded project. This should provide a good framework for ensuring that the results of research subject to review by both the national and international research community are more widely known internationally. Turkey's experience from implementing the fallow reduction program in Anatolia provides some useful lessons to other countries, namely:

The intensification of farming and raising of living standards may be possible even in apparently marginal and environmentally sensitive areas. To accomplish this the basic "facts of life" must be well understood before changes are made.

The existing farming systems and households may have considerable resources that are seasonally underutilized.

The provision of an assured market and, initially at least, of an attractive guaranteed floor price, are essential when promoting a new line of farm enterprise.

4—
Uruguay:
Dairy Development

Uruguay lies to the east of the Uruguay River, which separates it from Spanish−speaking Argentina. Portuguese−speaking Brazil lies to the northeast, and the River Plate to the south and the Atlantic Ocean form Uruguay's remaining boundaries. The country covers about 177,000 square kilometers, lying mainly between thirty to thirty−five degrees south latitude and fifty−three to fifty−eight degrees west longitude. The temperate climate and the extensive, open, natural grassland areas have resulted in the overriding importance of livestock ranching within the agricultural sector. By 1908 Uruguay already had 8 million cattle and 26 million sheep grazing the rangeland, equivalent to 11.6 million livestock units (a livestock unit is equivalent to one adult cow or steer or five sheep). This aggregate number of livestock units remained remarkably steady through 1992, when livestock numbers were estimated at 9.5 million cattle and 25.7 million sheep (12.1 million livestock units) (Table 4−1).

For several centuries the export of wool and hides has been important. With advances in meat processing, conservation, and international transport, beef exports became extremely important early in the twentieth century, and reached a peak in the 1980s. Until 1979, the export of dairy products was not important. Within the subsector, beef cattle and sheep production have been and remain the main economic activities, accounting for more than 70 percent of the gross value of production. The preeminence of beef cattle and sheep is not likely to change in the medium term, given Uruguay's natural resource base and socioeconomic structure, but dairying has increased in relative terms through the development of export markets, particularly in neighboring countries.

Uruguay's dairy industry started as a series of dairies in Montevideo. These were often owned and managed by settlers who had come to the country from the mountainous areas of northern Spain, Italy, and Switzerland, and were familiar with the system of carting forage to cows kept in stalls and selling milk from handcarts pushed around the city.

As the city of Montevideo expanded, the demand for whole milk and dairy products increased rapidly. People started dairy farms along the limited number of roads and railway lines leading to the capital city. They also transported grain and by−products into the city to supplement the feed of the stallfed cows. Most of the cereal products came from the newly ploughed grasslands close to the city and south of the River Santa Lucia Grande in the department of Canelones. Eventually, the continuous growth of cereals in this region led to serious sheet and gully erosion and the abandonment of much of the area. Recently, however, it has been rehabilitated for intensive dairy production as outlined in this chapter (see map of Uruguay). In the 1930s a severe milk price war broke out between six or so milk distributors in Montevideo, which led to producers receiving very low prices. They therefore cut milk production. The Cooperativa Nacional de Productores de Leche (CONAPROLE) was formed in 1935 with a monopoly of Montevideo's pasteurized milk market, which it retained until 1984. During this period the government developed a system of administered whole milk prices and provided dairy producers with an assured market and supporting services. Milk output increased steadily, and milk

Table 4−1. Livestock Population, Selected Years, 18521992 (million head)

Year	*Cattle*	*Sheep*	*Total*	*Ratio of sheep:cattle*	*Total livestock units*
1852	1.9	0.8	2.7	0.4	2.1
1860	3.6	2.0	5.6	0.6	4.0
1900	6.8	18.6	25.4	2.7	10.6
1908	8.0	26.0	34.0	3.3	11.6

1930	7.1	20.6	27.7	2.9	9.8
1951	8.2	23.4	31.6	2.9	11.3
1965	9.2	21.9	31.1	2.4	11.7
1970	8.6	19.8	28.4	2.3	10.8
1974	10.7	14.7	25.4	1.4	11.4
1978	10.0	16.1	26.1	1.6	11.2
1979	10.3	17.3	27.6	1.7	11.7
1980	11.2	20.4	31.2	1.8	12.6
1981	11.4	20.4	31.8	1.8	13.2
1982	11.2	20.3	31.5	1.8	13.0
1983	9.7	20.1	30.1	2.1	11.8
1984	9.1	20.6	29.7	2.3	11.2
1985	9.4	21.2	30.6	2.3	11.8
1986	9.3	23.9	33.2	2.6	14.1
1987	9.9	—	—	—	—
1988	10.3	—	—	—	—
1989	9.4	—	—	—	—
1990	8.7	—	—	—	—
1991	8.9	25.9	34.8	2.9	11.9
1992	9.5	25.7	35.2	2.7	12.1

— *not available.*

Source: *18521986:* World Bank data; *198792: El Observador Economico (1992).*

consumption per head rose to the sixth highest in the world. During 196570, seasonal milk surpluses arose, which by 1977/78 had become serious. This led CONAPROLE to seek and develop export markets and to build processing plants for all forms of dairy products throughout the milk production area. By 1992 CONAPROLE had sixteen milk plants, and the domestic whole milk market, whose price continues to be administered, accounted for only 30 percent of milk output. Since 1980 other local and export milk collection, processing, and marketing firms have built more than fourteen plants distributed throughout the dairy production area and have provided strong competition to CONAPROLE, which nevertheless is still the market leader. Izaguirre (1982) reported that in 1976 Canelones, Florida, and San Jose contributed 61 percent of national milk production, Colonia contributed 17 percent, and the rest of the country contributed 22 percent.

After World War II, milk production increased rapidly in the 1950s, and then, during a period of political tension in the 1960s and 1970s, stabilized at 700 to 800 millions of liters per year (Table 4−2). As the consumption of dairy products per capita was already among the highest in the world, and population growth was moderate—2.9 percent total fertility rate in 1970, with 1995 as the assumed year of reaching a net reproduction rate of 1 —experts realized in the 1980s that promoting dairy exports would be necessary to enable the subsector to develop. This would have to be accomplished in the face of difficult international market conditions, which had already caused serious difficulties to the beef and wool exporters. The transformation was achieved successfully: with the national dairy herd remaining at about 660,000 on 6,000 farms, annual milk production increased to more than 1,100 million liters per year in 1992, and the value of dairy exports increased from US$4 million in 1978 to US$68 million in 1991.

Table 4−2. Average Annual Milk Production, 194992 (millions of liters)

1949 53	*1954 58*	*1959 63*	*1964 68*	*1969 73*	*1974 78*	*1979 83*	*1984 88*	*1989*	*1990*	*1991*	*1992*
480	610	720	687	706	719	804	893	952	975	992	1115

Sources: *194963: Izaguirre (1982, pp. 11523); 196492: OPYPA (various reports).*

Local Conditions and Natural Resources

Uruguay's potentially productive area covers a total of around 16.5 million hectares, of which 88 percent is used for livestock production under three main systems:

Extensive beef cattle and sheep ranches, with little or no cropping, located in the northern, central, and eastern regions.

Extensive or semi−intensive mixed livestock and cropping in the western and southwestern regions, with more limited areas involving mixed livestock and rice production in the eastern areas.

About 6,000 dairy farms, mainly in departments adjacent to Montevideo, but also in other parts of the country near urban centers, which often include both livestock and cropping activities, and total about 1 million hectares. Most dairy farms are small in area and dedicated almost exclusively to milk production. Some large ranches have established dairy enterprises on part of their landholdings.

Rolling grassland covers most of the country, with trees naturally present only along water courses and some spring lines. However, introduced tree species (pines, poplar, and eucalyptus) grow well in planted shelter blocks or as wind breaks. Some ecologists have suggested that thousands of years ago extensive forests may have covered much of the Southern Cone of Latin America, including Uruguay.

The natural grasslands include well over 100 plant species, generally growing in a dense, short sward. Any square meter of native grassland often has at least twenty species growing within it. Even though livestock have grazed most of these grasslands, in some cases for more than 300 years, they retain most of their original ecological structure and species diversity. Those grasslands under the first two systems above could still be considered wild lands, defined as natural land and water areas modified only slightly or not at all by human society. Although extensive cattle and sheep ranching has modified these grasslands, they continue to provide a suitable habitat for most species of Uruguayan wildlife, and still support well over 90 percent of the animal and plant species present when the first Spaniards arrived.

In the south, especially close to Montevideo, much of the area was ploughed up for wheat production in the 1920s and 1930s, when tractors became widely available. The continuous growth of sugarbeet and maize as well as wheat led to serious degradation of the soil structure, and before long to serious sheet and gully erosion. The most serious erosion occurred in northeast Canelones. Other, more localized, areas of severe degradation include portions of the departments of Florida, Lavalleja, Maldonado, Paysandu, Rocha, and San Jose, and around the towns of El Carmen and Melo. The continuous cropping system had disastrous consequences leading to (a) erosion, (b) loss of soil structure as a consequence of very low organic matter; and (c) very low crop yields. The introduction of sown pastures has arrested this process and helped recuperate part of the soil productivity. Legumes (mainly clovers, trefoils, and medicagos) have adapted very well to the local soils, incorporating nitrogen and improving the nonlegume production (mainly grasses). After several years of sown pastures a rotational system was developed for commercial enterprises. This system alternates medium−term sown pastures with seasonal crops (oats for winter and sorghum for summer). In recent years hybrid maize for silage has been incorporated into the rotation and new varieties of wheat and barley are grown for early grazing before they are ready for grain harvest.

The main dairy production area includes much of the south, and then runs northwest along the east bank of the Uruguay River. The main soils are vertisols, brown earth soils, and mollisols, generally with 3 to 4 percent of organic matter, pH between 6 and 7, and high total base status, but low in phosphorus at around 3 parts per million. Applying 400 kilograms per hectare of single superphosphate or the equivalent amount of phosphorus in a compound fertilizer can usually raise the phosphorus level to 7, or even 12, parts per million, but within five years the level in the top 15 centimeters of soils usually drops back seriously.

Rainfall is fairly evenly distributed throughout the year; however, the much cooler weather of the winter months (April to August) leads to a sharp drop in pasture productivity during that season. The management of cattle grazing and forage supplies in the winter is the most crucial part of livestock farming in Uruguay. Sunshine is generally adequate at all times, with four to six hours per day in the winter, rising to seven to nine hours per day during the summer months (October to March). January is usually one of the driest months, and is also usually the hottest time of the year. Milk production builds up with the rapid flush of new growth of pastures from October, and continues through to January. Table 4−3 presents some typical rainfall and other climatological statistics.

Table 4−3. Annual Rainfall and Evaporation, Selected Departments and Years (millimeters)

	Annual rainfall			*Annual evaporation*	
Site of climatic record station	*Highest*	*Lowest*	*Average*	*Open type A*	*Modified "Penman"*
Canelones	1,428 (1963)	627 (1979)	1,028 (196392)	—	—
Florida	1,750 (1977)	777 (1965)	1,191 (196392)	—	—
Libertad	n.a.	n.a.	1,008 (194860)	1,440 (198190)	1,188 (198190)

— *not available.*

Source: *Meteorological Department (unpublished).*

Of Uruguay's total population of 3.1 million people (mid−1991), 1.3 million live in the capital, Montevideo. Other medium−size market towns in the dairy zone, linked to the capital by both rail and road (Canelones, Colonia, Florida, and San Jose), account for a further 634,000 people. Further to the north, market centers such as Paysandú, Salto, and Treinta y Tres, are fewer and more dispersed and serve mainly the extensive ranching areas.

However, because of the excellent main road reticulation, some dairying is carried out in these more remote areas for consumption in the small towns and processing in the milk plants that were recently built in this part of the country.

Traditionally, landowners have lived in the towns, many of them in Montevideo, leaving the day−to−day ranch management in the hands of field staff, who are usually strong on practical experience, but weak on the technical and financial aspects of farming. Owner−occupiers have been more common on dairy farms, but well−educated young people have been reluctant to live on the farms.

Uruguay has had a strong educational system for many years, including good professional training for agriculturists and veterinarians. The modernization of the dairy sector began in the early 1970s. At first, growth in the dairy subsector was based on improvements on small farms in the south, for example, official estimates are that in 1981, 47 percent of dairy farms had 49 hectares or less. In the early 1980s, the growth in the subsector occurred as a consequence of the lower world market prices for the more expensive commodities (wool, beef, and grains). New dairy enterprises appeared, often taking the place of grain enterprises in the Litoral region. In other cases, the milk enterprise is often part of a large cattle and sheep ranch, usually run with different staff but the same management. These types of dairy farms have now spread all over the country and will continue to do so. This has created the need for new milk processing plants in towns such as Durazno, Melo, Mercedes, Paysandú, Salto, and Treinta y Tres.

The number of family members and workers per farm unit has always been low in Uruguay, which was therefore one of the earliest countries in the world to use large numbers of tractors for crop farming, and also to introduce milking machines extensively before many other developing countries. More recently, forage harvesters and hay−making equipment have become common in the dairy sector. This mechanization has not displaced labor, but has enabled farmers to operate far more intensively on the land they already own or lease.

Market Demand for Dairy Products and Supply of Inputs

The consumption of dairy products in Uruguay is high by world standards and shows little signs of further growth. Acosta (1993) believes that domestic consumption is somewhat more than 260 liters of milk equivalent per person per year, or a total of about 800 million liters a year. The Office for Agricultural Programming and Planning (OPYPA) projects 1993 milk production to amount to around 1,170 million liters, which would leave an average of about 1 million liters a day for export as whole milk and dairy products.

A 1992 analysis (IICA/MGAP 1992) concluded that Uruguay was well placed among Argentina, Brazil, Paraguay, and Uruguay, the four countries of the common market of the Southern Cone countries of South America (MERCOSUR) to export whole milk and cheese to other MERCOSUR members. Furthermore, Brazil has a major import requirement for dairy products of the order of US$130 million per year. Studies by Kaplan and Secco quoted in the IICA/MGAP report provide the costs of production of selected dairy products in the four countries (Table 4−4). These clearly reveal Uruguay's competitive position.

Table 4−4. Cost of Production of Selected Milk Products in Four Latin American Countries, 1992 (US$)

Product	*Uruguay*	*Argentina*	*Brazil*	*Paraguay*
Whole milk in 1−liter polyethylene bags	0.22	0.25	0.35	0.29

(per bag)				
Sbrinz or Reggianito cheese (per kilogram)	2.34	2.87	3.51	3.70

Source: *IICA/MGAP (1992).*

The value of dairy exports has increased rapidly since 1979 (Table 4−5), but even by 1989 it had not equaled the value of rice exports, which stood at US$87 million, and amounted to only 27 percent of beef and mutton exports, which brought in US$223 million. Currently, Uruguay exports dairy products to about twenty countries, including whole milk to Argentina and cheese to Mexico and the United States. For the future, the most secure long−term market appears to be Brazil, however, as Uruguay now can produce dairy products that are competitive at the current very low world market prices, additional markets may be developed in the medium term. Acosta (1993) has commented that based on current expenses and dairy farming methods, meeting the export potential would require increasing the national dairy herd from the current 600,000 head to around 800,000 head.

The rural population has declined steadily, and now accounts for no more than 13 percent of the total population. This is also reflected in the steady fall in the number of farm workers, from 211,000 in 1961 to 145,000 in 1986. The shortage of farm labor, on both family−scale and large−scale operations, has led to considerable mechanization during the intensification of dairy operations.

Plastic tubing became available in the 1950s, and made possible the distribution of water to points in the improved pasture fields, thereby eliminating the need to herd cattle to rivers and ponds for watering. The second major advance was the use of electric fences, which started around 1975 with importation from New Zealand, and became particularly effective from 1985 with the long−line electric fences. Locally−made fences are now available that can activate 60 to 100 kilometers of movable fence line. By 1993 mechanization on dairy farms had been extended to cover almost every aspect of farm management: soil preparation, pasture seeding, fertilizer application, forage harvesting and silage making; milking and milk storage and cooling; water pumping and storage; and manure slurry distribution.

As discussed later, the introduction of phosphate fertilizers to Uruguay was essential for establishing legumes in grazing land. Initially (195080), the emphasis was on upgrading national rangeland for beef cattle and sheep. The practice declined in the 1980s in the rangeland, but rose on dairy farms, where farmers increasingly grew pure stands of legumes: clovers, lotus, and alfalfa. National fertilizer statistics show a sharp decline in the overall annual use of single superphosphate from 146,000 tons in 1979 to 58,000 tons in 1987 but the use of compound fertilizer has increased. The area of sown pastures increased by 100,000 hectares during this period, but rangeland that had been fertilized or otherwise improved decreased by nearly 400,000 hectares (Table 4−6).

Table 4−5. Export Value of Processed Dairy Products, 197892 (US$ millions)

Year	*Casein a /*	*Butter*	*Cheese*	*Milk powder b /*	*Butter oil*	*Other products c /*	*Total*
1978	0.914	0.387	2.138	0.000	0.668	0.223	4.330
1979	1.602	4.285	5.123	1.568	0.775	0.204	13.557
1980	3.599	4.429	8.014	2.880	0.164	0.886	19.972
1981	4.666	11.107	11.157	0.688	0.106	2.553	30.277
1982	6.047	8.863	5.987	2.117	0.317	..	23.331

1983	5.051	22.844	5.376	6.608	0.012	..	39.891
1984	4.294	7.791	7.170	2.725	0.016	..	21.996
1985	7.644	10.942	6.154	3.420	0.745	..	28.905
1986	8.146	9.670	18.985	2.333	1.395	1.971	42.500
1987	6.810	9.876	13.430	6.717	0.228	0.817	37.878
1988	5.732	11.945	13.303	8.433	..	3.242	42.655
1989	7.087	11.047	22.452	15.945	0.641	4.137	61.309
1990	7.134	19.205	21.641	13.679	0.328	11.239	73.226
1991	6.994	6.896	23.315	17.124	0.853	24.564	79.746
1992	6.117	2.634	21.883	6.203	0.015	27.590	64.442

. . *negligible.*

a / Including sodium caseinate and caseine lactate.

b / Including full cream and skimmed milk.

c / Including sweet cream, dulce de leche, protemilk, fresh milk, cream and condensed milk.

Source: *FAO (1992); OPYPA 1992.*

Table 4−6. Changes in the Area of Pasture and Forage Crops, Selected Years (thousands of hectares)

Category	*1979*	*1987*	*1992*
Permanent sown pastures	544	644	737
Improved rangeland	890	521	517
Annual forage crops	228	189	305
Total	1,662	1,354	1,559

Source: *IICA/MGAP (1992).*

The most important contribution of the Comission Honoraria del Plan Agropecurio (PLAN) was to introduce and stimulate local production of seeds of improved pasture grasses and legumes. The need to support pasture improvement led the PLAN to establish a unit to produce *Rhizobium* inoculum for farmers to mix with the legume seeds at the time of sowing to initiate nitrogen fixation. More recently, dung−consuming species have been introduced on a pilot scale, including earthworms *(Lumbricus americans)* and scarab beetles, to accelerate the decomposition of manure on intensively stocked and rotationally grazed improved pastures.

The PLAN was also responsible for importing milking machines in 1968 and 1969 for sale to dairy farmers, and pasture seed and forage harvesting machinery ten years later. Subsequently, commercial firms and farmers' associations took the lead in introducing more advanced farm equipment, such as the microchoppers one farmers' association imported from Germany. In recent years, sales of mechanical manure spreaders and irrigation equipment for forage crops and intensively managed legume pastures have increased.

Institutions and Investments

Many institutions play important roles in Uruguay's dairy industry. They can be broken down into three groups as Table 4−7 indicates.

The Ministry of Livestock, Crops, and Fisheries (MGAP) has overall responsibility for sectoral polices; however, ranchers and farmers have never viewed it as an operationally effective entity. In response, the government established the PLAN in 1955 to promote improved management of grassland and livestock, mainly for meat and wool production. During its first fifteen years of operations the PLAN was a particularly effective unit (World Bank 1976). Although it was still under the ministry's general supervision, it operated with considerable autonomy, organized the importation of phosphate fertilizers, and operated an active extension service and farm management monitoring program. Dairy farming was always within the scope of the PLAN's operations, but initially did not receive as close attention as the other parts of the livestock industry. However, the PLAN helped significantly by importing specialized equipment, promoting widespread interest in improving grasslands, and stimulating the public research service Centro de Investigaciones Agrícolas, Alberto Boerger (CIAAB) to undertake research of immediate relevance to the dairy subsector. The PLAN also sponsored surveys of national grasslands and how they might be improved (Millot, Risso, and Methol 1988) and of the stability of pasture composition, particularly the persistence of legumes (Sheath, Pottinger, and Cornforth 1989). However, during the 1980s the PLAN's capacity and reputation declined as the government reduced its autonomy and resources, and its organization as an extension agency deteriorated.

Table 4−7. Breakdown of Institutions Involved in the Dairy Industry

Category	*Institution*
Fully public	Bank of the Republic of Uruguay (BROU)
	Comision Honoraria del Plan Agropecuario (PLAN)
	Ministry of Livestock, Crops, and Fisheries (MGAP)
Partly public	Instituto Nacional de Investigacion Agropecuaria (INIA)
	Junta Nacional de la Leche (JNL)
Fully private	Asociación Nacional de Productores de Leche (ANPL)
	Cámara de Industrias Lactea del Uruguay (CILU)
	Cooperativa Nacional de Productores de Leche (CONAPROLE)
	Federacion Uruguaya de Centros Regionales de Experimentación Agropecuaria (FUCREA−CREA)

Intergremial de Productores de Leche (IPL)

Source: *Author's summary of information collected in the field.*

The government had established the Faculty of Agronomy at the University of the Republic in Montevideo as early as 1907, the National Center for Agricultural Research at La Estanzuela in 1910, and the Rubino Veterinary Institute in Montevideo in 1930. Each of these institutes soon earned a good reputation in their respective fields, but were less successful in integrating their strengths for the benefit of the farming community. The Instituto Nacional de Investigación Agropecuaria (INIA) now manages the National Center for Agricultural Research at la Estanzuela.

One of the first scientists at La Estanzuela was Albert A. Boerger, who was recruited from Germany in 1913. He led the work on both crop and forage improvement, and soon realized the critical importance of winter grazing or winter forage for livestock, and of phosphorus as a key element for all crops, especially legumes. Winter oats were introduced in the 1920s, but it was not until thirty years later that agriculturists understood the importance of *rhizobia* to legume growth, and the whole package of phosphatic fertilizer and inoculated legume seeds was put together on the basis of New Zealand's experience, and introduced to Uruguay by Campbell P. McMeekan (1961), who led a

Food and Agriculture Organization of the United Nations (FAO)/World Bank mission to Uruguay in 1950.

The 1950 mission took place at a key moment in Uruguay's agricultural history, and *el informe McMeekan* is still quoted as a key event. Not only did it lead to an FAO technical mission, but also to a series of seven loans totaling US$71.7 million from the World Bank for livestock development approved between 1959 and 1975. As Rosas, who founded the Federacion Uruguaya de Centros Regionales de Experimentacion Agropecuaria in 1966, pointed out (Rosas 1991):

The CREA [Centros Regionales de Experimentacìon Agropecuaria] movement was not born by spontaneous generation. There had been a fermentation stage which, I judge to have started with the visit of McMeekan to Uruguay at the beginning of the 1950s.

During World War II, La Estanzuela, which was part of the CIAAB, was reduced to being a center for seed multiplication, but it reverted to being a comprehensive agricultural research station in 1964, and during the next fifteen years laid the scientific foundations for the expansion in diary production that took place in the 1980s and 1990s. However, from the late 1970s research resources were curtailed, so that by 1993 the practices of the dairy farming community were moving ahead of the locally verified body of scientific knowledge. The Interamerican Development Bank recently granted a loan to strengthen national agricultural research, which should go a long way to restore the quality and relevance of public sector research.

The former CIAAB has been transformed into a mixed (public and private) organization and its name changed to Instituto Nacional de Investigacion Agropecuaria (INIA). The new system makes the farmers directly responsible for defining research lines and directing funding. Dairy farmers support INIA, paying on the basis of the value of milk delivered at the plant. Regional committees consisting o farmers and scientists are appointed to connect researchers with farmer's organizations, which in turn establish links with individual farmers. This new way of organizing research has brought scientists much closer to farmers.

Early in the 1980s the government tried to set up a dairy authority, but in 1985 this was replaced by a statutory board, the Junta Nacional de la Leche, whose chair is nominated by the ministry. The board's other members are two from CONAPROLE and two from other dairy industry firms, one large−scale and one small−scale milk producer. The Junta Nacional de la Leche is responsible for overseeing the dairy industry's legal, technical, economic, social, and operational frameworks, but is not involved in any procurement, processing, or sales of products.

CONAPROLE was legally established in December 1935 and became operational in June 1936. Its purpose was to assure a regular supply of good quality milk for Montevideo, and it was obligated to buy all milk consigned from any part of the country. It had a monopoly position for Montevideo until October 1984, and continues to have an unconstrained commitment, subject to quality standards, to receive all milk produced in Uruguay.

CONAPROLE's board of directors is composed of five elected members of the cooperative, one appointed by the municipality of Montevideo, one by the Ministry of Industry and Energy, and a supervising official appointed by the Bank of the Republic of Uruguay. The Ministry of Industry and Energy also runs an official quality testing laboratory (the Uruguayan Technological Laboratory {LATU}) to supervise the quality of all exports, including dairy products.

From 1965 to 1970 seasonal milk surpluses remaining after domestic requirements had been fulfilled became increasingly problematic. Thus, from 1972 1976 CONAPROLE's management turned its attention to seeking export outlets and determining how to manage this excess production. CONAPROLE resolved this issue successfully, and each year has absorbed an approximately 5 percent increase in production, while the domestic market has grown more slowly. As more milk has been processed into powder, cheese, casein, and so on, in real terms the prices to farmers have declined, on average, by 3 percent per year. Currently, about 30 percent of milk is sold for local consumption as pasteurized whole milk.

In 1952, CONAPROLE launched a livestock health program that focused on tuberculosis, brucellosis, and mastitis. After the severe drought followed by hail damage in 1967, the cooperative turned its attention to winter forage production. In 1976 it formed an agricultural extension department, which by 1992 had fifty−two veterinarians, twenty−three agronomists, and twenty field agents. This department contributed to the increase in the proportion of improved pastures on members' farms from 7 percent in 1967 to 34 percent in 1990.

About a quarter of the approximately 4,300 CONAPROLE members are organized into 160 groups who usually share specialized machinery and technical assistance agents. About 100 members produce more than 4,000 liters of milk per hectare per year. The system is based on an allowance that CONAPROLE pays to each group to help hire professional assistance. The grant represents the value of 5,000 liters of industrial milk per group per month for each advisor, with a maximum of one veterinarian and one agronomist per group.

In 1992 CONAPROLE had sixteen milk plants distributed throughout the production area. The cooperative's main export markets are Argentina (300,000 liters of whole milk per day), Brazil (milk powder, cheese), Mexico (cheese), and the United States (cheese).

Since CONAPROLE lost its monopoly position in 1984, several private dairy industry firms have been established. In 1993 PARMALAT, a large Italian conglomerate, acquired LACTERÍA, a small local dairy industry, and Nestlé is examining investment possibilities in the dairy industry of Uruguay. The private firms supply both the domestic and export markets in competition with CONAPROLE, which remains by far the largest operation in the dairy industry, but it has not yet fully adjusted and adapted to its new role as one of several industrial competitors.

Dairy farmers are almost invariably members of a local milk producers' association as well as being milk delivery members of the CONAPROLE cooperative system. Ten of the milk producers' associations are represented by the Intergremial de Productores de Leche, which presents dairy farmers' views to the central government authorities. Another important association is the Asociación

Nacional de Productores de Leche. Association members usually have access to a general veterinary facility, and quite often to hay−making and forage harvesting machinery that they can hire.

A recently introduced service some associations are providing is a *campo de recria,* which is a ranch for immature heifers until just before first calving. For example, the Florida Dairy Producers Association (1,000 members) obtained a 3,600−hectare ranch from the agrarian reform agency to raise immature stock belonging to its members. This allows the members to retain only milking cattle on their own farms. Members are classified into seven groups based on the size of their operation, with preference given to the smallest−scale operators. The ranch became fully operational in 1989, and in 1992 had 2,700 head belonging to 230 members. Stock is taken in at eight to fourteen months of age and held until one and a half to two months before calving. The ranch provides artificial insemination services, with the choice of semen from five bulls. The 1992 charge was NUr$20,000 per pregnancy (US$6), but no more than two inseminations per heifer are provided. The rental of the grazing and the cost of supervision and insurance is calculated as the price of 28 liters of quota milk per head per month, or about US$5.60 per month. The insurance fund receives the equivalent of the value of 1 liter of quota milk per head per month, with a limit of 2 percent of the total herd value, which has so far never been approached. This is an important service, particularly for medium and small−scale dairy farmers, as it allows them to concentrate their resources, including time, on the milking herd, while knowing that their replacement stock are under professional supervision and will be inseminated from bulls with high levels of progeny performance.

Uruguay's Centros Regionales de Experimentación Agropecuaria (CREA) (Regional Agricultural Experimentation Centers) movement grew out of a visit to France by Ramlot, who was impressed by the effectiveness of the Central d'Etude des Techniques Agricole (Study Centre for Farming Methods) groups of farmers. These groups share the costs of technical assistance staff, who also carry out field trials on members' land. Members share their experiences, including their financial and technical performance. In 1991 France had nearly 2,000 such groups, affiliated to the Federacion Nationale de Groups d'Etude et de Developpement Agricole (Brosson 1991). Ramlot initiated a similar movement in Argentina, and in 1966 Rosas and others started the CREA movement in Uruguay. By 1992 Uruguay had sixty CREA groups with a total of 600 to 700 members. Twenty of the groups (250 members) consist of specialized dairy farmers. The Federación Uruguaya de CREA (FUCREA) provides common services for all the groups. The federation's central office has about three and a half staff years of part−time staff (one dairy expert, one beef and crops expert, two farm management experts, one group dynamics expert, and one overall coordinator). This team provides training and exchanges of experience and liaison among CREA groups, which are charged based on their location and the number of members. Monthly training days are arranged for CREA staff in Montevideo. CREA members maintain farm management registers ("green folders"). Two training days per year are provided by FUCREA on the maintenance and interpretation of the registers.

Another institution of major importance to the dairy subsector is the Holstein Breeders Association, which has been very effective in ensuring that high−quality bulls and semen are regularly imported and made available to its members, and the township cattle auction yards, which hold weekly auctions to facilitate the buying and selling of livestock.

A National Committee for Dairy Herd Improvement was recently formed with technical assistance provided by the FAO. This committee and the services it offers are entirely managed by the users of the services. Its main activities so far have been to help dairy farmers to use the established system of milk recording for herd management, and to evaluate the genetic characteristics of cows and sires for milk output and composition. This is linked to a new system of milk analysis introduced by CONAPROLE in September 1992 which provides each milk supplier with four analyses a month of the protein and fat content of the milk collected by CONAPROLE.

Public investments in Uruguay have provided an essential basis for the recent impressive expansion of the dairy industry. The extensive railway network was developed more than 100 years ago, essentially to serve the beef and wool industries. It also led to development corridors consisting of small towns with support services for all types of agriculture, including dairying. The main all−weather road system received high priority in the 1960s and 1970s, and now extends throughout the country. More recently, the authorities have focused on feeder roads, particularly in Canelones, Colonia, Florida, and San José, to ensure that the milk collection tankers can reach all the dairy farms throughout the year. The authorities have also made major progress with rural electrification, which is important for operating the milking machinery and cooling tanks that are essential to allow refrigerated milk tanker trucks to collect milk once a day. Water pumps are now installed on almost all dairy farms.

Public education and social services in Uruguay have had high priority, although rather irregular financing, for more than 100 years. This is now reflected in the country having one of the highest literacy rates (96 percent) and longest life expectancies (73 years) in Latin America and among middle−income countries. During the last fifteen to twenty years, support for agricultural research has been uneven and inadequate. The systems currently used in the dairy sector grew from national research in the 1960s and 1970s, but at present the authorities are placing more reliance on farmers trying out systems developed elsewhere, for example, methods of manure distribution and waste disposal.

Milk Production and Output

Between 1980 and 1992 national marketed milk output increased by 40 percent, while the total area of dairy farms remained at about 1 million hectares, the national dairy herd remained steady at around 650,000 head, the number of dairy farms decreased by a third, the average herd size increased by some 44 percent, and annual milk production per head rose by about a quarter (Table 4−8). The substantial intensification in output was achieved during a period in which the real price of milk to producers declined by about 3 percent per year. This obviously created pressure on dairy farmers either to improve their production efficiency or to get out of the business. Both these responses are evident from national statistics.

Table 4−8. Number of Dairy Farms and Cattle and Milk Production, Selected Years

				Annual milk production		
Year	*Number of dairy farms*	*Number of cattle in dairy herds (thousands)*	*Average number of dairy cattle per farm*	*Total (millions of liters)*	*Per farm (thousands of liters)*	*Per head of cattle (liters)*
1970	8,098	584	66	742	83	1,271
1980	8,896	670	75	795	89	1,187
1982	7,208	—	—	818	113	—
1984	6,852	—	—	836	122	—
1986	7,278	646	89	901	124	1,395
1988	6,385	—	—	931	146	—
1990	6,103	658	108	975	160	1,482
1992	5,998	—	—	1,115	186	—

— not available.

Source: *OPYPA (1992).*

Following many years of importing breeding stock and semen, the genetic base of the predominately Holstein national dairy herd has the potential for high milk production efficiency. The limiting factor has been the availability of adequate grazing in the winter months. While most milk was intended for the domestic market, in which regulated prices could be adjusted to reflect the cost of milk production, relatively high levels of concentrate could be fed per unit of output. In 1960 dairy cattle received about 300 grams of concentrate per liter of milk, while the annual output was only 700 to 800 liters per hectare of pasture (Table 4−9). The transformation of the dairy industry has been possible by increasing the productivity of grazing and sharply reducing the use of concentrates. However, recently, as the relative price of grain to milk has fallen, there has been some increase in the amount of concentrates used for high−yielding cows.

Table 4−9. Milk Production, Concentrate Fed, and Grazing Area, 1960 and 1992

Category	*1960*	*1992*
Liters of milk/hectare/year	700800	2,5003,000
Liters of milk/vaca masa/year *a* /	1,500	1,8003,000
Grams of concentrate/liter	300	100
Cattle/hectare	0.36	0.75

a / *The term* vaca masa *includes all female cattle, from heifers just served to dry cows.*

Source: *Field interviews by the author in November 1992.*

The combination of improved management techniques has had a dramatic effect on productivity per adult female animal and per hectare since 1960. Clearly productivity has increased substantially, while concentrate use has declined. The most important reason is the use of mixed pastures of legumes (red and white clover and lotus or bird's foot trefoil) in which grasses such as rye grass and fescue gradually increase over three to four years, followed by two years of maize, sorghum, oats, wheat, or barley for grazing or silage. The quality of grazing land needed improvement since the time of Albert Boerger, but little progress was made until the changes introduced as a result of the report on the 1950 FAO/World Bank mission and the continuing support of the FAO technical mission in the 1950s.

Natural pastures in Uruguay produce only 1 to 4 tons of dry matter per hectare per year, with very uneven seasonal distribution of both bulk and quality, which are both lowest in the winter, and often insufficient to meet the nutritional requirements of livestock. Dry matter production in a particular area varies widely both from year to year and within years, depending on variations in rainfall, temperature, and hours of sunshine. Within any one year, pasture production usually peaks in the spring and the autumn, and has two periods of low growth, in the summer because of high temperatures and moisture stress, and in the winter because of low temperatures. The most critical period in the traditional livestock sector is late winter, when pasture growth virtually stops, and existing vegetation is "burned" by frost and reduced in quality precisely when breeding stock requirements are increasing sharply because of late pregnancy or early lactation.

Until the late 1960s, dairy farmers mainly used unimproved natural pastures and limited areas of oats to produce a greenfed supplement for the winter. In the 1960s the PLAN promoted local adaptation of the recently developed New Zealand system of pasture improvement, which used three alternative approaches:

1. Replacing *all* natural vegetation with mixtures of improved grass and legume cultivars. This involved destroying all natural vegetation through cultivation and sowing into the

prepared seedbed sufficient seed to provide a complete population of new plants of improved varieties. Such pastures are now known in Uruguay as "conventional" pastures.

2. Replacing part of the natural vegetation by introducing seed of selected improved species into the natural sward by sod−seeding or by oversowing. Sod−seeding involves introducing seed and fertilizer in drilled lines using specially adapted heavy−duty seed drilling equipment, while oversowing involves the mechanical distribution of seed and fertilizer by distributor truck or aircraft directly onto heavily grazed natural pasture. Distributed seed is sometimes partially covered by a subsequent light harrowing.

3. Replacing *none* of the natural plant population by improved species, but fertilizing it with phosphate to stimulate the growth of naturally occurring legumes and encouraging them to fix more atmospheric nitrogen, thereby stimulating the growth of companion natural grasses.

Agriculturists soon realized that an initial application of phosphatic fertilizer was essential before any legumes could be successfully introduced into the pasture mixture. The initial application rate recommended was typically 400 kilograms per hectare of 23 percent phosphorus (P_2O_5) fertilizer, and then about half this rate every year depending on soil phosphorus levels.

Legumes are scarce in Uruguay's natural grasslands, probably because of the low soil phosphorus levels, and thus the population of rhizobia in the soil is naturally low. The inclusion of active rhizobia with the initial sowings of introduced legumes was also important. A lotus species introduced from Brazil was found to do well at phosphorus levels as low as 5 parts per million. The red and white clovers require at least 10 parts per million, while alfalfa needs 15 parts per million.

In the 1960s and 1970s, many of the more progressive ranchers showed considerable enthusiasm for rangeland improvement using some combination of the phosphate−legume treatment. In 1976 the World Bank's Operations Evaluation Department quoted this as a successful example of the diffusion of innovations from Bank−supported projects (World Bank 1976), and reported that by the end of 1974, 2.4 million hectares of rangeland had been improved, out of a total of 14 million hectares. Subsequently the decline in the beef and wool markets and the removal of domestic subsidies on fertilizers sharply reduced ranchers' interest in intensifying production from the rangelands. Poor persistence of introduced legumes was a common complaint, probably because ranchers seldom applied supplementary phosphatic fertilizer, and because of the lack of management competence essential to obtain the full benefit from the pasture improvements.

Some dairy farmers had also began to apply the phosphate−legume combination to improve their grazing areas during the same period, and also experienced problems because of the variable and often poor persistency of legumes in their pastures. Confidence in the technique declined, but concurrently a solution was evolving through the development of a ley farming rotation in which crops alternate with pastures, with one or two forage or silage crops following three or four years under improved or "conventional" pasture. Furthermore, instead of sowing mixed grass and legume pastures, agriculturists found that it was far more productive to start with pure stands of legumes sown

at high seeding rates (15 to 20 kilograms per hectare for lotus and 6 to 8 kilograms per hectare for clovers).

After the first year of pure legume pasture, grasses such as Italian ryegrass (*Lolium* sp.) begin to enter the pasture, and by the third or fourth year of grazing, if management is less than excellent, grasses become dominant. Where soil nitrogen has been raised by strong legume growth and intensive grazing, African Star grass *(Cynodon dactylon)*, known locally as gramilla, can become a serious weed. Other problematic pasture weeds are margarita *(Coleostephus myconis)* and cuscuta (*Cuscuta* sp.), which are more common in less fertile pastures (Table 4−10).

Table 4−10. Some Pasture and Forage Crop Characteristics for Dairy Farming in Uruguay

Pasture Species	*Soil Phosphorust Requirement*	*Seeding rate/ha (Kg) Pure stand*	*Mixed stand*	*Sowing period*	*Persistence*
Legumes					
Lotus	Low	1520	10	Feb.−May or Sept.	More persistence
Red clover	Medium	68	4	Feb.−May	2 years
White clover	Medium	68	34	Feb.−May	35 years
Alfalfa	High	about 20	10	Feb.−May	More persistence
Grasses		Characteristics			
Lolium sp Italian ryegrass		Mainly self−seeding			
Festuca arundinacea		Some disease problems, mainly for beef cattle			
Dactylis glomerata		Not much used			
Phalaris tuberosa		Not much used			
Forage crops (for grazing or silage)					
Crops	*Sowing period*		*Harvest period*		
Maize	Sept.−Dec.		Jan.−Apr.		
Sorghum	Oct.−Dec.		Jan.−Apr.		
Wheat	Mar.−May		Grazing from April		
Oats	Mar.−May		and/or cut for silage		
Barley	Mar.−May.		in Nov./Dec.		

Source: *Author's summary of field observations.*

Harvesting surplus pasture grown as hay is a longstanding practice, but quite risky in Uruguay because rain storms can occur at any time to spoil the drying hay. Silage making is far less dependent on fine weather, and as better machinery became available, Uruguayan dairy farmers developed or adopted efficient ways of making low−cost, high−quality silage from a wide range of materials.

In Uruguay silage is made out of two types of crops:

Annual crops: mainly maize or sorghum, and winter crops such as wheat, barley, or oats. There is an excellent set of recommendations available for farmers. Maize and sorghum are cut for silage in late summer (February/March).

Improved pastures (legumes and grasses) cut and made into silage in October/November. The product is often used to complement sorghum grazing in the summer as it has a higher protein content than sorghum.

By alternating legume−based pastures for grazing with seasonal crops grown for mechanically handled silage, the dairy farmers now have a rotation that combines far higher total productivity, improved nutritional quality of cattle feed, and hence a much lower requirement for concentrate feeds, which are almost always produced off the dairy farms. The farms are more self−sufficient and are able to produce a higher output of milk at a lower unit cost. They have avoided prolonging the debate on how to improve the persistence of pasture legumes by recognizing that in practice, except possibly in New Zealand and southern Chile, legumes do not persist unless the standard of grazing management is particularly high and serious droughts are rare. This view is in line with the conclusions of a workshop on the persistence of forage legumes reported by Marten (1989).

Today sustainability as a concept is beginning to be understood. To also achieve maximum output requires a rotation on dairy farms of 2025 percent of annual crops and 7580 percent of sown pasture. In essence, to increase the feed available to milking cows the most important practices are to:

Remove herd replacements from the area devoted to cows in milk.

Make hay or silage or both from material outside the grazing area used by cows in milk.

Introduce concentrates.

Use irrigation (this is just beginning).

In 1963, the government established sanitary conditions that farmers producing fresh milk were required to comply with. CONAPROLE paid a premium price when farmers met these conditions.. The decree specified the minimum requirements for the milking parlor, cooling room, water supply and sewage handling, as well as compulsory health certificates for dairy workers and health requirements for cattle.

All cattle have to be vaccinated annually against anthrax. A veterinarian must vaccinate cows of between three and six months of age against brucellosis. Furthermore, all cattle over one year of age are tested for tuberculosis. Tuberculosis incidence dropped from 4.1 percent of tested animals in 1965 to 0.93 percent in 1992. All animals that test positive for brucellosis or tuberculosis are slaughtered. At present there is a proposal to certify farms that qualify as free from brucellosis and tuberculosis. With regards to foot and mouth disease, the success of the campaign started in 1967 has been such that Uruguay is now internationally recognized as free from foot and mouth disease with vaccination.

An annual California Mastitis Test, given by specially licensed veterinarians, is compulsory for all cows in production. Breeding cattle that are sold, male or female, must test negatively for tuberculosis and brucellosis and be up−to−date with the foot and mouth disease and anthrax vaccinations.

Ectoparasites are not a problem in the dairy areas because herds are under daily surveillance. However, horn fly *(Dermatobia irritans)* has recently appeared in Uruguay and has to be controlled on all farms.

Import restrictions on semen and embryos are quite strict. At present imports from Europe are banned due to the mad cow syndrome present in some European countries.

The development of permanent milking sites, and more recently, the installation of milking machines, has led to the concentration of each milking herd at the same location twice a day for one or two hours. This inevitably results in a concentration of manure and urine, which is both an asset and a liability. A moderate (only about sixty in 1992), but increasing, number of dairy farmers is collecting and distributing waste products on the pastures using manure spreaders (LaManna 1992) and by pumping manure slurry through irrigation pipes. Some farmers have tried producing biogas, but temperatures in the winter months are too low to make this a practical year round option.

The effluent from dairy installations is often drained to local water courses, a few of which discharge into river systems and cause serious localized pollution. Excessive use of chlorine for disinfecting dairies has also give rise to concern, but this practice is slowly declining as other disinfectants are introduced. The effluent from cheese and casein production can cause serious pollution; however, some dairy industrial plants have successfully established pig production units to make profitable use of the milk whey, and thereby reduce river pollution (of course, they then have to arrange for the disposal of the pig manure).

Commentary

The recent intensification of the dairy industry in Uruguay shows how rapidly farming systems can adapt to economic changes and new public policies. The modernization of the dairy industry has followed more than 100 years of farming experience and 50 years (193584) of an assured domestic market at prices generally attractive to farmers. The creation of CONAPROLE in 1935, with the obligation to receive all milk of an acceptable quality, provided the industry with a strong core of security. For many years this structural stability provided farmers with little incentive to intensify production, until surpluses remaining after domestic requirements had been fulfilled became increasingly common. The surpluses had to be disposed of through exports, which thus increasingly exposed the national dairy sector to a discouraging world market scene dominated by subsidized exports of dairy products, particularly by the European Community.

The early and mid−1980s saw an energetic and skillfully managed policy transition that eliminated domestic protection and promoted intensified dairy production, mainly from pasture and forage, including silage. CONAPROLE lost its monopoly on the Montevideo market, but retained, its leadership of the dairy sector. None of this would have been possible without the generally good physical infrastructure (rural roads and electrification) and social services provided by the government and, some believe, the more positive political climate that followed the assumption of power by a democratically elected congress in 1985.

The technical systems used on dairy farms have benefited considerably from the experience of other dairy countries, such as New Zealand and the United States. Local research has also provided useful, although rather sporadic, technical advice for farmers. Nevertheless, considerable scope and increasing need for improvement in some of the most basic performance coefficients of the national dairy herd remain. Currently, only about 70 percent of mature cows are in milk at any moment. The aim should be to obtain a calf per cow per year. With greater attention to raising immature stock, as is possible at the *campo de recria,* bringing heifers to their first service (through artificial insemination) at fifteen to twenty months should be possible. Currently, the average age is much higher, ranging from twenty−four to thirty months. Further improvement is possible in the stocking rate per area using well−proven grazing (60 percent) and forage (40 percent) management practices. Achievable annual productivity targets for the medium term (three to five years) would be 3,000 liters of milk per hectare and 5,000 liters per *vaca masa.* There may be some increase in the use of concentrates once more, because the MERCOSUR will hold down the price of grain imported from Argentina. As the general level of nutrition of the national dairy herd continues to improve, paying attention to the herd's genetic composition is becoming more important. The recently formed National Committee for Dairy Herd Improvement could have an important effect on the intrinsic quality of the national dairy herd.

A wide range of enterprises is engaged in dairy production in Uruguay. Many are of small to medium scale with 20 to 200 hectares, but some are part of large properties covering several thousands of hectares. This diversity is one of the strengths of the industry, and the structure is expected to continue to adjust to economic and social conditions. Some examples are:

The increased contracting of farm machinery by small−scale units.

The venture capital used to invest in cattle, while the farmers own the land, facilities, and manage the whole dairy enterprise.

The possibility of ranchers continuing to set aside part of their properties for dairying.

The collection of milk and the processing and marketing of dairy products is still in a period of rapid change stimulated by the policy changes introduced in the mid−1980s. International food companies are expected to continue to buy out small milk plants, because Uruguayan milk is now internationally competitive. CONAPROLE requires substantial restructuring to meet the active competition from domestic and foreign dairy industry firms.

5—
Colombia:
Associated Cropping in Antioquia

The Republic of Colombia lies to the extreme northeast of South America, with coast lines on the Caribbean (Atlantic) and the Pacific, and common boundaries with Panama, Venezuela, Brazil, Peru, and Ecuador. The mainland covers about 1,139 square kilometers and lies just north of the equator to twelve degrees north latitude and between seventy and seventy−eight degrees west longitude. The topography, climate, vegetation, and population is dominated by the northern extension of the Andean mountains, which are in three ranges separated by the major valleys of the Cauca and Magdalena rivers flowing northwards to the Caribbean. The Andean region is highly populated, while the Orinoco and Amazon lowland plains and the Pacific coastline are sparsely inhabited, so that at a national level the population density is only about twenty−nine people per square kilometer.

The medium temperature zone of the country (seventeen to twenty−four degrees centigrade) covers only 10 percent of the country and is entirely in the Andean region. The several tribes and many clans of the Amerindian people have lived here for many centuries, since well before the Spanish conquest. These temperatures occur mainly at altitudes of 1,300 to 2,400 meters. In the areas below 1,800 meters coffee has become the dominant cash crop, while in the higher areas associated food cropping remains the predominant farming system. At one time, rather surprisingly, farmers in eastern Antioquia grew sisal quite extensively, although this crop is generally grown at much lower altitudes in Colombia. More recently dairying and horticulture have become important in the upper areas of Antioquia.

Systems of associated cropping (intercropping and relay cropping) are followed on all Colombian small− and medium−scale food crop farms, and have recently been tried on some medium−scale coffee farms. For example, beans are interplanted among young coffee bushes or just after older coffee has been pruned when there is less competition for light. Even some large−scale sugar estates have experimented with alternating lines of sugarcane with maize and bush beans. Yields from small−scale farmers have traditionally been low, although fairly regular, and have provided most of the maize and beans eaten in the cities. However, generally low standards of living have continued in the upper half of the medium temperature zone, while not far away in the coffee growing areas, family incomes and all forms of physical and social infrastructure have improved steadily and substantially, particularly in the 1950s and 1960s. The Federación Nacional de Cafeteros de Colombia (National Federation of the Coffee Growers of Colombia) (FEDERACAFE), through the local district growers' committees, directed and funded the development programs, particularly in the coffee zone. Since 1963 FEDERACAFE has also promoted the diversification of farming through five programs to reduce reliance on coffee. The World Bank made a US$50 million loan in 1984 to support the fifth phase.

In 1974 the government of Colombia began planning how to close the gap between the standards of living of people in rural, noncoffee areas with favorable ecological conditions and those living in the adjoining coffee zones. This led to the launching of the Desarrollo Rural Integrado (Integrated Rural Development Program) (DRI) in 1976, which received external funds from the World

Bank, the Inter−American Development Bank, and the Canadian International Development Agency (CIDA) for separate geographic areas of the country. The CIDA−funded component was for the northern coastal region, far from any coffee zone.

In the DRI area of eastern Antioquia, the development strategy was to improve access to markets, health services, and schools; to promote new farming enterprises, such as dairying and horticulture; and, in particular, to raise the total productivity of the long−established systems of associated food crops. Up to that time plant breeders and agronomists had concentrated on each major crop (potatoes, maize, beans) separately, whereas farmers were concerned with the complementarity between the crops in growth characteristics and periods to maturity. In the late 1970s the Instituto Colombiano Agropecuario (Colombian Agricultural Institute) (ICA), the International Center for Tropical Agriculture (for beans), and the International Potato Center began to take into account the special requirements for associated cropping, and by the mid−1980s appropriate improved crop varieties had become available.

The many institutional changes that have occurred in Colombia during the past twenty years, including the delegation of many responsibilities to the departments (provinces), makes compiling any long−term series of data on the area and production of crops grown in associated systems difficult. The statistics published by Antioquia's secretary for agriculture show the area, production, and costs of production for each crop, by municipality, for two seasons each year. Table 5−1 shows the statistics for 1989 for seasonal crops for the whole department.

Table 5−1. Crop Areas, Yields, and Total Production, Antioquia, 1989

	Season A			*Season B*		
Crop	*Area harvested (hectares)*	*Average yield (kilograms/ hectare)*	*Total production (tons)*	*Area harvested (hectares)*	*Average yield (kilograms/ hectare)*	*Total production (tons)*
Rice	4,053	4,141	16,785	1,945	3,326	6,469
Maize	63,567	1,048	66,630	62,114	1,112	69,075
Beans	19,023	807	15,346	17,335	1,031	17,873
Potatoes	9,441	17,447	164,193	10,088	17,506	176,598
Tomatoes	579	34,724	20,088	505	32,346	16,319

Source: *Secretary for Agriculture, Antioquia,* Annual Report 1989.

The area of beans indicates the minimum probable area of associated cropping in Antioquia, because beans are almost always grown in association, and the figure is close to Suescún Gòmez's (1990) estimate of 18,000 hectares. Note, however, that farmers grow two crops a year, so each year

they grow at least 36,000 hectares in association. The actual figure is probably higher, since some crop associations do not include beans.

The national statistics for the crops most often grown in association suggest little change in maize productivity in recent years, but significant, though modest, increases in yields of beans and potatoes (Table 5−2).

Table 5−2. Crop Production, Area, and Yields, Colombia, Selected Years

Crop	1980	1985	1990	1991	1992
Maize					
Production (thousands of tons)	853.7	762.6	1,213.3	1,273.6	1,055.6
Area (hectares)	614.4	540.6	836.9	821.8	695.6
Yield (kilograms/hectare)	1,389.5	1,410.7	1,450.0	1,550.0	1,518.0
Beans					
Production (thousands of tons)	74.0 a /	99.0	132.2	129.7	—
Area (hectares)	116.8 a /	131.9	164.6	151.9	—
Yield (kilograms/hectare)	634.0 a /	751.0	803.0	854.0	—
Potatoes					
Production (thousands of tons)	1,726.7	1,910.4	2,464.4	2,371.9	2,281.4
Area (hectares)	142.0	139.1	161.3	151.4	146.5
Yield (kilograms/hectare)	12,159.0	13,734.0	15,274.0	15,665.0	15,565.0

—not available.

a / Figures are for 1981.

Source: *Ministry of Agriculture as quoted in IICA/IFAD (1993).*

An assessment by the Ministry of Agriculture for 1990, quoted by IICA/FIDA (1993) suggests that using 197376 as the base period, yields on small−scale farms had increased by 1988, particularly of potatoes and beans, but also of maize. However, on medium−size and large−scale holdings bean yields changed little, but maize and potato yields have actually decreased since 197376 and are now similar to current smallholder yields (Table 5−3).

The agricultural sector report by the Inter−American Institute for Cooperation on Agriculture for the International Fund for Agricultural Development (IICA/IFAD 1993) confirms that small−scale farmers in DRI areas, including Antioquia, have succeeded in raising their yields of potatoes substantially above the national average. They have also achieved good progress in raising their yields of cassava, plantains, and sugarcane (for *panela* or jaggery) and in achieving a modest advance over national average yields for maize and beans.

Table 5−3. Percentage of Smallholders and Yield Index for Different Size Farms, 1988

Smallholders (%)			*Yield index (197376 = 100)*	
Crop	*Area*	*Product*	*Small−scale farms*	*Medium size and large− scale farms*
Maize	80	69	123	82
Beans	59	58	158	102
Potatoes	89	90	404	71

Source: *Ministry of Agriculture (1990).*

There is ample visual and anecdotal evidence that in eastern Antioquia substantial progress has been achieved in raising the productivity of some traditional, associated cropping systems and generally improving natural resource management. There is also little doubt that the rural standard of living has improved considerably, although the general level of prosperity continues to be greater in the coffee zone than in most of the higher altitude areas of the department.

Local Conditions and Natural Resources

A comprehensive study of eastern Antioquia is available (Chavarriga G. 1992). It was sponsored by FEDERACAFE and the Regional Autonomous Corporation of Rionegro to assess the potential use of soils and their suitability for coffee and other crops. The coverage extended well above and below the current coffee zone and included the whole catchment area of the El Penol hydropower reservoir. For the area in which associated cropping is most prominent and productive (above 1,600 meters), the study identified the two ecological subzones shown in Table 5−4.

The parent material of most soils in the two subzones is volcanic ash, therefore the chemical composition is variable and not necessarily, as often claimed, very fertile. Although initially large amounts of organic matter are found in the top soil, phosphorus content may be so low as to be undetectable by the method used by Chavarriga. For example, the analyses shown in Table 5−5 for two local soils (type Dystropept) are typical of this highland temperate region.

It is not surprising that high yields of food crops could not be produced in this area without soil amendments, despite the favorable moisture and temperature conditions. The high initial organic matter content is readily lost by surface erosion, and nitrogen, phosphorus, and total base levels are low. However, the potassium level is usually adequate.

Table 5−4. Characteristics of the Two Ecological Subzones in Eastern Antioquia

Subzone	*Temperature (°C)*	*Rainfall (millimeters/year)*	*Altitude (meters)*
Very moist low montane forest	*1218*	*2,0004,000*	*1,9002,900*

Very moist premontane forest	*1824*	*2,0004,000*	*9002,000 (coffee 1,4001,900)*

Source: *Chavarriga G. (1992).*

Most of the area has a positive balance of rainfall over potential evapotranspiration every month, although slight deficiencies may occur in January and February. The moisture surpluses drain through the soil profile to feed the streams flowing to the El Penol reservoir and the Cauca River. The township of E1 Carmen de Viboral lies in about the center of the farming area under consideration, and has the average climatic characteristics shown in Table 5−6. Under these favorable climatic conditions and with the prevalent generally deep, well−draining soils, high annual farm output should be possible with good land management and appropriate amendments to the nutrient content of the soils, provided that the genetic characteristics of the crops and livestock selected are well matched to local ecological conditions.

Table 5−5. Some Typical Soil Characteristics from Two Sites in Eastern Antioquia

	SON 1		*OR* 1	
Characteristic	*Soil depth 030 cm*	*Soil depth 3140 cm*	*Soil depth 020 cm*	*Soil depth 2192 cm*
Organic matter (%)	14.50	6.70	7.10	3.40
Nitrogen total	0.59	0.27	0.23	0.09
Phosphorus (parts/million)	0	0	1	0
Potassium (mEq/100 grams)	0.30	0.41	0.11	0.09
Calcium (mEq/100 grams)	5.7	1.3	0.20	0.10
Magnesium (mEq/100 grams)	1.0	0.3	0.10	0
Cation exchange capacity	33	24	20	12
Aluminum (mEq/100 grams)	0	0	1.10	0.40
Soil acidity (pH)	5.5	5.7	5.1	5.4
Sand (%)	42	48	40	27
Silt (%)	29	16	42	50
Clay (%)	29	36	18	23

mEq = Milliequivalents.

Note: extraction methods were not given.

Source: *Chavarriga G. (1992).*

The traditional crops were well adapted to the low level of production possible on the nutrient deficient soils, and were usually adequate for family subsistence purposes. As the external market increased through the rapid growth of the nearby city of Medellin and roads for farm access were built under DRI programs, improving both the genetic productivity potential and soil fertility, it became necessary to meet the growing market opportunities (see map of Colombia).

Table 5−6. Location and Climatic Characteristics of El Carmen del Viboral, Eastern Antioquia

Latitude	06° 05′ north, longitude 75° 20′ west
Altitude	2150 meters
Average temperature	16.4° C
Number of days with precipitation	250260
Hours of sunshine per year	1,8002,000
Average annual rainfall	2,624 millimeters
Average potential evaporation	992 millimeters
Average annual moisture surplus	1,632 millimeters
No moisture deficit months	

Source: *CENICAFE 1989.*

Market Demand and Public Policies

The government launched the National Plan for Food and Nutrition in 1976 at the same time as the DRI. The plan was designed to provide an integrated approach to malnutrition among the poorest Colombians, particularly in urban areas. It was initially effective through several well−targeted programs, but in the longer run the situation deteriorated. For example, the average daily consumption of calories per person in urban areas fell from 2,387 in 1981 to 2,015 in 1984 (IICA/IFAD 1993). During the 1980s national per capita consumption of cereal products, edible oil, tubers, horticultural products, beans, plantains, and meat fell. While the supply of potatoes, horticultural products, plantains, and meat appears to have been adequate, people did not have the purchasing power to buy all that they needed. Maize and bean supplies failed to keep up with the demand of the growing population, and other products in short supply during the 1980s included rice, sorghum, cotton seed (for oil), palm oil, sugar, and milk.

Market demand for the main crops of the upper areas of Antioquia has generally been good; however, potato growers faced a major challenge following the improvement of the main highway from Bogota to Medellin. This enabled potato growers in Boyaca to deliver their product to the major market of Medellin at lower prices than the nearby farmers of eastern Antioquia, mainly because yields in Boyaca were generally more than 20 tons per hectare. This market challenge pushed Antioquian potato growers to intensify their production methods and improve their market presentation by washing the potatoes and packaging them in smaller plastic mesh sacks for direct marketing to supermarket outlets. Antioquian potatoes have now regained their share of the Medellin market.

The eastern Antioquian highlands have conditions ideal for producing a local climbing bean called cargamanto. The seed is generally cream colored and speckled with red spots and stripes. This is sometimes referred to as the gourmet bean of Colombia, and commands a premium price over other dry beans. The conditions are not well suited for maize, but farmers grow it for domestic consumption, and once it has matured, sometimes in ten months, the old stalks when bent over provide support for climbing beans of the cargamanto type. The principal marketed products from small−scale farmers in eastern Antioquia are beans and potatoes, although fruit, horticultural crops, and dairy products are growing in importance.

The government sharply reduced price supports and subsidies for crops from 1986, and according to Agudelo (1992), quoted in the IICA/IFAD (1993) report, in 1990 and 1991 the effective producer subsidy was negative for maize, although the effective subsidy for milk rose sharply, and by 1992 accounted for almost the entire flow of subsidies to the sector.

Public policy has had a major effect on the amount and availability of credit for farm investments and operational expenses, particularly on small−scale farms. In eastern Antioquia the Caja Agraria has several branches that provide a wide range of services to farmers, including credit, as well as input supply and farm implements. The government has subsidized agricultural credit heavily for many years, but gradually decreased the level of interest subsidy in the 1980s. The policy adjustments between 1986 and 1990 retained preferential lending terms for small−scale farmers, who still benefited from negative interest rates in real terms. For other farmers the availability of credit from public banks was severely reduced during this period. The officially stated policy is that by 1994 all borrowers will pay uniform interest rates.

For the products important in eastern Antioquia, all marketing is effectively in the hands of private traders, and in the case of potatoes, associations of producers. The government marketing agency has only minor and declining involvement.

Small−scale farmers are present throughout eastern Antioquia, and while they may not have full title to their plots, they generally have secure medium−term rights of occupation and use. The area also has medium−size and large−scale farms, particularly at the higher altitudes, where dairy production is becoming increasingly intensified based mainly on kikuyu grass *(Pennisetum clandestinum)* pastures.

The most significant government actions have taken place through the DRI program, particularly the rural roads component, the reconstruction of the Bogota−Medellin highway, and the research and extension services provided by the ICA mentioned in the next section.

Institutions and Investments

The large number of public institutions, parastatals, and producers' associations in Colombia is grouped under the Sector Publico Agropecuario, formed in 1971. It is chaired by the minister of agriculture, and includes the ministers of development, labor, and health. Among the producers' associations, FEDERACAFE, formed in 1927, is the oldest and most powerful. A similar federation

representing cattle owners, was established in 1963, and there are ten other specialized federations, each with their local committees in the areas of production.

The following seven decentralized public agencies report directly to the minister of agriculture. Of these the ICA and DRI have been the most relevant to associated cropping in Antioquia:

Research and technology transfer	
ICA	− Instituto Colombiano Agropecuario (Colombian Institute for Agriculture)
CCAR	− Colombian Corporation for Agricultural Research
SINAP	Sistema Nacional de Transferencia de Tecnología Agrícola y Pecuaria (National System for the Transfer of Crop and Livestock Technology)

Integrated rural development	
DRI	− Desarrollo Rural Integrado
Land reform and settlement	
INCORA	− Instituto Colombiano para la Reforma Agraria (Colombian Institute for Agrarian Reform)
Irrigation and drainage	
HIMAT	− Instituto de Hidrología, Meteorología y Adecuación de Tierras (Institute for Hydrology, Meteorology, and Land Improvement)
Natural resources, particularly forests and wildlands	
INDERENA	− Instituto de Recursos Naturales Renovables y del Medio Ambiente (Institute for Renewable Natural Resources and the Environment)

There are also two important public commercial entities: the Banco Cafetero, which provides banking services in the coffee zones, and the IDEMA, which markets designated products and inputs. Of the six mixed−capital enterprises, the most important in Antioquia are the Caja Agraria, which provides all farmers with banking and supply services, and the Banco Ganadero, which provides banking services for cattle owners.

Since 1989, the secretaries of agriculture of each department have had a unit whose duties include coordinating with the national Ministry of Agriculture. These are called Regional Units for Agricultural Planning, and since 1987 agriculture secretaries have been encouraged to be more active in providing farm extension services, particularly to small−scale farmers.

The ICA was formed in 1962 as part of a general policy of decentralizing operational units from ministries. It had special responsibilities for carrying out research on food crops and providing backup services for the research stations of the specialized federations of producers, such as those producing coffee, sugarcane, and rice; universities; and nongovernmental organizations. The ICA also provided an extension service that was particularly important for the DRI program. By 1990 the ICA was using only 35 percent of its operational budget directly for research and technology transfer. The balance covered overhead costs, debt service to the World Bank and other creditors, and miscellaneous expenses. Therefore in 1992, the Colombian Corporation for Agricultural Research was formed as a mixed−capital entity to carry out all agricultural research, with financial support from the private sector. The ICA is to provide its existing infrastructure to the Colombian Corporation for Agriculture Research and to continue being responsible for planning, monitoring, and evaluating research operations.

Most of the ICA's responsibility for technology transfer is to be delegated to the National System for the Transfer of Crop and Livestock Technology created by Decree Number 1946 of 1989, and to regional centers for training, extension, and technology diffusion, which will consist of municipal units for agricultural extension within the structure of the departmental secretaries for agriculture, as was originally envisaged in Decree Number 077 of 1987. The agricultural extension units are required by law to provide free technical services to all small−scale farmers, who are defined in terms of their capital assets and family income and composition. In 1991, the department of Antioquia was one of the first to form an agriculture extension unit to serve the 2,000 eligible small−scale farmers within the rural zone of the municipality of Medellin (Corderas M. 1991). The government intends to support the units through the National Program for the Transfer of Agricultural Technology, with financial support from a World Bank loan and the regional centers for training, extension, and technology diffusion.

Since 1987 the DRI has reported directly to the minister of agriculture. However, for most of the first two phases of the DRI (197682 and 198288), the central planning, coordinating, and evaluation unit was in the National Planning Office, and existing specialized units of the various ministries, including the Ministry of Agriculture for research and extension by ICA staff, carried out all component activities. Other important components were rural roads, electrification, domestic water supply and hygiene, rural primary education, and health clinics.

The municipalities of Antioquia in which coffee was not important were included in the first phase of the DRI. This led to substantially improved internal communication and better access to the main highways leading to the important market of Medellin. In addition, major improvements were made by extending rural electrification to all municipalities and improving schools and clinics. In contrast with integrated rural development programs in many other countries, the first two phases of the DRI program in Colombia had a major and positive impact on the standard of living in areas such as eastern Antioquia, where the ecological conditions permitted intensifying farm production without detriment to the area's natural resources. The changes evident in eastern Antioquia between 1974 and 1992 are striking, and include positive improvements to natural resource management, for example, eliminating sisal, reducing the use of stakes for climbing beans, and encouraging more general adoption of planting crops along the contour.

The ICA research station of La Selva near Rionegro in eastern Antioquia has played an important role in plant breeding and research into better soil management for associated cropping systems in the surrounding areas. This was an integral part of the DRI for which the ICA created a special program for research on associated cropping systems in 1979, but which, regrettably, it closed in 1989. During the time of the research program, the staff of La Selva conducted a wide range of investigations of existing systems and of the characteristics required in crop varieties to enable them to fit into combined and relay farming systems. Little, if any, of this work was published, except as mimeographed papers presented at national conferences (Rios B. and Roman V. 1987; Rivera G. 1990; Suescun G. 1990). This valuable work would be of interest in many parts of the world, but is not known outside Colombia. Apparently ICA's management cut out the associated cropping program in preparation for the transfer of research responsibilities to the Colombian Corporation for Agricultural Research, and the unlikelihood of any private sponsor agreeing to finance further work on associated cropping systems, which are important only on small−scale farms. As part of the latest reorganization of the ICA's operations, it is planned that the ICA will be able to restore its research programs relevant to small−scale farmers through its existing field stations, which will be known as regional centers for training, extension, and technology diffusion, and will provide technical support to all the municipal units for agricultural extension, but this has not yet been done.

Factors and Systems of Management for Associated Cropping

Associated cropping can be practiced in four distinct ways (Ruthenburg 1971):

Mixed intercropping is the simultaneous growing of two or more crop species in an irregular arrangement, without a well−defined planting pattern.

Row intercropping is the simultaneous growing of two or more crop species in a well−defined row arrangement.

Strip intercropping is the simultaneous growing of two or more crop species in strips wide enough to allow independent cultivation, but at the same time sufficiently narrow to induce crop interactions.

Relay intercropping is the planting of one or more crops within an established crop in a way that the final stage of the first crop coincides with the initial development of the subsequent crop or crops.

Intercropping crop species with similar growth durations is advantageous in the use of space only, whereas the association of crops with different growth durations results in a gain in total yield through better use of space, light, and time (Leihner 1983).

As summarized in Table 5−7, the cropping combinations and sequences practiced in eastern Antioquia (Suescún G. 1990) all fall into the row and relay cropping categories.

The three−crop relay (potato ↔ maize ↔ beans) lasts about fourteen or fifteen months. The exact timing of planting is not critical because of the climate's uniformity, with adequate moisture throughout the year. The most favored periods for maize planting are either late February to mid−March or between August and September. Beans are sown about five months later as the maize is approaching maturity. The period varies considerably with altitude; as the altitude increases the maize matures more slowly. At the time of bean sowing, or shortly thereafter, farmers strip off the lower six or seven leaves on the maize stems to provide the beans with more light, and bend the stems ninety degrees at about 1.6 meters from the ground to form a trellis along which the beans can grow while the maize cobs dry out for harvesting.

Table 5−7. Six Typical Cropping Sequences and Combinations Used in Eastern Antioquia

1. Type municipalities: La Ceja, La Union
   potato ■ potato ↔ maize ↔ Kikuyu grass pasture 34 years
   potato ■ potato ↔ maize ↔ Kikuyu grass pasture 34 years, etc.

2. Type municipalities: Carmen de Viboral, Marinilla, parts of Rionegro
   potato ↔ maize ↔ beans (bush or climbing) ■
   maize ↔ climbing bean ■ potato ↔ maize ↔ beans (bush or climbing), etc.

3. Type municipalities: as for system 2
   potato ↔ maize ↔ climbing bean ■
   potato with bush beans ■ potato ↔ maize ↔ beans (bush or climbing), etc.

4. Type municipalities: Rionegro, Guarne, San Vicente, El Carmen, Marinilla
   maize ↔ climbing bean ■ maize ↔ climbing bean, etc.

5. Type municipalities: La Ceja (not common)
   potato with *arracacha* and alternate rows of bush beans

6. Type municipalities: El Carmen de Viboral and Marinilla
   potato with peas ■ maize ↔ climbing beans ■ potato with peas ■
   maize ↔ climbing beans, etc.

■ *Gap between crops for land preparation.*

↔ *Cropped in relay.*

Source: *Suescun G. 1990.*

As soon as the beans are harvested, the farmers immediately prepare the land for potato planting. This is the time for soil amelioration, and most farmers apply about 0.5 tons per hectare of lime (or dolomitic limestone) along the furrows before potato planting, and many also apply 2.0 to 3.0 tons per hectare of dried poultry manure. These innovations were introduced through the DRI/ICA program, and have been widely adopted and proven effective. The rapid expansion of intensive poultry production in Colombia has meant that poultry manure is widely available, particularly close to big cities such as Medellin. The improved reticulation of rural roads has made possible the distribution of lime and poultry manure throughout eastern Antioquia.

Formerly potato yields in this area ranged from 10 to 15 tons per hectare, but with better soil management and improved varieties the average yield is now about 18 tons per hectare. Where bush beans are grown as an associated crop with potatoes (system 3 in Table 5−7), yields of beans range up to 400 kilograms per hectare depending upon the relative speed of growth of the two crops and how much the potato plants shade the bean plants.

Advances by the ICA and the International Center for Tropical Agriculture in bean breeding and selection have led to cargamanto varieties of climbing beans that mature ten to twenty days more rapidly than the local type. Furthermore, the improved varieties are resistant (ICA Llanogrande) or tolerant (Frijolica L.S.−3.3) to anthracnose disease *(Colletotrichum lindemuthianum)*, which can have a devastating impact on bean yields in some seasons. These improved varieties have spread widely since being released in the mid−1980s. Improved bush bean varieties became available in the late−1980s and

have also proved popular, particularly within the coffee growing zone (Henry 1992; Rios B. and Roman V. 1987). One general complaint among farmers is that the beans of the new varieties are smaller in size than traditional bean types, but the improved varieties are nevertheless continuing to displace older types. The more rapid maturing of the new bean varieties has allowed farmers to reduce slightly the total duration of potato ↔ maize ↔ bean and similar associated cropping systems, while increasing the overall output per unit area. Table 5−8 sets out the characteristics of improved climbing and bush beans.

Maize yields are generally low under these high altitude, cool growing conditions, but the main purpose of the maize is to support the climbing beans while providing food for the farm family. Spacing is usually 80 to 90 centimeters on the square (15,000 to 11,000 sites per hectare) with four seeds per site, later thinned to three plants per site. Fertilizer recommendations are to apply 250 kilograms per hectare (10:30:10) at sowing and 100 kilograms of urea a month or two later, but in practice farmers probably use much less fertilizer, although there is no direct evidence for this. When beans are sown in maturing maize, three or four seeds are placed close to each clump of maize plants to the windward side to help the young bean vines start climbing up the maize. This requires 25 to 30 kilograms of bean seed per hectare.

Fungal diseases of beans are a serious factor limiting production in Antioquia. Important advances have been made in bean breeding for resistance or tolerance (Table 5−8); however, farmers frequently have to apply fungicide sprays. Insect pest are occasionally serious on beans, and on maize diseases and pests also can be locally serious. Control measures are generally well understood by farmers, following many years of intensive farm extension work, and are applied selectively where it is judged that economic loss could be severe.

Two notable improvements in natural resource management have occurred during the last fifteen years or so. First, more farmers have adopted contour planting, although seeing rows planted straight up and down steep hills is still not unusual. It is evident that as farmers grow crops of higher value they devote more attention to land management. In Antioquia moisture is abundant, therefore a major problem is to ensure that heavy rain rapidly penetrates the topsoil by maintaining soil cover and high levels of soil organic matter, and that any surplus is safely drained to the natural water courses. Fortunately, under good management the soil is highly permeable; however, continuing work is needed to control localized erosion. Second, farmers often grew cargamanto beans up individual stakes cut from the nearby forest or purchased. Some 12,000 stakes are required per hectare, which can lead to considerable forest clearing, and currently amounts to about 30 percent of the cost of producing beans grown without maize. As the practice of using maize stalks to train the climbing beans has become widespread, this has reduced forest clearing, provided a supplementary crop and additional organic matter for ground cover and soil improvement, and reduced the cost of production.

Table 5−8. Improved Climbing and Bush Beans

Bean type	*Seeds at 15% moisture: 100 seed weight in grams*	*Vegetative period (days)*	*Protein content (%)*
Climbing beans: cool climate, 1,8002,400 meters altitude above coffee zone			
Cargamanto type			
(ICA Viboral) susceptible to anthracnose.	75	150	22.0
(ICA Llanogrande): Loja Ecuador; joint testing ICA from 1978; CIAT from 1979; regional trials from 1980. Resistant to anthracnose.	50	130	20.0
(Frijolica LS−33): ICA cross of Mexico 235 x local Bola roja; regional trials from 1981. Tolerant to anthracnose.	6064	136144	—
Bush beans: medium climate (coffee zone), 1,3001,800 meters altitude			
ICA Citara (PVA 476); CIAT cross of ICA Guali x ICA L.23; regional trials from 1984.	56	90	—
ICA Cafetero (PVA 916); CIAT cross of BAT 1276 x Peru 69 x Vermelho; regional trials from 1985. Resistant to anthracnose and rust.	45	8090	18.5
ICA Caucaya: CIAT cross of ICA L24 x (ICA 10009 x Mulato Gordo); regional trials	43	7286	21.0

from 1985.

— *not available.*

CIAT = International Center for Tropical Agriculture.

Source: *Rios B. and Roman V. (1987).*

Commentary

The associated cropping systems in eastern Antioquia have received much less study than similar systems practiced in Central America. It is therefore not possible to express Antioquian systems in terms of comparative land equivalent ratios, particularly because some sequences may extend for periods of more than twelve months. The intensification discussed in this chapter relates to improvements in the genetic quality of the crops and the use of soil amendments and fertilizers, using only slightly modified traditional systems of crop association.

The bibliography at the end of this document includes references to many useful papers that are not widely known. However, there is surprisingly little work available on the potato component of the systems outlined in this chapter, although this crop provides one of the main sources of income for smallholders in eastern Antioquia.

Recent agricultural statistics are not available at the level of municipalities and there is little evidence of financial analysis at the level of farm enterprises. Despite these deficiencies in the information base for this chapter, it is evident from field visits made in the mid−1970s and at the end of 1992 that substantial improvements have occurred in farming and in the living standards of smallholders in the highlands of eastern Antioquia. This has been achieved by raising the productivity of land already farmed rather than by extending farms into forested areas. In contrast with the farming systems in Turkey, (chapter 3) or Nigeria (chapter 6), fallowing land had never been a common practice in Antioquia. However, ley farming (potatoes/pastures) is spreading in the region, as well as the intensification of traditional systems of associated cropping.

The experience in Antioquia illustrates the importance of linking crop improvement and agronomic research programs with the characteristics of existing, as well as potential, farming systems. The ICA and the International Center for Tropical Agriculture achieved rapid progress over a relatively short period of ten years in the 1970s and 1980s, and the benefits are evident in the 1990s.

The research results could only be put to practical use because of the major public investment in social and physical infrastructure during approximately the same period. The improvements to the rural roads gave remote upland farmers access to many small markets, as well as to the highway leading to the city of Medellin. An interesting by−product of the highway improvement was that it brought in some cheaper products from distant farms producing higher yields of potatoes than farmers in Antioquia. Initially this was a serious challenge, but it was effective in stimulating Antioquian farmers to pay more attention to crop and market management, as a result of which they were able to regain their competitive position marketing potatoes in Medellin.

The integrated rural development program was effective in Antioquia because of the initial wide gap between actual and potential farm output. Until recently the ICA managed both the agricultural research and farm advisory services, and other experienced and specialized public agencies implemented the other components of the DRI program, such as the provision of rural roads, domestic water supplies, rural electrification, schools, and health centers. This integrated rural development program was one of the few in the world that was broadly successful, and laid the groundwork for the successful, intensification of farming by smallholders in eastern Antioquia.

The improved varieties of beans will continue to spread rapidly, and as the main elements of the alternative intensified relay cropping systems are now widely known, they can be expected to spread still more widely among smallholders as demand increases for their main products, beans and potatoes. The uncertainties and discontinuities in public research and extension systems seem likely to continue, at least in the short term. However, as farming becomes more intensive, there is greater need for a good quality research system. In the medium term a large body of knowledge accumulated by farmers and researchers in the 1970s and 1980s is available, but this may be inadequate to cope with outbreaks of new pests and diseases that may occur under the excellent climatic conditions and continuous cultivation in Antioquia. Resuming integrated research relevant to associated cropping

systems is therefore important because it is now evident that the traditional levels of productivity can be raised substantially, while conserving natural resources such as soil and forests. Continuing modifications will be necessary as knowledge, market and other socioeconomic changes take place to assure the long run viability of the system.

6—
Nigeria:
Associated Cropping in the Forest Zone

The southern part of Nigeria, which lies below the broad sweeps of the Benue and Niger rivers (see map of Nigeria), was originally heavily forested. A large part of this formerly forested area is now classified as derived savanna, but an extensive, very humid forest zone remains south of a line running from Ibadan in the southwest to Enugu in the southeast, where the annual rainfall averages generally exceed 1,800 millimeters. This forest zone has been occupied for many centuries, and has been the site of important civilizations, such as the one centered on Benin City.

Nigeria's population statistics have generated much political debate. The most recent national census found some 10 million fewer inhabitants than previously estimated. The World Bank estimated that Nigeria's total population in 1991 was 99 million people. Voter registration in 1993 provided an indication of the population's spatial distribution. It indicated that about 45 percent of the 39 million registered voters (*Lagos Guardian* June 5, 1993) lived in the forest and delta zones, 6.1 percent of whom lived in Lagos. Assuming that the number of voters is closely related to the total population, a high proportion of Nigerians lives in the south, many of them dependent upon farming in the forest zone.

Population densities are very high in some local government areas, for example, in Anambra state the Ihiala local government area has more than nineteen persons per hectare and the Essa local government area has more than thirteen persons per hectare (World Bank 1992). Population density increases steadily from west to east as shown in Table 6−1 for representative states.

Table 6−1. Population Densities, Selected States (number of people per hectare)

West of the Niger River		*East of the Niger River*	
Bendel (Edo/Bendel)	1.38	Anambra (Enugu)	4.06
Ogun	1.86	Imo (Abia)	6.18

Ondo	2.62	Akwa Ibom	7.12
Oyo (Osun)	2.76		

Source: *World Bank (1992, map 23933).*

Much of the forest area has been converted to a rotational cropping and fallow system. Many years ago fallow periods may have been as long as thirty years. More recently, however, a seven− to ten−year fallow was quite usual. By 1993 the fallow periods to the west of the Niger River had

declined to about five years in the southwest to three years closer to the river (Edo and Delta states). To the east of the Niger River, very little land remains under fallow each year because of the increasing population density.

Throughout the forest zone farmers grow many combinations of crops in association. In the Eastern Agricultural Zone a 1982 survey (Unamma and others 1985) indicated that farmers grew the crops shown in Table 6−2 in four contrasting land management systems.

Table 6−2. Frequency of Four Different Tillage Systems, by Crop, in a Sample of 373 Villages (percent)

Crop	Mound	Ridge	Bed	Minimum tillage
Yam	67	13	0	7
Cassava	60	19	0	13
Maize	16	9	0	17
Cocoyam	33	2	0	5
Vegetables	8	3	10	10
Other crops	9	5	10	8

Source: *Unamma and others (1985).*

There are essentially two groups of cropping associations: yam based (staked yams, maize, and egusi melons) and cassava based (cassava, maize, and egusi melons). The yam−based system dates back to ancient times and predominates in the southeast. Men are responsible for the yams, and great prestige in the community goes to those men who grow the largest yams. The cassava−based system has evolved since the Portuguese introduced the crop to the coastal region around 1558 (Leihner 1983). It is now prevalent throughout the south, particularly in the southwest and central regions. Cassava is a woman's crop.

Traditionally yams and cassava have been planted into irregularly spaced mounds of soil varying from 0.5 to 1.0 meter in height and from 1.0 to 2.0 meters in diameter. Farmers have also planted cassava in yam mounds, as well as maize and melons. The normal sequence has been early sowing of melons, followed by yams, then maize. Cassava is planted some two months later.

These systems were satisfactory while there were long periods of fallow during which soil organic matter and mineral nutrient levels were restored naturally. As farmers had to reduce the length of the fallow periods because of increases in the population, yields declined. Some farmers attributed this to the gods' displeasure; others closer to the oil fields believed that the "strength" of the soil was

being extracted with the oil. While there was at least some period of fallow, farmers left some cassava in the ground for later harvesting for longer than a year after planting. They then dug it up from among the regenerating bush as they needed it. Once annual cropping becomes necessary, as is the case in parts of the southeast, the traditional time for planting cassava, about eight weeks after the yams and maize, is not satisfactory, because the following year the cassava will still be in the ground when the yams and other crops have to be planted.

Nigerian and International Institute of Tropical Agriculture (IITA) scientists have been working on crop improvement through breeding and selection for many years. This has led to substantially improved maize and cassava cultivars, but initially farmers showed little interest in using the improved material, which they did not recognize as having all characteristics superior to those of the traditional varieties. he scientific community, including research workers from many other countries, began to tackle the problems farmers faced at the First National (Nigeria) Cassava Workshop held at Umudike in 1977 and on subsequent occasions (IITA 1989a). During the 1980s researchers conducted field trials of crop association at the IITA, and later at various sites in the southeast managed by the National Root Crops Research Institute based at Umudike. These confirmed that for the highest total yields of yams and maize, cassava should be planted two months after the other crops, although with fertilizer use this interval could be reduced to a month (Unamma and others 1989). However, overlapping cropping cycles remained a problem unless a fallow period followed immediately. Further careful and extensive work led to the recommendation to follow the one−year associated cropping system described later, rather than the traditional relay cropping and fallow system of land management. This one−year system has stimulated great interest throughout the forest zone, but farmers have not yet widely adopted it. Thus this case does not report an intensification of resource management that is already in common use, but describes a system that shows considerable promise and should be of interest to all those concerned with substantially raising the output of small−scale farms without having an adverse affect on the natural resource base.

There is already an extensive body of research findings from West Africa and many other countries on the interactions among associated crops, and these have been interesting trials on alley−cropping systems. However, none of this work appears to have led to widespread modifications to traditional systems of associated cropping, although there are some promising developments, for example, in the Central Visayas region of the Philippines and the piedmont region of the Andes in eastern Bolivia.

Local Conditions and Natural Resources

The forest zone coincides approximately with the very humid and humid the zones, which cover about 35 percent of Nigeria's total area of about 924,000 square kilometers. Table 6−3 provides further characteristics of this agro−ecological zone. The very humid zone is a tropical, lowland, rain forest area receiving an annual rainfall of 1,200 to 2,000 millimeters, with the south receiving the higher levels of rainfall. Human activity has, however, removed most of the forest, and except in forest reserves, the species that occur now are mostly secondary. Much of the zone consists of deltaic alluvial sediments deposited within the shifting Niger estuary, and now extending up to 280 kilometers inland. The soils, both alluvial and those derived from the Basement Complex and sedimentary rocks

further east, are highly weathered and infertile because of the humid tropical environment. General elevation is about 100 meters.

The humid zone is low−lying, centered on the confluence of the Niger and Benue rivers, with the plain rising to 500 meters west of the Niger and below the plateau zone. The annual rainfall of 1,100 to 1,400 millimeters is bimodal in contrast to the unimodal distribution in the north; however, the bimodal pattern is not well marked as some rainfall may occur during the "August break," between July and September, which are usually the wettest months of the year. The extent of deep, but relatively infertile, sedimentary soils is greater than in the subhumid zone east of the confluence and along the river valleys. The vegetation mosaic of woodland, grassland, and rain forest changes gradually, with the latter increasing toward the south. Human activity is steadily reducing the forests. The zone is well supplied with water from the main rivers and their tributaries, and sedimentary deposits are the main source of groundwater.

Table 6−3. Characteristics of the Very Humid and Humid Zones

		Wet season			*Mean monthly temperature (° C)*		
Zone	*Area (square km thousands)*	*Rainfall (millimeters)*	*Distribution*	*Days of rain*	*Maximum*	*Normal range*	*Minimum*
Very humid	129	1,2002,000	Bimodal	250300	33	2428	21
Humid	194	1,1001,400	Bimodal	200250	37	2630	18

Source: *FAO/WBCP (1991).*

Soil fertility depends on complex inter−relationships between chemical and physical characteristics, linked to both inorganic mineral reserves and physical properties. In many Nigerian soils, inorganic sources of plant nutrients are not readily available in the rooting zone of annual crops, because sandy−textured soils in the main plant rooting zone are widespread, and the soils are dominated by clays that do not provide a reservoir of available nutrients. Nutrient reserves are either very low because of the highly weathered nature of the underlying rocks, or occur below the rooting zone. Most of the available nutrients are linked to the soil organic matter, which provides the only means by which essential nutrients can be retained in the rooting zone. At the same time, organic matter plays a key role in maintaining soil physical characteristics. Loss of soil organic matter, which under Nigerian conditions is extremely rapid once the vegetation has been cleared, results in the deterioration of granular structure, reduced waterholding capacity, reduced infiltration rates, surface crusting, and compaction, leading to increased runoff and sheet erosion. Many of these changes, particularly in soil physical characteristics, are irreversible.

The problems described above apply particularly to the most widespread Nigerian soils, the Luvisols and related Lixisols, which dominate the center of the country, occur extensively to the southeast of the Benue, and are found in large areas of western Nigeria. Another soil type, derived from sandstone, is the Acrisols in the Enugu area, noted for their liability to gully erosion once the

vegetative cover is disturbed. The majority of the soils have a low nitrogen and phosphorus status, while potassium levels are generally adequate except in the coastal belt.

Market Demand and Input Supply

Nigeria's most pressing need is to maintain, or sometimes to restore, food self−sufficiency at the farm family level. Given the rapid growth of the urban population, farm demand for food crops is rising. The demand side of the equation presents no constraint to intensification, indeed, it is the driving force that has led to the steady degradation of natural resources. The World Bank (1992) has calculated that family food requirements are increasing at 3.3 percent per year, while yields are declining by at least 1 percent per year with a two−year fallow. As the fallow period is reduced, the average yields go down (Table 6−4). This assumption would allow the aggregate national output to increase for twenty−one years, but it would then rapidly decline as explained in the World Bank report. This model is probably too optimistic as applied to the poor soils of the forest zone.

Table 6−4. Fallow Duration and Yields

Fallow duration (years)	*Yield decline from 2 tons cereal/hectare (percent per year)*
2	1.0
1	2.5
No fallow	5.0

Source: *World Bank (1992).*

The south of Nigeria has a good reticulation of main roads linking the market towns, although road maintenance is not fully satisfactory. Minor feeder roads are extensive, but many may be impassable during periods of heavy rain. There is clearly much room for improvement, but access to urban markets does not appear to present a serious problem. Numerous traders and a few associations of producers ensure an active market for products surplus to farm families' requirements.

The availability of inputs, particularly fertilizers, is a serious problem. This has been one of the reasons for the somewhat slow dispersion of seed of improved maize varieties. In contrast, the recent spread of the mosaic−resistant or mosaic−tolerant cassava cultivars has been remarkably rapid, although some resistant material had been available since 1976. This was started by public agencies, but farmer to farmer sales soon took over as the advantages of the new cassava became obvious and widely known. This rapid adoption was a direct result of the substantial improvements made to the organization and coverage of the state agricultural extension services, particularly through the amalgamation of the National Farming Systems Research Program and the Training and Visit

Agricultural Extension System (between 1982 and 1988), reinforced by a special cassava promotion program financed by the International Fund for Agricultural Development (Unamma 1991).

The most unsatisfactory situation concerns fertilizers, where a curious paradox is apparent. Because of the increased effectiveness of the extension services most farmers now realize that they should apply additional nutrients to land that is not close to their homestead, which receives all domestic waste products. The government is maintaining a substantial subsidy on fertilizers in two categories, high nutrient analysis products and low analysis products, yet little or no fertilizer is available to farmers at the village level throughout the south of Nigeria.

In contrast with the findings of the benchmark survey carried out in eastern Nigeria in 1982, which revealed farmers' limited understanding of or interest in fertilizer use (Unamma and others 1985), by 1993 there was a substantial unsatisfied demand for fertilizers in the same areas. Some farmers reported that they had paid up to five times the official price for the few bags they had been able to find, but they were confident that it was worthwhile.

The government has agreed on many occasions that it should phase out fertilizer subsidies, which constitute a major public cost without any apparent benefit to the supposed beneficiaries, namely, small−scale farmers. Much of the benefit is believed by many in Nigeria to accrue to those who are able to consign the subsidized fertilizers to neighboring countries. The official prices in naira have been raised steadily, but have not kept pace with the devaluation of the naira. The total removal of the subsidy would, no doubt, raise strong protests in political circles, but could assure the availability of fertilizers to the farmers, many of whom now fully understand that they need to use fertilizers while also incorporating as much organic matter as possible into their farmland.

Yam−based farming forms the core of traditional systems in the south of Nigeria. Yams grown under local conditions are individually staked for support, and the stakes have to be 2.5 to 3.5 meters long. While extensive nearby areas of forest or land under bush fallow existed, farmers could cut the stakes and carry them to the newly planted yams with little trouble. Now, however, the provision of stakes can represent a considerable outlay, which according to some farmers' estimates amounts to 30 percent of the cost of production. One of the important advantages of the modification to the traditional yam−based systems as described later is that it requires the same number of stakes for four times the number of yam plants.

Institutions and Investments

The institutional situation in Nigeria is complex and subject to frequent changes, often reflecting adjustments in the relative power of federal and state authorities. The FAO/WBCP (1991, annex 4) land resource management study, on which the following paragraphs are based, with additional information, described the situation in 1991 well.

The main federal institutions concerned with natural resource management and conservation policy are the Federal Ministry of Agriculture and Natural Resources (FMANR); the Federal Environment Protection Agency, which has considerable regulatory powers; and the newly created

Natural Resources Conservation Council, which with the president as chairman, is specifically concerned with the formulation and coordination of a national policy for natural resource conservation.

The FMANR is responsible for the agricultural, livestock, forestry, and fisheries subsectors; the control of pests and disease at the national level; and the execution of two World Bank projects, the Afforestation Project, which is concerned with on−farm tree planting, village woodlots, and shelterbelt establishment, and the Livestock Project, which includes the selection and establishment of grazing reserves and initiatives that relate to grazing, land degradation, and fertility maintenance, including an alley−cropping program.

At the state level, ministries of agriculture and natural resources plan and implement all sectoral activities. Each ministry now includes a department of planning, research, and statistics (primarily concerned with short−term budgetary planning), and some state ministries have active soil conservation units, for example, Plateau state, but these are severely constrained financially.

The World Bank−funded agricultural development projects, implemented under the auspices of the ministries of agriculture and natural resources in each state, are principally responsible for promoting crop production. They are increasingly providing advice to farmers on land resource management and conservation, but programs are still very limited, and institutional arrangements to tackle off−farm land degradation are not very developed. However, with the formation of the unified state extension services, which are being supported through the Bank−funded agricultural development projects, more attention has recently been paid to conservation. Of these projects, the first Multistate Agricultural Development Project covers most of the forest zone states. Since 1981 the Federal Agricultural Coordinating Unit (FACU) has been responsible for supporting agricultural development projects throughout Nigeria.

An extensive network of research stations, formerly under the Federal Ministry of Agricultural and Natural Resources and later under the Federal Ministry of Education, Science, and Technology are currently under the

Federal Ministry of Agricultural and Rural Development, serves the agricultural sector. Of these the National Root Crops Research Institute at Umudike, Umuahia, is the most relevant in this case. This is a long−established research station that has regularly collaborated with the International Institute of Tropical Agriculture (IITA), which is based near Ibadan, Nigeria.

The role of local government authorities in agricultural development and land management remains uncertain. In the long term they might be important in mobilizing community participation in land management programs.

Factors and Systems of Management for Associated Cropping

Associated cropping can be practiced in four distinct ways (Ruthenburg 1971):

Mixed intercropping is the simultaneous growing of two or more crop species in an irregular arrangement, without a well−defined planting pattern.

Row intercropping is the simultaneous growing of two or more crop species in a well−defined row arrangement.

Strip intercropping is the simultaneous growing of two or more crops species in strips wide enough to allow independent cultivation, but at the same time sufficiently narrow to induce crop interactions.

Relay intercropping is the planting of one or more crops within an established crop in such a way that the final stage of the first crop coincides with the initial development of the subsequent crop or crops.

Intercropping crop species with similar growth durations is advantageous in the use of space only, whereas the association of crops with different growth durations results in a gain in total yield through better use of space, light, and time (Leihner 1983).

The traditional cropping system in Nigeria's forest zone has been a combination of mixed and relay intercropping leading to a bush fallow after two to three years. The intensified system developed by research workers at the National Root Crops Research Institute and the IITA corresponds most closely with a row intercropping system that can be repeated annually. As mentioned earlier, the proportion of land under a restorative period of fallow is decreasing rapidly in the forest zone, as in many other parts of the world, because of increasing population density in rural areas. The broad term fallow encompasses four distinct conditions:

Forest fallow, where trees continue to be dominant;

Bush fallow, which consists of dense woody scrub without large stems or trunks;

Derived savanna, where grasses progressively dominate woody species through the effects of drought or fire; and

Savanna, which consists of grasses without woody species dominating.

At the time of the benchmark survey of the eastern region reported by Unamma and others (1985), the proportions of the various forms of fallow were as shown in Table 6−5.

Table 6−5. Frequency of the Use of Specific Fallow Types in 373 Villages in 1982

Fallow type	*Percent*
Forest	9
Bush	56
Derived savanna	20
Savanna	10
None	5
Total	100

Source: *Unamma and others (1985).*

Using traditional methods, farmers plant yams in the center of large mounds of soil spaced at irregular intervals. The advantages of the mounds are that the limited amounts of topsoil and organic matter are concentrated at a restricted number of spots, and during heavy rain the crop is kept above surface flooding. Other crops are planted or sown in the sides of the mound, sometimes in an elaborate concentric pattern. Typically these may include maize, cassava, melons, and other vegetables. This spatial distribution is not ideal for any of the crops, and leads to strong competition among them for light and soil nutrients (Figure 6−2).

The customary timing and sequence of planting is, of course, related to the climate, but is also designed to yield a steady supply of food throughout the year and to minimize the number of hungry months between the harvests of the various crops. A typical sequence is as follows:

November−March:	burning, clearing, and preparing fallow land for planting
January−May:	yam planting, usually with maize, melons, and other crops
March−June:	cassava and cocoyam planting

This should result in the main sources of food being as follows, but this varies substantially depending upon the weather:

April−May:	fresh maize cobs
June−August:	maize grain
September−January:	yams, fresh and stored
February−March:	cassava
All−year reserve:	cassava

Cassava is the last food crop planted before the land reverts to fallow, and some cassava is left in the ground as the bush regenerates. This provides an additional assurance of a food supply if the maize crop is late or inadequate for a family's needs.

Each farmer has secure and continuing access to particular parcels of land within the local community, as well as an area immediately around the family homestead. Each dry season the whole community will clear a contiguous sector of land within which each member may have several plots. The advantage of this communal, coordinated action is that the joint burning and clearing forms a relatively large block of land from which livestock can be excluded. Once the fallow system is totally eliminated, preventing livestock from entering cropped areas becomes much more difficult as there are no livestock−proof fences.

The objective of the revisions to the traditional associated cropping system proposed by Unamma and others (1989) is to make fuller use of the available natural resources, including sunlight, through reconfiguring the crops in space and time. The main crops involved are as follows:

Yams	−White:	Discorea rotundata (Nwopoko or Abii)
	−Yellow:	*Dioscorea cayenensis*
	−Water:	*Dioscorea alata*
	−Green:	*Dioscorea bulbifera*
	−Bitter:	*Dioscorea dumentorum*

Cassava: *Manihot esculenta* (Tropical Manioc Series 30572, 30555 or 4[2]1425)

Maize: *Zea mays* (Tropical Zea Streak Resistant yellow and white)

Egusi melon: *Colocynthis citrulus*, for soup and fried seeds

Fluted pumpkin: *Telfairia occidentalis*, for boiled leaf or seeds and marmite

Okra: *Abelmoschus esculentus,* vegetable

In the revised planting system the land is first prepared to leave ridges about 25 centimeters high and 1 meter apart. Yams and cassava are planted at the same time along alternate rows, or alternating two rows of each crop, with the spacing within rows such as to give a population of 10,000 plants of each crop per hectare. Only one stake is needed for each four yam plants, which requires the same number of stakes per hectare as the traditional system of one stake per mound. Along one side of each ridge two seeds of maize are sown at 25 centimeters between planting sites, while two seeds of egusi melon are sown at the same spacing on the other side of each ridge. This gives a population of 40,000 planting sites for each crop per hectare (Figure 6−2). Fertilizer application is recommended for the maize component of the association at 400 kilograms per hectare of a 15:15:15 compound, but as explained earlier, this is not readily available.1 Obviously the associated crops may also benefit from the fertilizer.

This restructuring of the traditional relay cropping system has many consequences. Among the more striking are the following:

The high seeding rate for egusi melons leads to a rapid ground cover and reduces the number of weedings necessary from three to one per season. However, if growth of the combined crops is very rapid, there may be insufficient sunlight to stimulate many melon flowers, and thus the fruit yield may be limited.

The yield of yams planted from mini−setts is usually raised from around 6 to 8 tons per hectare, but the average size of the yams is less than from mounds. However, the smaller yams have a longer shelf life, which the women value more than the prestige−building monster yams the men value.

The yield of maize may be raised from 0.5 to 1.0 ton per hectare, which is still a low yield for improved maize varieties, and would seem not to compensate for the cost of fertilizers, even at currently subsidized prices.

The yield of cassava may be raised from 8 to 12 tons per hectare and be harvested before it is time to plant the following season's crops. Yam harvesting does not disturb the immature cassava roots, which occurs when both are grown in the same mound.

Additional miscellaneous vegetable crops, such as okra and fluted pumpkin, are generally interplanted irregularly in the homestead or compound garden, which benefits from inputs of organic matter and nutrients from household waste.

1 Proportion of nitrogen, phosphorus as P_2O_5, and potassium as K_2O per 100 units.

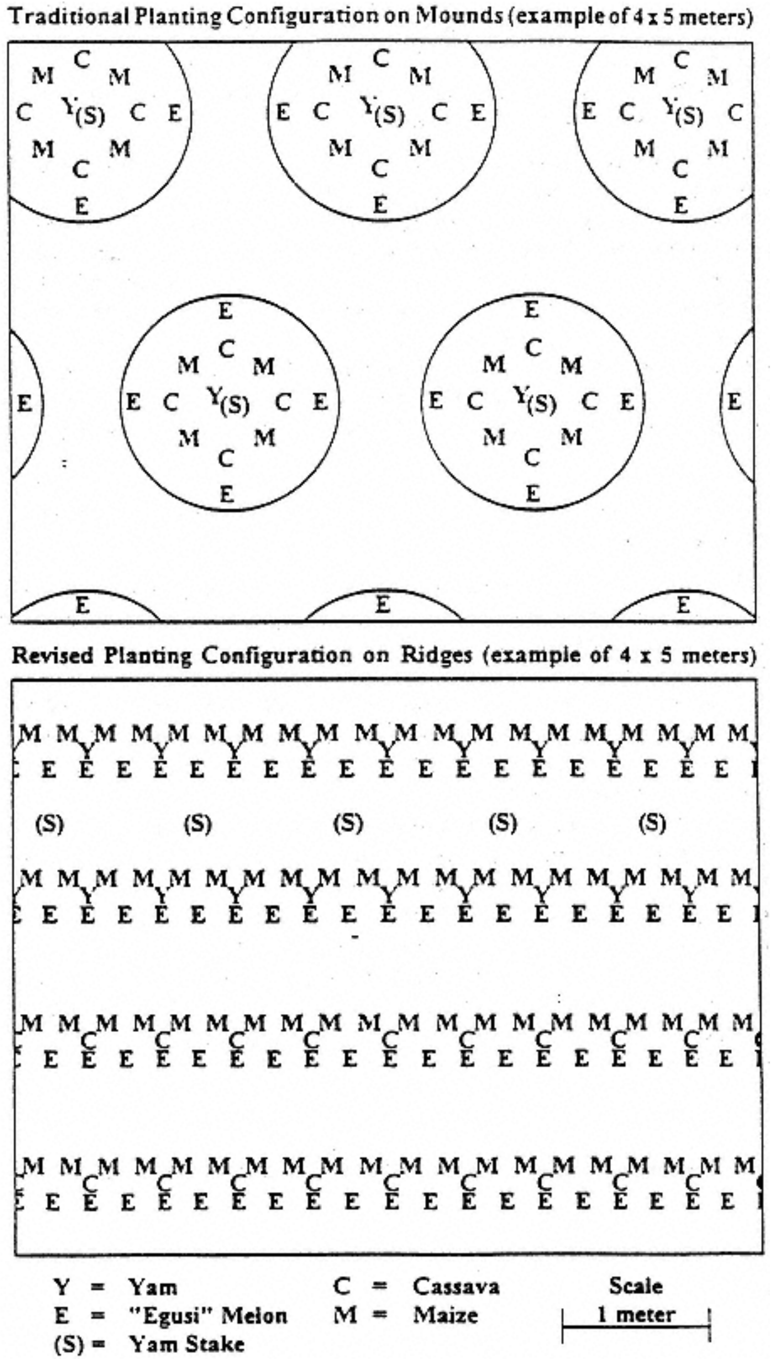

Figure 6−2.
Traditional and Revised Planting Con figurations for Mixed Cropping
Source: *J.A. Nicholas Wallis.*

The combined effects of these various responses over a two−year cycle can lead to savings equivalent to between 45 and 67 percent of land area, based on trials in 1986/87 and 1987/88 reported by Unamma and others (1989).

Since around 1989, the state unified agricultural extension services have progressively introduced on−farm verification trials and demonstrations of the restructured and rephased associated cropping system. These have stimulated widespread interest and led to local variants of the new system, for example, east of the Niger River farmers prefer the single alternate row layout, while to the west the double alternate row layout has been more widely demonstrated. However, even farmers who have seen the benefits through trials and demonstration plots on their own land, so far have rarely adopted the system for their own plantings in the following season.

No doubt many factors are restraining the rate of adoption of the new system, but one should recognize that it has only been promoted widely for about three seasons. The apparently straightforward, simple adjustments to the traditional yam−based or cassava−based cropping associations on mounds may actually require relatively large changes to the farm family's way of life.

In the first place, farmers will be concerned that by restricting cassava to a cycle of not more than twelve months, there is no food security margin to cover crop deficits in the first four to six months of the year. Therefore, until no more land is available to set aside for bush fallow, farmers are likely to be hesitant to move from a relay to a row intercropping system. However, it is possible to plant separate blocks of cassava as late as between June and August to cover food requirements at a critical period in the following year. Furthermore, a simple technology in now available that permits processed cassava (gari) to be stored for more than three months.

Second, time is required to resolve the debate between men and women on the most desirable size of yams. In the long term the women are likely to win, but men still retain a decisive role and many favor mounds for maximum sized yams.

Third, more work is needed to evaluate alternative ways to handle surplus surface water at the height of the wet weather. Mounds raise the crops' rooting zone more than ridges and allow water to flow past according to the general lie of the land. Ridges, by contrast, focus the flow in one direction, which in the absence of an overall landscape drainage plan covering many parcels of land may provoke erosion. Tied ridges have been suggested, but these may restrict the drainage of surplus water.

Fourth, a more productive system will extract more nutrients from the soil, and thus accelerate the rate of nutrient depletion. This is well understood by most farmers, who realize that until they have reliable access to fertilizers, they cannot expect to be able to increase their overall level of production. The intensified system will not be viable without some introduced plant nutrients.

Fifth, how to manage the transition from some bush fallow to no bush fallow at the community level is not clear. Unless the whole community makes the switch in the same season, which is highly improbable, how will the no fallow farmers manage parcels of land interspersed among others with some residual fallow?

The cropping system outlined above lacks any leguminous crop that can contribute to soil nitrogen accumulation. Traditionally, farmers in the forest zone have grown cowpeas on trellises for green pods, but so far cowpeas have not been successfully incorporated as a field crop, mainly because of severe attack by aphids, thrips, *Maruca* pod borer, pod−sucking bugs, and bruchids (IITA 1989b). Agriculturists have considered the use of the African yam bean *(Sphenostylis stenocarpa)* or the tropical lima bean *(Phaseolus lunatus)*, but possibly the most promising legume for integration into the system may be cultivars of pigeon pea *(Cajanus cajan)* adapted to humid tropical conditions.

Clearly, therefore, much further work is needed on crop selection and adaption while changes in social priorities evolve as land area becomes a binding constraint. The valuable research already accomplished and the strengthened alliance between research and extension staff provide a much stronger basis for helping farmers make the major structural change from fallow−based to continuous cropping systems. Provided public policies ensure adequate farm inputs at open market prices, the prospects for more intensive food crop production in the forest zone, without detriment to the natural resource base, are good.

Commentary

In the 1970s and 1980s researchers explored many alternative ways to improve the fertility of tropical soils, or at least to check their further degradation. Many of these attempts built upon observations of traditional field practices without fully understanding the often complex socioeconomic reasons for the existing systems of land and crop management. Many of the traditional systems included long−term fallows, which have become less and less feasible as the rural population has increased.

The public policy in Nigeria has clearly been to raise domestic food production, and the central government has financed agronomic research and farm advisory services for this purpose. Important technical advances were made in the 1980s in understanding more about associated cropping systems, but this was not accompanied with family and community−level social studies to see how the improved technical understanding and new crop varieties could be put to practical use.

The ongoing agricultural extension program concerning the revised associated cropping system includes a large number of on−farm verification trials and demonstration plots, and is rapidly spreading knowledge and understanding across the forest zone of southern Nigeria. Adoption of the new configuration and timing of the crops is advancing more slowly, however. This may be because the degree of land pressure varies, intensifying from west to east. Adoption of the new systems may be expected where there is no longer any possibility of leaving land fallow, even for one year. Moving from the traditional systems based on one or more seasons of fallow to continuous farming represents a major social and economic transformation, which apparently has not yet been fully analyzed or understood. It implies a major change in how communities operate and, particularly regarding yams, in how families make decisions. Farmers can only achieve the full benefit of the recommended changes if modest amounts of nitrogen and phosphorus fertilizers are reliably available, and in Nigeria this is not the case.

The most exciting lesson for others dealing with reduced land availability in high rainfall areas is that there are major opportunities to intensify production through modifying the spacing and temporal relationships among traditional crop associations. As the total output increases, introducing some phosphatic fertilizer and retaining as much crop residue and other organic material as possible in the field is usually necessary. Nitrogen is also required, although the quantity may be reduced if a legume can be found that is compatible with the association, is resistant to the most common pests and diseases, produces a marketable product, and is shown to be associated with *Rhizobia* that are effective in fixing atmospheric nitrogen.

7— Brazil: The Cerrados Region

Brazil is the sixth largest country in the world, with 8.5 million square kilometers of mainland area (larger countries are Russia, with 17.1 million square kilometers; Canada, with 10.0 million square kilometers) China, with 9.6 million square kilometers; and the United States, with 9.4 million square kilometers. The complex of ecological conditions in Brazil covered by the collective term *Cerrados* extends to just over 2.0 million square kilometers (204 million hectares), of which experts believe that as much as 137 million hectares (67 percent) could be brought into arable farming, which is greater than the total land area of Peru or South Africa. Of this potential cropland area, at the beginning of the 1970s about 4.6 million hectares (3 percent) was under cultivation. By 1990 the area had more than doubled to 10.2 million hectares; however, it was still less than 8 percent of what agriculturists believe is the potential total area for crop production. Yet even this relatively small proportion already accounted for 26 percent of the national production of six important crops in 1990 (Table 7−1)

Table 7−1. Production of Six Main Crops from the Core Region of the Cerrados, 1970 and 1990

Category	*Year*	*Soybeans*	*Maize*	*Rice*	*Beans*	*Coffee*	*Wheat*	*Total*
Cultivated Cerrados area (thousands of hectares)	1970	12	1,681	2,308	621	..	..	4,622
	1990	4,381	2,730	1,640	802	482	157	10,192
Production (thousands of tons)	1970	15	2,327	2,894	384	..	..	5,620
	1990	6,802	4,500	1,550	432	572	184	14,040
Yield (kilograms/hectare)	1970	1,259	1,384	1,254	619	n.a.	n.a.	n.a.
		1,553	1,648	945	538	1,187	1,175	n.a.
Cerrados production as a percentage of total Brazilian production	1970	1.0	16.4	38.3	17.4	..	..	20.6
	1990	34.2	21.1	20.9	19.4	19.5	6.0	26.0
Cerrados yield as a percentage of overall Brazilian yield a /	1970	110.3	96.0	82.7	94.8	n.a.	n.a.	n.a.
	1990	89.6	88.0	50.3	112.9	117.8	101.8	n.a.

. . *negligible.*

n.a. = not applicable.

a / Includes irrigated rice areas.

Source: *EMBRAPA−CPAC preliminary data extracted from FIBGE Municipal Agricultural Survey Statistics.*

The *Cerrados* of Brazil are distributed through the contiguous states of Sao Paulo, Minas Gerais, Distrito Federal, Mato Grosso, Mato Grosso do Sul, Goias, Tocantins, Bahia, Maranhao, and Piaui and some neighboring countries, such as Bolivia. This area constitutes one of the few remaining lightly used, but potentially highly productive, farming areas of the world, which makes Brazil's

experience during the past thirty years or so particularly interesting. Many factors have led and driven the expansion of the farming frontier in Brazil. Some have been accidental, but many have been the result of deliberate public policy decisions. Undoubtedly mistakes have been made and locally serious erosion and other ecological damage has occurred, such as damage to the wetlands of the *Pantanal.* However, the diversity of views and experience that is characteristic of Brazil has led to the evolution of minimum tillage and direct drilling farming systems for the *Cerrados* that many farmers are adopting, usually on a pilot scale. These now appear to be sustainable and do not cause serious damage to the environment. This success may also lead to less demographic and livestock pressure on the ecology of the fragile Amazon Basin to the north and west of the main *Cerrados* areas.

For several hundred years, since Brazil was first colonized by the Portuguese, ranchers used the *Cerrados* as extensive rangelands for large herds of Iberian−type cattle, although typically they moved the young breeding stock to the wetlands, including the *Pantanal.*

For many years development strategists urged that the government should move the national capital from Rio de Janeiro to a more central position. Of the many possible sites, the authorities selected Brasilia's present location because it was fairly central and the climate was generally agreeable. However, it was far from the traditionally food surplus states of central and southern Brazil, yet Brasilia would require a regular supply of food for what was expected to be a rapidly growing city population. Feuer (1956) reported favorably on the soil and agricultural potential of the future Federal District of the Central Plateau of Brazil, where almost all the land is part of the *Cerrados* complex. Hardy (1959) provided a commentary on the *Cerrados* soils at experiment stations in Minas Gerais, in which he pointed out the soils' serious deficiencies in phosphorus, sulfur, and several micronutrients, including zinc and boron.

In the late 1950s, McClung led a soil fertility research group funded by the International Basic Economics Corporation (IBEC), the research division of the American International Association for Economic Development, which was based at Fazendas do Cambuhy in Sao Paulo state, this later became the IRI Research Institute. The group investigated a wide range of treatments on *Cerrados* soils initially using potted crop plants, giving special attention to responses to phosphorus and sulfur (see McClung and Freitas 1959; McClung, Freitas, and Lott 1959; McClung and Quinn 1959; McClung and others 1958). Subsequently, after many field trials the group realized that aluminum toxicity was limiting yields. The focus thus turned to liming and other soil amendments (Freitas, McClung, and Lott 1960), including for cotton growing (McClung and others 1961).

All this work and other studies were presented and hotly debated at the First Brazilian Meeting on the Reclamation of the *Cerrados*, held at Sete Lagoas in 1961 (Freitas, Mikkelsen, and McClung 1964). Under a U.S. Agency for International Development contract, Williamson (1963) carried out a further survey of the Planalto of Brazil that benefited from the IBEC research results, and presented a more informed and realistic picture than Feuer (1956). The survey confirmed that extensive areas of land were suitable for mechanized farming provided that moderate (3 to 4 tons per hectare) applications of dolomitic limestone were applied as part of the land preparation. The investigators expected that most crops would require subsequent applications of phosphorous, nitrogen, and micronutrients, including zinc and boron. Thus, by 1963 the basic soil science groundwork for the agricultural

development of the *Cerrados* had been established, but it did not really occur for a further fifteen years, although further special conferences on the *Cerrados'* potential were held in 1965, 1967, 1971, and 1977. Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) has issued an analytical bibliography covering most of this early work (Lemos and Pinto 1976).

In the 1960s and 1970s the coffee sector, predominantly in the south of Minas Gerais, much of Sao Paulo, and the north of Parana, attracted a high level of public policy attention. Following the coffee price boom caused by the rapid increase in market demand at the time of the Korean War, coffee planting in Brazil proceeded at a rapid pace, particularly in Parana. This quickly led to massive overproduction, so that by 1966 Brazil had coffee stocks equivalent to one year of world consumption. In response, the government, through the Brazilian Coffee Institute took the lead in negotiating the first International Coffee Agreement in 1962, and sponsored a major program, managed by GERCA, to compensate farmers for uprooting coffee plants and to promote alternative farm activities. The second International Coffee Agreement (1968) included a diversification fund that was to play an important role in Brazil in the 1970s by assembling a consortium of Japanese banks to finance port and railway investments necessary for three "export corridors" from the interior to the ports of Vitoria, Santos, and Paranagua.

In the early 1970s, some coffee farmers used the compensation they had received from the GERCA to buy cheap land in Goias, Mato Grosso, and parts of Minas Gerais where, among other farming activities, they planted the crop they knew best, coffee. It was the discovery that micronutrient deficiencies of coffee on *Cerrados* soils could be corrected by foliar sprays (where soil applications had failed) that made coffee productive in this region and restored Minas Gerais state as a major producer, a position it had lost to Parana several decades earlier. The authorities had not anticipated this, but by 1990 the *Cerrados* soils were producing almost 20 percent of all Brazilian coffee. Another unexpected consequence of the GERCA program was that as Parana coffee farmers uprooted their coffee in frost−prone areas to grow soybeans in rotation with wheat, the displaced workers and small−scale farmers in areas where farms were uneconomic without coffee moved north to the Amazon frontier in the states of Rondonia and Mato Grosso, where land was cheap or free. This migration bypassed the *Cerrados* region. It was chiefly large−scale commercial farmers from Rio Grande do Sul and Sao Paulo who moved into the *Cerrados* region from the late 1970s to grow soybeans. Cattle ranchers from the center−south undertook the intensification of livestock farming in the *Cerrados* region from the early 1970s using improved pastures of *Brachiaria decumbens*, preceded by rainfed rice as a pioneer or nurse crop.

During the 1970s public investment in roads extended the national network into the states of the center−west, where the *Cerrados* is the most common land form. Since the importance of lime for the economic use of these soils was by then well established, an important criterion used to route new roads was to link the scattered limestone outcrops with potential crop farming areas. The export corridor program was particularly important for the states of Minas Gerais and Parana, but to some extent it also improved the accessibility of the center−west states to the main export ports. This became important as the production of soybeans from the *Cerrados* rapidly increased from 0.2 million tons in 1977 to 6.8 million tons by 1990 (Table 7−2)

Early *Cerrados* development in the 1970s was based mainly on upland rice as a pioneer crop on freshly cleared, weed−free soil that required only low inputs of lime, fertilizers, and microelements, leading after one or two years to pasture establishment. In later years, soybeans, with additional inputs, followed rice.

Agriculturists found that soybean varieties adapted to short day lengths well adapted as an early crop following the opening up of the *Cerrados*, provided that farmers applied an initial adequate quantity of lime to the soil. The farmers quickly made large profits because the land was cheap and credit for machinery and inputs was heavily subsidized. The clearing of the *Cerrados*, principally for soybean production, proceeded rapidly throughout the 1980s. However, the level of farm management was uneven, and farmers rarely paid enough attention to water and soil management, and the contour terracing soil conservation system proved inadequate for soils already degraded by excessive cultivation with discs. As a result, erosion by water and wind became increasingly serious throughout the area of the *Cerrados* being opened up for agriculture. This led to an outcry, both in Brazil and elsewhere, against the "ecological disaster" being caused by ploughing up the *Cerrados* as well as the "destruction of the Amazonian forests." In the late 1980s and the early 1990s the government eliminated most distorting subsidies, and enterprising farmers successfully adapted the direct drilling or minimum tillage techniques that had evolved in the southern states of Brazil during the previous decade. The later sections of this chapter examine how this change was effected and comment on prospects for the future.

Local Conditions and Natural Resources

The *Cerrados* of Brazil cover an extensive area centered on fourteen degrees south latitude and fifty−two degrees west longitude, and lie primarily between latitudes ten and twenty degrees south and longitudes forty−six to fifty−two degrees west. They have some similarities with the savannas of East and South Africa and Australia, but differ in that the Brazilian savannas generally receive more rain and the soils are much more acid and infertile, but initially have a good structure. The contiguous areas total about 180 million hectares, but other Brazilian states, including Sao Paulo, also have some fairly extensive savanna areas, bringing the total to about 204 million hectares (Goedert 1985) (see map of Brazil), or somewhat more according to Azevedo and Adamoli (in Goedert 1988).

The *Cerrados* occur over some ten classes of soil, of which the most common are 45 percent Latosols (FAO/UNESCO, Ferralsols; United States, Oxisols); 15 percent Podsols (FAO/UNESCO, Acrisols or Nitosols; United States, Uultisols or Alfisols); and a further 14 percent quartz sands (FAO/UNESCO, Arenosols; United

States, Entisols). Azevedo and Adamoli summarized the *Cerrados'* agro−ecological characteristics at a 1982 symposium (Goedert 1988). They pointed out that the Brazilian collective term *Cerrados* covers a wide range of ecological conditions, with altitudes ranging from below 300 meters to over 1,200 meters. They distinguished between a number of ecological groups in the *Cerrados,* and ten other categories described as transitions and inclusions. They concluded that the overall distribution was as shown in Table 7−3.

Table 7-2 Soybean Areas, Production, and Yields from the Core Cerrados Region and the state of Sao Paulo, 1957-93

Harvest Year		South East		Center West				North	Northeast	All	A
		Sao Paulo	Minas Gerais	Distrito Federal	Mato Grosso	Mato Grosso Do Sul (from 1977)	Goias*	Tocantins	Bahia	Cerrado Areas	Braz
1957	Area (p) (thousands of ha)	2.4	0.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a
	Production (thousands of tons)	3.4	0.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a
	Yield (kg/ha)	1,394	533	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a
1962	Area (p) (thousands of ha)	4.0	0.3	n.a.	n.a.	1.0	n.a.	n.a.	0.4	n.a.	313.6
	Production (thousands of tons)	4.6	0.1	n.a.	n.a.	0.9	n.a.	n.a.	0.7	n.a.	345.2
	Yield (kg/ha)	1,147	483	n.a.	n.a.	851	n.a.	n.a.	1,743	n.a.	1,101
1967	Area (h) (thousands of ha)	27.7	0.5	n.a.	n.a.	2.3	n.a.	n.a.	0.5	n.a.	612.1
	Production (thousands of tons)	38.2	0.4	n.a.	n.a.	2.7	n.a.	n.a.	1.0	n.a.	715.6
	Yield (kg/ha)	1,381	941	n.a.	n.a.	1,157	n.a.	n.a.	1,909	n.a.	1,169
1972	Area (h) (thousands of ha)	100.2	8.9	n.a.	n.a.	21.7	33.5	n.a.	0.1	n.a.	2,191.5
	Production (thousands of tons)	175.3	8.9	n.a.	n.a.	27.9	49.9	n.a.	0.1	n.a.	3,224.0
	Yield (kg/ha)	1,750	994	n.a.	n.a.	1,282	1,492	n.a.	1,593	n.a.	1,471
1977	Area (p) (thousands of ha)	449.3	98.2	n.a.	n.a.	13.8	68.0	n.a.	0.4	180.1	7,070.3
	Production (thousands of tons)	768.0	103.0	n.a.	n.a.	18.6	89.7	n.a.	0.4	211.4	12,513.4
	Yield (kg/ha)	1,709	1,048	n.a.	n.a.	1,346	1,320	n.a.	1,169	1,174	1,770
Cerrado Production as percentage of State Totals		n.a.	97.5	n.a.	n.a.	7.4	99.9	n.a.	n.a.	23.7	1.7
1982	Area (p) (thousands of ha)	516.0	228.6	17.0	127.9	432.6	314.5	2.8	0.5	1,124.2	8,203.3
	Production (thousands of tons)	993.3	389.1	32.4	242.2	787.4	556.8	4.1	0.2	2,012.7	12,836.0
	Yield (kg/ha)	1,925	1,702	1,903	1,893	1,820	1,770	1,471	500	1,790	1,565
Cerrado Production as percentage of State Totals		n.a.	99.7	100.0	66.3	51.2	100.0	100.0	69.2	69.7	15.7
1987	Area (p) (thousands of ha)	461.7	415.3	43.9	683.5	858.2	522.4	13.5	162.1	2,716.4	9,134.3
	Production (thousands of tons)	923.4	794.3	90.1	1,509.6	1,690.9	1,026.4	21.4	147.3	5,035.5	16,968.8
	Yield (kg/ha)	2,000	1,913	2,053	2,209	1,970	1,965	1,584	909	1,953	1,858
Cerrado Production as percentage of State Totals		n.a.	99.8	100.0	63.2	74.0	98.6	90.8	99.1	78.2	31.3

(continued...)

(table continued on next page)

Table 7-2 continued

Harvest Year		South East		Center West				North	Northeast	All	
		Sao Paulo	Minas Gerais	Distrito Federal	Mato Grosso (from 1977)	Mato Grosso Do Sul	Goias	Tocantins	Bahia	Cerrado Areas	Bra
1988	Area (p) (thousands of ha)	512.5	482.8	42.8	845.1	874.0	728.8	22.7	238.8	3,271.4	10,515.
	Production (thousands of tons)	1,001.9	929.2	81.9	1,769.0	1,805.7	1,412.4	38.9	359.5	6,469.1	18,049.
	Yield (kg/ha)	1955	1924	1915	2093	2066	1938	1713	1505	1978	171
Cerrado Production as percentage of State Totals		n.a.	99.8	100.0	65.7	72.8	97.3	84.4	98.3	80.0	35.
1989	Area (p) (thousands of ha)	594.0	586.0	56.3	550.2	829.2	990.0	45.5	385.5	3,478.7	12,200.
	Production (thousands of tons)	1,348.4	1,165.8	122.9	1,305.1	1,720.5	1,980.0	79.8	580.2	7,089.9	24,051.
	Yield (kg/ha)	2,270	1,989	2,183	2,372	2,075	2,000	1,754	1,505	2,038	1,97
Cerrado Production as percentage of State Totals		n.a.	99.7	100.0	34.4	60.4	n.a.	76.4	99.9	66.1	29.
1990	Area (p) (thousands of ha)	582.0	556.0	53.5	1,503.0	1,209.0	940.5	n.a.	360.0	4,380.7	11,481.
	Production (thousands of tons)	969.0	747.1	79.6	2,900.8	1,934.4	1,410.8	n.a.	220.4	6,801.7	19,887.
	Yield (kg/ha)	1,665	1,344	1,487	1,930	1,600	1,500	n.a.	612	1,553	1,73
Cerrado Production as percentage of State Totals		n.a.	99.8	n.a.	n.a.	n.a.	n.a.	n.a.	100.0	91.2	34.
1991	Area (p) (thousands of ha)	500.0	472.0	43.1	1,007.0	1,013.1	790.0	n.a.	n.a.	n.a.	n.
	Production (thousands of tons)	967.5	962.9	101.3	2,235.5	1,935.0	1,619.5	n.a.	n.a.	n.a.	n.
	Yield (kg/ha)	1,935	2,040	2,350	2,220	1,910	2,050	n.a.	n.a.	n.a.	n.
1992	Area (p) (thousands of ha)	463.0	456.0	42.0	1,452.0	969.5	820.0	12.0	330.0	n.a.	9,582.
	Production (thousands of tons)	907.5	1,003.2	95.1	3,484.8	1,929.3	1,804.0	19.2	495.0	n.a.	19,418.
	Yield (kg/ha)	1,960	2,200	2,265	2,400	1,990	2,200	1,600	1,500	n.a.	2,02
1993 estimate	Area (p) (thousands of ha)	510.0	522.0	44.7	1,655.3	1,066.5	967.6	15.5	380.0	n.a.	10,620.
	Production (thousands of tons)	1,071.0	1,148.4	89.4	3,890.0	2,271.6	2,080.3	15.5	638.4	n.a.	22,890.
	Yield (kg/ha)	2,100	2,200	2,000	2,350	2,130	2,150	1,000	1,680	n.a.	2,15

Notes: * = Excluding Tocantins from 1982. h = area harvested. p = area planted. n.a. = not available

Sources: 1957-1972: Anuario Estatistico de Brasil (IBGE).
1977-1989: Production from Cerrados soils only. Producao Agricola Municipal (FIBGE) except Sao Paulo; CONAB/DIPLA.
1990-1993: Producaao Agricola Municipal (FIBGE) except Sao Paulo; CONAB/DIPLA.

Several others have made assessments of the extent and composition of the *Cerrados*, which differ in detail, but generally confirm that around 60 percent is open or scattered tree savanna totaling around 137 million hectares, most of which consists of gently undulating terrain well suited to large−scale mechanized farming. Annual rainfall is quite high, ranging from 1,200 to 2,000 millimeters, but is sharply seasonal and storms may exceed 40 millimeters in half an hour (Assad 1992). Five or six months of the year are very dry. Furthermore, within the rainy season there is frequently a dry period of one to three weeks (the *veranico*) that often occurs at a critical stage of crop growth (Wolf 1975). Sunlight is generally abundant, temperatures are favorable, and wind storms are rare. The main factor limiting agriculture on the *Cerrados* is the soils' low fertility and fragile structure.

Two useful books on the soils of the *Cerrados* are available. The first (Lopes 1984) provides an overview of the mineralogical, chemical, and physical characteristics of *Cerrados* soils, while the second (Goedert 1985) includes coverage of water management and agricultural mechanization. More recently, Arantes and de Souza (1993) have brought together a valuable set of papers on soybean growing on the *Cerrados*, including a comprehensive review of soil amelioration and management. Both research and experience have shown that essential components of soil management on the *Cerrados* are to reduce the soil's free aluminum content, and hence its acidity; to maintain the organic matter on the surface and in the upper soil layer; and to correct nutrient and micronutrient deficiencies. Once this is done, the soil responds well to other agronomic treatments.

Table 7−3. Composition of the Cerrados by Ecological Group

Ecological group	*Description*	*Percentage of total land*
Cerradao	Closed tree cover	8.30
Cerrado	Scattered tree savanna	49.12
Campo	Open tree savanna	11.65

Campo cerrado inundavel	Seasonally flooded, Scattered tree savanna	0.47
Campo inundavel	Seasonally flooded, open savanna	5.16
Cerradao/floresta densa	Dense, closed forest	0.24
Cerradao/floresta mesofitica	Closed mesophytic forest	0.76
Cerradao/caatinga	Open, dry forest/woodland	0.96
Subtotal		76.66
Transitions	Intermediate and mixed groups	18.06
Inclusions	Small patches of other groups	5.28
Total		100.00

Note: *Of the Cerrados total acreage of some 239 million hectares, Azevedo and Adamoli estimate that 49 million hectares are transitions and 12 million hectares are inclusions.*

Source: *Goedert (1988).*

Until recently the *Cerrados* areas of Brazil were remote from the population centers along the coast (Salvador, Recife, Rio de Janeiro, Sao Paulo, and Santos). Brazil's interior south and east of the Amazon Basin has been an area of extensive ranching for hundreds of years. By 1970, only 15 million people lived in this region, mainly in the market towns. Ten years later, the population had reached more than 20 million. This growth was stimulated by the move of the national capital to Brasilia and the rapid expansion of the states' capital cities. The rural population continued to be low and widely dispersed, with little access to social services, such as schools and health centers, although there have been considerable improvements since 1970.

The rapid agricultural expansion in the *Cerrados* areas has been mainly through large−scale mechanized agriculture. This was facilitated until the 1990s by the high level of subsidy on credit funds used to finance the purchase of farm machinery and equipment, as well as purchased inputs, and on working capital in general. Over the years the farmers used ever−larger tractors, so that by the 1980s some were of over 200 horsepower. During the busiest seasons many farmers operate their tractors on night shifts as well as day shifts. Soybean monoculture and excessive reliance on disc ploughs and harrows led to extensive areas of the *Cerrados* becoming highly susceptible to erosion both by wind and by water. (Resck 1981, 1991; Dedecek 1986).

Market Demand

The strategy to open up the center−west of Brazil in the 1960s formed part of an overall policy to promote new areas of development, one of which would be the new capital city of Brasilia. The government was also concerned about increasing foreign exchange earnings while reducing dependence on the increasingly volatile international market for coffee. It considered various export possibilities, including beef, maize, orange juice concentrate, and oilseeds, particularly soybeans, which were proving to be a successful new crop in the south. Two events in the United States provided a strong impetus to the last two products. First, a severe frost in Florida in 1961 led a number of major U.S. producers to sponsor citrus development in the Brazilian states of Sao Paulo and Minas Gerais. Second, the embargo on soybean exports from the United States to Japan imposed in July 1973 by the Nixon administration led Japan on an urgent search for new, more reliable sources for one of the country's most essential imports. Argentina and Brazil appeared particularly promising to the Japanese authorities. Japan's interest in securing assured supplies of soybeans, as well as of iron ore and woodchips, led to the substantial financing of the export corridors' transport infrastructure by a consortium of Japanese banks, together with US$40 million from the Diversification Fund of the International Coffee Organization.

The 1970s were a period of rapid economic growth in Brazil, which averaged 8.1 percent per year. The agricultural sector also performed well, increasing at a rate of more than 4 percent per year in the 1970s and just ahead of the population growth rate in the 1980s. The share of the agricultural sector in GDP declined slightly from 12 percent in 1970 to 10 percent in 1991. Grain imports continued at between 6 and 7 million tons a year, but overall food production per capita rose annually by 1.7 percent between 1979 and 1991 (Table 1−1).

The availability of markets has not been a constraint to opening up the *Cerrados* to large−scale mechanized agriculture, although some periods of market weakness have, naturally, occurred, and the distance to the main consumption areas and export ports will always be an important factor in the economics of farming the *Cerrados.*

Farm machinery suppliers and agrochemical distributors rapidly extended their marketing network into the *Cerrados* region. The demand for their products was strong, and as long as the government provided substantial subsidies, high financial returns were possible. However, as Scolari pointed out (Goedert 1988), at a real rate of interest of 4 percent, none of the crop or pasture enterprises would have been profitable at the guaranteed minimum price for products. At market prices, rice and maize production would be profitable, but soybeans would not. When the government withdrew the subsidies nearly ten years later, soybean production was still profitable as farmers raised their yields and reduced their investments in farm machinery. While subsidies were still in effect, many farmers introduced long−line center pivot sprinklers to irrigate winter crops such as beans, and thereby double their cropping intensity. Further investment in irrigation equipment may still be feasible, but now much greater attention to the financial viability of the investment is necessary, so that irrigation is likely to be limited to high value crops.

Institutions and Investments

The state of Sao Paulo provided the leadership in establishing the Instituto Biologico (Institute of Biology) and the Instituto Agronomico (Institute of Agronomy) − Campinas {IAC} at the turn of the century. These two institutes served Brazil's subtropical and temperate regions well, but had little to offer those developing the country's tropical interior. During the 1950s the government realized that state and federal authorities would have to take a more active part in the development and transfer of technology to farmers. Therefore in 1953, with the help of the Rockefeller Brothers Fund, the Association for Credit and Rural Assistance (ACAR) was formed, and operated initially in the state of Minas Gerais. As other states joined the association, it eventually became the Brazilian Corporation for Technical Assistance and Rural Extension (EMBRATER), and played an important part, together with various private entities, in disseminating technical advice to farmers new to the *Cerrados.* This organization has now been abolished, leaving the states to organize their individual services with overall responsibility vested in a new department of the Ministry of Agriculture, Supply, and Agricultural Reform. This latest arrangement is not yet entirely complete in all the states.

In 1973 the government created the Brazilian Corporation for Agricultural Research (EMBRAPA). Two years later it launched the Special Program for the Geoeconomic Region of Brasilia as part of the Program for the Development of the *Cerrados.* It was this entity that was able to coordinate and plan infrastructure development to link a dozen limestone quarry sites with local development areas to distribute the lime that was essential to initiate crop farming and pasture improvement on the *Cerrados.*

In 1975 EMBRAPA took over the research experiment station near Brasilia and upgraded it to the Regional Center for Agricultural Research for the *Cerrados* (CPAC). The World Bank provided a Loan to help EMBRAPA develop this and other research centers. CPAC also benefited from financial and technical support provided by CIRAD and ORSTOM (France), Cornell University (United States), the Wageningen Agricultural University (Netherlands), JICA (Japan), the International Society of Soil Science, and the Inter−American Development Bank and technical support from the Centro Internacional de Agricultura Tropical, Colombia. The CPAC was initially successful in investigating farming methods and the special problems of the *Cerrados.* More recently, it has been less able to keep ahead of the rapid development of the dynamic private sector, and both individual farm companies and agricultural suppliers have established their own field research units. These are generally small, well staffed and funded, and highly focused on solving immediate problems, such as product testing, soil compaction, and the introduction of minimum or zero tillage direct drilling systems.

Factors and Systems for Managing the Cerrados

Cerrados development has been characterized by two almost entirely separate series of technological advances in beef cattle and pastures and in annual crops. After hundreds of years of little change in the extensive grazing system of *Cerrados* exploitation with small, slow−maturing Iberian−type cattle *(Bos taurus),* the first significant innovation in technology was the introduction of Zebu cattle *(Bos indicus),* imported from India in small numbers to the Minas Triangle from about 1900 onward. A herd book was established in 1919, and from then on selection for the rusticity, drought−resistant and tick−resistant characterization of the various Zebu breeds began to generate considerable genetic improvement of the beef herd in the region. Importation of vastly superior Nelore animals in 1962 raised the live weight of mature bulls from 800 kg. to more than 1,000 kg, and laid the foundation for the present dominance of this outstanding tropical beef breed in the *Cerrados* region, and in all other tropical and subtropical areas of Brazil (Costa 1988). These cattle were resistant, or at least tolerant, to endemic tick−borne diseases, and cattle numbers in the core *Cerrados* states of Minas Gerais, Mato Grosso, and Goias increased from 13.2 million in 1920 to 32.4 million by 1970.

As a result of the pioneering research work of the late 1950s and early 1960s, the principles and techniques for soil fertility enhancement were well established, based on a combination of liming and the application of phosphatic fertilizers with micronutrient additions. By 1966/67 the Brasilia Experiment Station (later CPAC) had achieved hybrid maize yields of over 6 tons per hectare once the soil aluminum toxicity and nutrient deficiency limitations had been addressed (Freitas, Labato, and Soares 1972). The development of the cattle herd and pastures in the *Cerrados* states from 1920 to 1985 (the date of the last census) took place in two phases. There was a period of slow growth up to 1960, and then of increasingly rapid expansion over the next 25 years. From 1970 most of the growth occurred in *Cerrados* areas, as summarized in Table 7−4. Slow growth up to 1960 was probably because of low herd performance and the lack of roads (cattle were then walked to Sao Paulo). The 55 percent increase in stocking rate during 197085 is notably due to the improved grasses introduced.

The introduction in the late 1960s of the improved pasture grass *Brachiaria decumbens* represented a major breakthrough for the management of the *Cerrados* for cattle raising. The introduction of this grass, and of other species tolerant of low soil fertility conditions following an initial crop of rice, led to a rapid expansion of the area of improved grazing land at a low cost. However, there has been little success so far in introducing legumes into the pastures because of

difficulties in obtaining good seed and the management difficulties of retaining legumes in sown pastures. The problem of poor persistence of legumes in extensive pastures has also proved to be serious in Uruguay (Chapter 4).

From the late 1970s, soybean growing became the most dynamic force promoting the opening up of the *Cerrados* to intensive, mechanized agriculture. The basic science of soil management had been understood for fifteen years or more, and the main highway from Sao Paulo to Brasilia had been asphalted since 1966, but it was not until the sharp increase in export demand and the infrastructure improvement of the export corridor program had been completed, that growing large areas of soybeans on the *Cerrados* became financially attractive. In 1971/72 the three core *Cerrados* states had a combined area of only about 64,000 hectares of soybeans. Ten years later this had increased to 1.6 million hectares, and by 1991/92 the total area of soybeans grown in the region (now five states and the Federal District) was more than 4.25 million hectares. The key technical advances that made this possible were the understanding of soil fertility improvement measures and the development of locally adapted varieties of soybeans.

Table 7−4. Cattle and Pasture Statistics for the Major States of the Cerrados Region (Minas Gerais, Mato Grosso and Goias), Selected Years

Livestock census year	*Total number of cattle (thousands)*	*Annual herd growth rate (%)*	*Improved Pastures Percentage*	*Improved Pastures Thousands of ha*	*Stocking rate (head/ha)*
1920	13,186	n.a.	n.a.	n.a.	n.a.
1960	22,858	1.4	n.a.	n.a.	n.a
1970	32,362	3.5	15	12,783	0.38
1985	56,623	4.2	43	41,786	0.59

n.a. = not applicable.

Source: *IBGE agricultural census statistics.*

The drive to breed and select new soybean varieties was led initially by IAC in Sao Paulo, where the group 7 cultivar IAC 2, with a growth cycle of 135 days, was released about 1970, followed shortly by other cultivars adapted to short day lengths from the Federal University at Vicosa, Minas Gerais (UFV). Field testing gained momentum with the creation of a network including EMBRAPA (CPAC), UFV, and the state research agencies EPAMIG (Minas Gerais) and EMGOPA (Goias) in 1975. The state extension agencies and commercial seed sales companies were effective in the rapid dissemination of information on the new varieties and of the seed itself. The first consistently high yielding variety of soybean bred specifically for *Cerrados* conditions was of group 10, and was called

Cristalina after the municipality where it was first planted commercially. De Souza and others reported that Cristalina out−yielded IAC2 by 36 percent (Goedert 1988), and by 1986 it became the principal variety grown in the *Cerrados,* where it is still important. However, it has a growth cycle of 145 days, which restricts its suitability for use in double cropping or minimum tillage systems. It is also susceptible to the stem canker disease that has recently occurred in some *Cerrados* areas.

Short season (rapidly maturing) maize and soybean varieties became available in the late 1980s and made possible the next fundamental change in crop farming on the *Cerrados.* The recently released soybean varieties now have growth cycles of 105 to 115 days, with a similar yield potential as Cristalina of around 2,400 to 3,000 kilograms per hectare under farm conditions. Likewise the growth cycles for recently released maize hybrids range from 115 to 120 days, compared with the 130− to 140− day periods required for earlier maize hybrids. These advances in plant breeding have allowed farmers to grow two successive crops on the moisture from one season of rain. The first crop is soybeans or maize, and the second crop is selected in the light of the moisture retention and storage characteristics of the local soils. The second crops can be maize, sunflowers, or cotton under the most favorable conditions, or sorghum, black oats, or millet where residual soil moisture and expectations of further rainfall are least favorable. The decision on what to sow for the second crop also depends substantially on the date by which the land can be prepared after harvesting the first crop, most commonly soybeans. The need for a rapid turnaround has contributed to the rapid adoption of direct drilling, and even of oversowing soybeans with the second crop. The following sowing dates are indicative, and may vary according to local soil and rainfall conditions:

<u>Sowing dates up to February 15</u>	
Maize	For grain
Sunflowers	For grain
Cotton	For fiber
<u>Sowing dates up to March 15</u>	
Black oats (Avena strigosa)	For seed
Millet (Pennisetum typhoides)	For grain or seed
Sorghum	For grain
Wheat	For grain
<u>Sowing dates up to April 15</u>	
Black oats	For forage or as a cover crop
Millet	For forage or as a cover crop

On the most efficient farms less than a week passes between harvesting the first crop and sowing the second crop. A few farmers manage a turnaround time of just one or two days by using direct drilling or minimum tillage practices.

It is now standard practice to apply dolomitic lime, typically about 4 tons per hectare, when opening up new *Cerrados* land for cropping. The actual rate used may be modified where the results of initial soil testing are available. Subsequently, additional liming is required every three to five

years to maintain the soil pH at around 5.5 to 6.5 and the base saturation level at over 41 percent (Table 7−5). This level of application is usually sufficient to create favorable conditions for rooting in the top 20 centimeters of soil. However, this restricted depth may have insufficient storage capacity for soil moisture to carry crops through a serious *veranico* without wilting, and can seriously hinder growth. Agriculturists have studied this problem extensively, and research has clearly shown that if the more soluble gypsum (calcium sulfate) is used to complement the dolomitic lime (calcium and magnesium carbonate), amelioration to a greater depth of soil is quite possible, thereby increasing the potential rooting zone for crop plants (Pieri forthcoming; Seguy and Bouzinac 1992; Seguy and others 1988).

Table 7−5. Cerrado Soil Survey Results and Target Nutrient Coefficients

Soil chemical analysis	*Unit*	*Range*	*Mean*	*Target*
Organic Matter	percent	0.7 to 6.0	2.2	greater than 1.6
Soil acidity water extract	pH	4.3 to 6.2	5.0	5.5 to 6.5
Aluminum ions	mEq/100cc	0.08 to 2.40	0.56	less than 0.3
Aluminum and hydrogen ions	mEq/100cc	n.a.	n.a.	less than 2.5
Extractable calcium	mEq/100cc	0.04 to 6.81	0.25	greater than 1.6
Extractable magnesium	mEq/100cc	0.00 to 2.02	0.09	greater than 0.6
Total extractable calcium and magnesium	mEq/100cc	n.a.	0.36	greater than 2.1
Extractable potassium	ppm	0.02 to 0.61	0.08	greater than 45
Extractable phosphorus	ppm	0.10 to 16.50	0.40	−
Clay soils	ppm	n.a.	n.a.	greater than 10
Sandy soils	ppm	n.a.	n.a.	greater than 20
Total Bases	mEq/100cc	n.a.	n.a.	2.6
Calcium: magnesium	ratio	n.a.	n.a.	3:1
Cation exchange capacity (CEC)				
CEC:potential	mEq/100cc	n.a.	n.a.	5.1
CEC:soil acidity dependent	mEq/100cc	n.a.	n.a.	1.1
CEC:effective	mEq/100cc	0.35 to 8.10	1.10	2.4
Aluminum saturation index	percent	1.10 to 89.40	59.00	less than 20
Base saturation index	percent			greater than 41
Micronutrients				n.a.
Extractable zinc	ppm	0.20 to 2.15	0.60	n.a.
Extractable copper	ppm	0.00 to 9.70	0.60	n.a.
Extractable iron	ppm	3.70 to 74.00	32.50	n.a.
Extractable manganese	ppm	0.60 to 92.20	7.60	n.a.

mEq = milliequivalents.

n.a. = not available.

ppm = Parts per million.

Source: Target − *FUNDAP (1992);* Range − *Lopes, (1984).*

In the *Cerrados* region gypsum is only available as a waste from the production of triple superphosphate at Uberlandia, Minas Gerais state, where it has been available at no charge for farmers to pick up at the factory gate. Several economic analyses have shown that transporting the gypsum 800, or even 1,000, kilometers to farms with serious subsoil aluminum toxicity problems would be feasible. In practice farmers have been slow to use gypsum, probably because the Uberlandia gypsum has quite a high moisture content (10 to 12 percent), which makes transport, and especially field distribution, difficult, and secondly because of unwarranted fears of excessive leaching of other important plant nutrients (bases).

Under natural conditions the organic matter content of the topsoil of the *Cerrados* is often about 3 percent, and it can be as high as 4 or 5 percent under *cerradao* conditions (Table 7−3). About half the initial organic matter content serves to bind the fine clay particles together into soil aggregates or crumbs. This is so effective that the initial moisture infiltration rate of the *Cerrados* soils with a physical analysis of over 50 percent clay particles is almost as rapid as through sand, reaching between 17 and 22 centimeters per hour (Wolf 1975). The balance of the organic matter plays an active part in the chemical exchange processes between the soil and the plants. In a survey cited by Resck, Pereira, and de Silva (1991), 58 percent of soil samples from cultivated land had between 1.8 and 2.6 percent organic matter content. They also reported that from the fifth to the eleventh year of continuous soybean cultivation the proportion of stable soil aggregates dropped from 90 to 45 percent. As a result of ploughing, particularly with disc ploughs; exposure to hot, dry conditions; and compaction by heavy farm machinery, the organic matter in the topsoil rapidly breaks down and the soil crumbs disaggregate into highly erodible fine particles. Furthermore, some of the finest particles sift down to the limit of cultivation depth where they accentuate any compaction at this depth, effectively forming a "disc pan." This can seriously impede root growth to deeper layers of soil, and so restrict nutrient and moisture uptake, and thus the crop plants' capacity to withstand periods of drought such as the *veranico*.

The physical changes to the soil structure can transform a freely draining soil into soil that is susceptible to serious erosion. The sustainable management of *Cerrados* soils therefore requires:

Initial amelioration with dolomitic lime and possibly with gypsum, phosphatic fertilizer, and usually with micronutrients (zinc, boron, copper, and molybdenum);

Maintenance of as much soil surface cover as possible;

Continuing attention to the organic matter content of the soil;

Periodic reapplication of lime to maintain soil acidity conditions favorable to root growth.

For many years agriculturists had been aware that some form of minimum or zero tillage of *Cerrados* soils would probably check, or eventually prevent, soil degradation and the consequent wind and water erosion. Farmers were rapidly adopting such land management techniques in the east and south of Brazil (the states of Sao Paulo, Parana, Rio Grande do Sul, and Santa Catarina) and in Argentina, where double cropping soybean:wheat was progressively introduced from the 1960s. Double cropping in the *Cerrados* was not possible until rapidly maturing crop varieties adapted to local conditions had been bred and tested. Furthermore, while farm machinery remained heavily subsidized through artificially cheap lines of credit and the price of the most effective herbicide remained at more than US$15 per liter, farmers were not interested in minimum tillage techniques. Nevertheless, during

the 1980s some enterprising farmers began to introduce minimum tillage methods to the *Cerrados* on a pilot scale with somewhat limited success. In the late 1980s, when subsidized credit lines were no longer available, the overall rate of soybean area expansion slowed down, the price of the main herbicides dropped to more attractive levels, and, most significantly, short−maturing soybean and maize varieties were released.

From around 1989/90, interest in minimum tillage, and direct drilling grew rapidly. By 1993 many large−scale farms on the *Cerrados* had tried out various forms of minimum tillage, and some enterprises had already sharply reduced their stock of tractor power, for example, from 0.75 horsepower to 0.42 horsepower per hectare of cultivated land (Landers 1994). Some farmers found that the amount of herbicide needed to control weeds a month before drilling the main crop through the stubble could be reduced from 5 or 6 liters per hectare to 2 or 3 liters per hectare, and that this rate could be reduced further by nighttime application, when the effective absorption time of the herbicide droplets on the weed vegetation is longer. There is also less spray drift, because the *Cerrados* region experiences little rain or wind at night.

By 1993 agriculturists estimated that about 1.5 million hectares of land were under direct drilling or no tillage systems. Even though the figures are not entirely reliable, they indicate that farm testing had been widespread, and that a considerable number of farmers had adopted direct drilling and minimum tillage on the *Cerrados*, particularly since 1989/90.

A number of private and government colonization initiatives assisted expansion of farming in the *Cerrados* region. The largest and most successful was the Japanese−funded Japanese−Brazilian Program of Cooperation for the Development of the *Cerrados* (PRODECER) executed by CAMPO (CAMPO 1992), a Brazilian/Japanese parastatal company. From 1980 to 1992, 270,000 ha were resold to 561 qualified farmers selected mainly through existing farmers' cooperatives in the center−south of Brazil. Finance covered land purchase, farm equipment, buildings, and infrastructure for new cooperatives, as well as working capital through rural credit (originally subsidized) lines. By 1992 investments totaled about US$400 million, generating an estimated annual production of 1 million tons of grain and 30,000 additional farm jobs (CAMPO 1992).

A consensus is forming in favor of the following sequence of land opening and longer−term soil management practices, exemplified by the experience and excellent records of the Fazenda Agropecuario Michels in Minas Gerais. This is one of the original members of the Irai Mixed Agricultural Cooperative of twenty−six colonists who moved to the *Cerrados* from the south of Brazil in 1980 under the PRODECER. Each colonist received 350 hectares, of which 20 percent had to be retained as an uncleared reserve. A measure of the success of the Irai colonization project was that by 1992, the 26 settlers who had started with a total of 8,000 ha had acquired a further 12,000 ha, both to gain economies of scale and to diversify their operations into mixed crop and cattle enterprises. This reflects a general trend to larger arable production units and diversification away from soybean monoculture and into cattle raising.

The colonists had found that clearing should be done in the wet season using anchor chains drawn between crawler tractors, as this removes the most roots while causing the least lateral

movement of the surface soil. Farmers sell the larger timber for lumber or firewood, and windrow and later burn the remaining small branches and roots. They apply 2 tons of lime per hectare followed by heavy discing, then apply a repeat dose of 2 tons of lime per hectare followed by a second discing. They later remove the roots by hand and lay out broad−based, contour terraces at 1−meter vertical intervals, followed by a third discing around August or September. Ideally they should sow the first crop a year later to allow full incorporation of the lime and decomposition of the remaining roots and other materials, but they seldom do this, even though immediate sowing with soybeans may yield less than 2,100 kilograms per hectare, which farmers now regard as uneconomical. Well−inoculated soybean seed is essential on new land, and is usually sown with 500 kilograms per hectare of O:20:20 compound fertilizer, as well as 12.5 kilograms per hectare of fritted trace elements to provide micronutrients.2 Following the opening up of the *Cerrados* and the treatment described above, the following yields were recorded for soybeans sown annually for four years:

1988/89	2,280 kilograms per hectare
1989/90	2,400 kilograms per hectare
1990/91	2,580 kilograms per hectare
With a supplement of 2 tons of lime per hectare:	
1991/92	2,700 kilograms per hectare

The preferred rotation is now a main maize crop after each two years of soybeans to maintain soil organic matter levels and prevent the buildup of nematodes. At maize planting farmers apply 400 kilograms per hectare of 4:20:20 plus zinc, and then an additional 60 kilograms per hectare of nitrogen thirty−five days later. Maize yields have steadily increased from 4 to 6 tons per hectare.

The transition from traditional cultivation, which typically involves two heavy discings and one or two light leveling discings, to direct planting requires either one heavy discing (reduced tillage) or a chisel ploughing to 20 centimeters (minimum tillage) at the end of the rains. In preparation for sowing, farmers slash the residue from the second crop and all subsequent weed growth around August with a rotary cutter. About a month later, by which time a large crop of weed seedlings will have germinated, the whole area is sprayed with a herbicide such as glyphosate ("Roundup") at 3 liters per hectare plus 0.5 percent urea, or paraquat with some diuron ("Gramocil") at 2 to 3 liters per hectare. The main crop is then drilled through the straw and dead weeds about a week later.

During the past ten to fifteen years, farmers, and more recently local agricultural machinery manufacturers, in Brazil and Argentina have developed a range of robust and effective machinery for drilling crop seeds and placing fertilizer into the soil through the considerable layer of mulch that is one of the main, and generally positive, characteristics of direct drilling systems. Machinery from the

2 The figures 0:20:20 indicate nutrient content units per 100 of nitrogen, phosphorus as P_2O_5, and potassium as K_2O.

United State and Canada is too complex and expensive, and often not sufficiently robust to withstand local conditions.

Formal field trials usually do not reveal strong yield or operational cost advantages for direct drilling, at least over the limited duration of the trials so far reported (Seguy and Bouzinac 1992). The benefits are, however, quite evident in the field and in the economics of the total farm management system (Landers 1994). The reduced capital investment in tractor power has already been mentioned. A second important benefit that is more difficult to quantify is the reduced surface evaporation caused by the mulch effect of the straw and weed residues, which allows farmers to start planting earlier (with less rain) and to continue planting longer during a dry spell. This results in an earlier average planting date, and thus an earlier harvest, which gives farmers more time to prepare for the second crop. Other benefits are more obvious, for example, the layer of mulch protects the surface soil from the direct destructive impact of raindrops and moderates the surface temperature. This provides more favorable conditions for biological processes, including seed germination, *Rhizobium* activity, and the incorporation of organic matter into the active soil system. Surface soil compaction is reduced, and the indications are that after one or two seasons, the internal consolidation or disc pan breaks down and soil bulk density in the top 12 to 15 centimeters of soil reverts to the natural level of about 1.0. The layer of mulch almost completely prevents surface soil erosion, and has also been credited with reducing the distribution of fungal spores by rainsplash.

Questions remain concerning the periodic re−application of lime and whether ploughing it in is necessary. A recent report from Parana (Sa 1993) indicates success with lime application on the soil surface. Certainly using the same herbicide for several years is inadvisable, as this will select for the few resistant or tolerant weed species. A more fundamental question concerns the extent to which livestock can be reintegrated into the *Cerrados* farming system. Some farmers are already making silage from the second crop or bringing cattle back to graze on arable lands for winter feeding. Other systems are being developed to integrate livestock with crop farming on the *Cerrados*, including direct drilling into a permanent legume sward (Vasconcelos and Landers 1993) and or into established grass pastures (Seguy and Bouzinac 1992) to provide dry season grazing and a summer grain crop. A new technique using the mold board plough for pasture renovation, taking a catch crop of upland rice in the first year (Kluthcouski 1991), was reported as being widely adopted in 1993, and some farmers have started to oversow maturing soybean fields with black oats or rye grass *(Lolium perenne)* to provide winter grazing for cattle.

Commentary

Public sector policies and investments have been crucial to the development of the *Cerrados,* particularly to the spread of soybean production. The initial geopolitical decision to open up the interior of Brazil led to a major program of highway construction extending across much of the *Cerrados* region. The decision to limit coffee production while promoting other agricultural exports led to the major export corridor program that improved railways and the ports' grain handling facilities. The policy of cheap credit and low land prices in the interior led to rapid agricultural expansion, combined with unsustainable exploitation of the natural resources and serious degradation of the soil over large areas of the *Cerrados.*

Public investments have also been important in building up the education system, including several universities and many research institutes. The quality and quantity of academic and scientific output has fluctuated considerably during recent decades, but in aggregate has produced a large number of well−trained individuals and a substantial body of scientific knowledge and varieties of crops suitable for the conditions of the *Cerrados.* Much of the knowledge, particularly of soil management, could not be used until effective market demand and access to markets were improved by the public investments in physical infrastructure.

While credit subsidies were reduced and eventually eliminated, the costs of farm machinery and some other inputs increased; however, the market prices for farm outputs were weak or declining. This obliged farmers who wished to stay in business to improve the efficiency of their operations, and in almost all cases to increase productivity per unit of area and unit of tractor (horsepower) investment. These circumstances have led to a rapid adoption of direct drilling with minimum or no tillage operations. This important change in farm practice has halted land degradation and has initiated the restoration of some land that had been seriously affected by the frequent use of heavy machinery without maintaining the soil organic matter content, and thus the physical structure and biological activity of the soil.

Individual investors have been the driving force in developing, and in many instances exploiting, the *Cerrados.* In most cases these have been large to very large−scale farmers, although some medium−scale settlements have been supported with public funds. Commercial traders have been active in the provisions of inputs and marketing of outputs. In addition, several strong associations or cooperatives of farmers have been successfully built up. There is therefore diverse and active private sector involvement throughout the farming areas of the *Cerrados.* Recent testing and development of direct drilling techniques has been almost exclusively done by farmers and suppliers of agricultural inputs.

The experience of recent decades gained on the *Cerrados* of Brazil is of great significance to the search for means of increasing the world's food supply in ways that are not detrimental to the local or global environment. The *Cerrados'* development has been overshadowed in international circles by the continuing heated debate on the future of the Amazon Basin and on who should pay for the costs of mitigating measures to protect the environment. The more actively Brazil's center−west is developed, the less the likely pressure on the natural resources of Amazonia. The current spread of direct drilling for crops and pasture improvement on the *Cerrados* is proceeding with little involvement of the public sector in research or extension, but this is possible because of earlier public investments in the physical infrastructure and in research and extension services.

Direct drilling is likely to continue to spread rapidly in the *Cerrados* as it allows farmers to reduce investment in farm machinery, provides them with greater operational flexibility at planting time, and minimizes soil erosion. It also promotes bioactivity in the soil, which further improves the fertility of this basic natural resource. The future rate of adoption of direct drilling in the *Cerrados* region may follow the pattern of the Coopamil Cooperative in Irai (Minas Gerais), where from an initial 500ha of direct drilling in 1987/88, the area planted using this technique in 1992/93 was about 15,000ha, representing 50 percent of the crop area of all the members of the cooperative. On rented land the rate of adoption is slower, but on land farmers owned, about 80 percent of the area was planted by direct drilling in 1992/93. Over the *Cerrados* region as a whole, the direct drilled area is expected to increase by between 35 and 50 percent between 1992/93 and 1993/94.

Few, if any, parts of the world have the same combination of natural conditions as the *Cerrados* of Brazil and nearby areas in other Latin American countries. However, acid tropical soils with high levels of aluminum saturation are much more common. The body of knowledge now available from EMBRAPA and many other academic and commercial entities in Brazil could be important for countries in Africa and Asia and for Australia. Much of this information is not widely known, therefore a fairly extensive bibliography is given at the end of this document to guide others to some of the valuable papers, mostly in Portuguese, many of which have been presented at conferences since 1961. The dual importance of reducing aluminum saturation and retaining, or even increasing, the soil organic matter appear time and again as being necessary conditions for taking advantage of other scientific and technical advances. Agriculturists are rapidly perfecting the direct drilling, minimum tillage, and zero tillage systems under a wide range of conditions in Brazil and further south. These may be especially relevant to those seeking to modernize the agriculture of the former Soviet Union.

8— India: Soybeans on "Black Cotton" Soils

India is one of the world's most populous countries, with 866.5 million inhabitants in mid−1991, and an annual population growth rate of 2.3 percent. The population is expected to double before stabilizing in the first half of the twenty−first century, by which time India's population will exceed China's, even though the total area of India is 3.3 million square kilometers, while China covers 9.6 million square kilometers. Providing food for its huge population remains a matter of the highest priority for the Indian government. For many decades the focus was on irrigated agriculture, which succeeded in substantially raising rice and wheat production as the new high−yielding varieties (HYV) were introduced in the 1960s and 1970s.

The agriculture sector's overall contribution to the gross domestic product increased annually by 1.8 percent from 1970 to 1980, and then the rate of increase almost doubled to 3.2 percent per year from 1980 to 1991 (Table 1−1). Much of the increased agricultural output came from the irrigated areas, while in most of the rest of India, progress under rainfed conditions has been much slower. It is in these rural areas without irrigation that the standard of living continues to be low. It was also in these same areas that periodic famines caused serious loss of life until the railway system was developed, permitting deliveries of imported grain, and more recently grain and many other products transferred from the irrigated areas in the north to central India.

Black cotton soils, classified technically as vertisols, cover extensive areas (73 million hectares) of central India. Vertisols are very hard when dry and very sticky when wet, and consequently are difficult to manage, but they are initially rich in bases (calcium, magnesium, and potassium). The mid−year monsoon rains (Kharïf season) are heavy over much of this area and may total 500 to 1,200 millimeters annually. This should be sufficient to support the growth of many seasonal crops, but because of the difficulty of cultivating black cotton soils, farmers plant only some of the area in the Kharif season and leave extensive areas of the vertisols fallow throughout the rains, and then sow wheat and green or red grains after the monsoon period that grow on the residual moisture during the winter (Rabi season).

As India's supply of cereal grain improved through irrigation and the use of HYVs, the government's attention turned to improving the supply of fats and oils. One of the first programs was the National Dairy Program, also known as the Amal program or Operation Flood. This was very successful and provided the model for the later National Oilseeds Program. Part of the latter program focused on promoting soybean growing, particularly in the state of Madhya Pradesh, where rural poverty was most serious, and which had 16.7 million hectares of black cotton soils, which accounted for 23 percent of India's black cotton soil (Murthy 1988).

Between 1978/79 and 1992/93, the total production of soybeans in India increased tenfold, from 293,000 to 2,900,000 tons, almost entirely from increases in planted area (Table 8−1), and about 80 percent of this total came from the black cotton soils of Madhya Pradesh. Soy oil is now the third

most important edible oil in India, and the value of soybean meal exports as defatted soymeal or deoiled cake (DOC) grew from nothing to US$25,730,000 in 1991 (FAO 1992). The following sections outline the factors that led to this impressive intensification of land use and review prospects for the future.

Table 8−1. Soybeans: National Area, Production, and Yields, 1978/791992/93

Crop year	*Area (thousands of hectares)*	*Production (thousands of tons)*	*Yield (kilograms/ hectare)*
1978/79	307	293	954
1979/80	496	282	569
1980/81	608	442	727
1981/82	622	467	751
1982/83	770	491	638
1983/84	836	614	734
1984/85	1,243	955	768
1985/86	1,340	1,024	764
1986/87	1,392	835	600

1987/88	1,543	898	582
1988/89	1,655	1,501	907
1989/90	2,253	1,805	801
1990/91	2,554	2,599	1,018
1991/92	2,865	2,344	818
1992/93	3,424	2,900	847

Source: *1970/711987/88: Reports of the National Research Center for Soybean (various publications); 1988/891992/930: Reports of the Soybean Processors Association of India (various editions).*

Local Conditions and Natural Resources

The state of Madhya Pradesh lies in the heart of India between seventeen to twenty−six degrees north latitude and seventy−four to eighty−four degrees east longitude (see map of India). The state covers 443,000 square kilometers and ranges in altitude from 50 to 1,200 meters. The Malwa Plateau is in the east of the state and consists of extensive, undulating plains of scattered tree savanna on black cotton soil areas dotted with flat−topped hills. The soybean area has expanded most rapidly in the Malwa Plateau, in part because it is closer to Bombay then the rest of the state, and to which it is

linked by railway, which facilitates the export of de−oiled cake. The oilseed processing industry has invested heavily close to the railway, particularly in the Indore and Ujjain districts. Many other parts of Madhya Pradesh are also suitable for soybean production.

As Dudal (1965, page 69) pointed out:

While difficulties of farming in the dark clay soil regions are real enough and deserve attention, their favorable features in relation to agricultural production should be given equal emphasis. Compared with other soils in the same climatic zones, the dark clays generally have a high content of nutrients. In many cases, they develop a good surface structure, have a high water holding capacity, strong biological activity and show a certain stability with regard to their fertility status and salinity hazards owing to the self−mulching process.

Twenty years later Sombroek (1985) drew attention to the successful agricultural management research on vertisols (black cotton soils) in Australia, India, and the Sudan, while in many other countries the vertisols areas remain underutilized in respect to their overall high fertility.

In the *Benchmark Soils of India* study (Murthy and others no date) the authors describe the Sarol and Kamliakheri series as being the most widespread of the black cotton soils on the Malwa Plateau in Madhya Pradesh. These are members of the fine, montmorillonitic, hyperthermic families of *Typic Chromusterts* and *Lithic Vertic Ustochrepts*, respectively. They occur mainly at altitudes of 540 to 580 meters, where the climate is subhumid and subtropical, with a mean annual temperature of 24.4° centigrade and a mean annual rainfall of 1,050 millimeters. Garg and Sharma (1984) provide more details about local soils.

The soils in the Malwa region are generally medium black, of variable depth, and with a clay content of 45 to 60 percent; low in nitrogen content; low to medium in phosphorus content; and high in potassium and extractable bases. This leads to a cation exchange capacity ranging from 45 to 55 and a pH in the alkaline range of 7.5 to 8.0.

Soil management problems arise because of the high content of montmorillonitic clay, which develops deep cracks as it dries. After a few heavy rain storms the soil expands to close the cracks, and under saturated conditions the soil became very sticky and the moisture infiltration rate is low. These soils have a high water holding capacity that enables crops to be grown after the monsoon rains in what is known as the Rabi season. Rabi crops may also be irrigated with water from surface reservoirs or tanks and pumped water from tubewells. Farmers use two basic measures to manage black cotton soils: first, cultivating the soil immediately after harvest while some moisture remains in the soil to make it workable; and second, providing surface drains to remove surplus water at the height of the wet season. Farmers sometimes also use these drains to introduce irrigation water for the subsequent dry, Rabi season crops. As the general topography is rather flat and the farm sizes mainly of under 10 hectares, individual farm drainage is not satisfactory, but so far there has been little attempt to arrange drainage on a community basis.

The timing of the onset of the monsoon, its distribution, and the total amount of rainfall are all factors that affect the success of farming in central India. Investigators (Garg and Sharma 1984) have analyzed the daily rainfall amounts for the years 1928 to 1977 for Indore. The average total annual rainfall was 964 millimeters, of which 85 percent fell during a sixteen−week period in the middle of the year (weeks 24 to 39). On average, July had twenty−two wet days and August had twenty (Table 8−2).

Another more detailed study of the rainfall pattern at Sehore on the Vindhyan Plateau for the years 194785 (Rathore, Sharma, and Khan 1987) produced a higher average annual rainfall of 1,263 millimeters, but a substantially lower number of rainy days, averaging only fifty−four (range thirty−three to ninety days), with an average of only sixteen wet days in July and in August. Furthermore, gaps of two to four dry days frequently occurred during the monsoon season, when field work such as weeding was possible. Some people believe the frequency and duration of these short dry spells have increased, but this has not been closely analyzed. These periods of a few dry days during the Kharif season are crucial for sowing crops just as the monsoon arrives, and a few weeks later when an initial weeding is required. This point needs to be analyzed closely before trying to apply the Indian experience to other black cotton soil areas of the world.

Table 8−2. Measures of the Southwest Monsoon at Indore, Madhya Pradesh, 192877

Coefficient	*Monsoon onset*	*Monsoon conclusion*	*Monsoon duration (days)*
Median	June 18	September 23	99 days
Mean	June 19	September 21	98 days
Standard deviation	9 days	10 days	14 days
Coefficient of variation	47	44	14

Source: *Garg and Sharma (1984).*

Table 8−3. Average Daily Protein Requirements per Person by Age

Age group (years)	*Percentage of national population*	*Protein requirements (grams/capital/day)*
Under 5	17	20
515	23	47
Over 15	60	55
Weighted average	n.a.	47

n.a. = not applicable.

Source: *Indian Council for Medical Research, unpublished data.*

Market Demand and Public Policies

The basis for promoting cereal production in India from the 1950s was that domestic requirements were so huge that market demand would not constrain production. Once India had achieved self−sufficiency for cereals in most years, attention turned to other components of the human diet. Diet and nutrition surveys undertaken by the National Nutrition Monitoring Bureau of the National Institute of Nutrition, Hyderabad, showed that people who have sufficient calorie intake do not suffer from protein deficiencies, because traditional foods and eating habits in India provide balanced nutrition, provided that people can afford to buy sufficient food products. Based on the recommendations of the Indian Council for Medical Research, daily protein requirements for different age groups are as shown in Table 8−3.

Rounding the average requirement to 50 grams per capita per day, India's current population of approximately 870 million would require 16 million tons of protein annually. An unpublished estimate by the Indian Council of Agriculture Research estimates that, as an average for the three years 1989/90 to 1991/92, national protein production from all sources, allowing for retention of 12 percent of cereals, pulses, and potatoes for seed, was 21.2 million tons (Table 8−4). This supports the official view that the problem of protein malnutrition in India is not caused by a shortage of protein, but by the low purchasing power of a considerable proportion of the population.

Table 8−4. Net National Availability of Protein from All Sources, Annual Averages, 1989/901991/92 (millions of tons)

Commodity group	*Net protein availability*
Cereals	13.0
Pulses	2.4
Vegetables	1.5
Spices	0.2
Other crops (coconut, cashew nuts, fruits)	0.4
	3.7

Animal sources (meat, fish, milk, eggs)	
Total	21.2

Source: *Indian Council of Agriculture Research, unpublished data.*

When researchers advocated soybeans as an important source of protein, particularly for infant foods and as a base for texturized vegetable protein, in the 1960s and 1970s, there was little official support and considerable market resistance because of the public's unfamiliarity with soybeans and the relatively high price of soybean products. An extensive list of publications advocates soybeans as an important source of protein, including Bhatnagar (1986c), but this market has developed slowly.

India became a major importer of edible oils only in the 1970s, but by 1989/90 had once more become self−sufficient in most years. According to the *National Mail of Bhopal* (June 12, 1993), in 1992 the government still accepted 50,000 tons of soy oil under the US PL−480 aid program, and imported a further 10,000 tons of palm oil under a long−term contract with the government of Malaysia. According to the same source, in mid−1993 it was believed that the Indian government still held 40,000 tons of edible oils in its buffer stocks that it could release if the domestic open market price continued to rise despite the record 11.1 million tons of oilseeds harvested from the 1992 Kharif season by October. Another source (personal communication with Oilfed Regional Soybean Producers Cooperative Union Ltd., 1993) confirms the good 1992 Kharif production of oilseeds, which stood at about the same level as in 1988, but the composition had changed, with soybean production almost doubling. Since 1985/86 the total production of oilseeds in India has nearly doubled, increasing from 10.8 million tons in 1985/86 to 20.0 million tons in 1992/93, while soybean production has almost tripled. (Table 8−5).

Table 8−5. Oilseed Production, 1985/86 and 1992/93 (millions of tons)

Crop	*1985/86*	*1992/93*
Groundnuts		
Kharif season	3.76	5.60
Rabi season	1.36	2.20
Subtotal	5.12	7.80
Rapeseed and mustard	2.68	5.80
Soybeans	1.02	2.95
Sunflower		
Kharif season	0.17	0.38
Rabi season	0.11	0.80
Subtotal	0.28	1.18
Cottonseed	n.a.	n.a.

Safflower	0.35	0.40
Linseed	0.38	0.30
Nigerseed	0.10	0.19
Total	10.83	20.00

Source: *Personal communication with Oilfed Regional Soybean Producers Cooperative Union, Ltd., Nagziri, Ujjain, Madhya Pradesh (1993).*

There is ample scope for further soybean production in rainfed areas, despite soybeans' relatively low oil content, because of the steady external market for soybean cake or meal, also known as de−oiled cake. According to the Soybean Processors Association of India quoted by N.N. Jain (1993), there were 110 soybean processing plants in India in 1992 with a crushing capacity of 6.5

million tons per year, or more than double the current production. Soybean meal exports in 1992/93 earned foreign exchange equivalent to more than Rs 1,000 crores (US$318 million), and soy oil production had an import substitution value of Rs 600 crores (US$191 million).3 The *FAO Trade Yearbook* (1992, vol. 45) shows the rapid increase in the volume of exports of soybean cake between 1989 and 1991 (Table 8−6) at an average f.o.b. price bombay of between 82 and 93 percent of the commodity price indicator prices for Rotterdam (1990) and Argentina (1991) (World Bank 1993).

Table 8−6. Exports of Soybean Cake, 198991

Year	*Export volume (tons)*	*Export value (US$ thousands)*	*Average value per ton (US$/ton)*	*International indicator price (US$/ton)*	*Indian export value as a percent of the international indicator price*
1989	98,500	19,800	201	246	82
1990	126,045	24,429	194	209	93
1991	143,700	25,730	179	197	91

Source: *Export volume and value: FAO (1992); international indicator prices: World Bank (1993).*

Soybean cake export destinations are mainly in South Asia and the Far East, with the bulk (more than half) between April 1992 and March 1993 going to Singapore, probably for onward consignment. In Europe, Germany continues to be an important customer for Indian de−oiled cake, but exports to the countries of Eastern Europe and the former Soviet Union, which had been debited in rupees, have dropped (Table 8−7).

3 A crore = 10 million. Exchange rate June 1992: Rs 25.890 = US$1.00; June 1993: Rs 31.407 = US$1.00.

Table 8−7. Distribution of Exports of Soybean Cake, April 1992March 1993

Destination of exports	*Volume (thousands of tons)*	*Percentage of total exports*
Rupee payment area countries	45.4	3
European Community and Switzerland	245.8	14
South Asia and the Far East	1,277.7	72
Middle East	177.3	10
Other	24.7	1
Total	1,770.9	100

Source: *SOPA (1993).*

International trade prospects for soybean meal are moderately good, ranging around US$200 (1990 U.S. dollars) per ton for Argentina 45/46 percent protein as shown in Table 8−8. While the Indian authorities hope that the domestic market will strengthen as more people can afford an adequate supply of protein in their diet, the prospects are reasonably good that India will continue to find attractive markets for its soybean meal to be used mainly for livestock feed,. particularly in South Asia and the Far East, where the demand is firmer than in other international markets.

Table 8−8. Soybean Meal Price Projections, Selected Years (US$ ton) a /

Unit of value	*1993*	*1994*	*1995*	*2000*
1990 constant US$ per ton	189202	157273	145289	131328
Current US$ per ton	203217	174303	165329	171427

Note: *70 percent probability distribution (for base case price forecasts of November 2, 1993).*

a / Indicator price for Argentina Soybean Meal 45/45 percent protein.

Source: *World Bank (1993).*

The government of India administered fertilizer supplies and prices for many decades until they were decontrolled in 1992/93. However, that year the central government provided the states with Rs 340 crore (US$131 million) to provide selective subsidies to soften the impact of any price increases following their deregulation. For the 1993/94 season, the central government increased the funds for fertilizer subsidies substantially to Rs 756 crore (US$241 million) in response to public pressure. This is to subsidize locally produced diammonium phosphate, about 40 percent of which is imported; single super phosphate, all locally produced; and muriate of potash, all of which is imported (Table 8−9). In

contrast with the experience in Nigeria (chapter 6), fertilizers are generally available throughout the area of India in which soybeans have developed rapidly.

Table 8−9. Fertilizer Subsidies and Estimated Farm Gate Prices, 1993/94 Season

	Subsidy		*Estimated farm gate price range*	
Type of fertilizer	*Rs/ton*	*US$/ton*	*Rs/ton (excluding local taxes)*	*US$/ton*
Diammonium phosphate (local only)	1,000	31.84	6,200 to 6,400	197204
Single superphosphate	340	10.83	−	−
Muriate of potash	1,000	31.84	3,800 to 4,000	96127

− not available.

Source: Hindustan Times, *New Delhi (June 13, 1993).*

The provision of certified seed of improved varieties of soybeans accounts for only 6 or 7 percent of the market, and as with many other crops, the supply falls far short of national and local requirements. However, other less controlled "true to type" seed is available through local merchants and farmers' cooperative associations. One of the problems mentioned later is the frequently poor stand of soybean plants, which agriculturists believe is often the result of the low percentage of seeds that germinate. Similarly, the uneven effectiveness of *Rhizobium* inoculum applied with the seeds of legumes is probably caused by the material's low viability. These difficulties are particularly serious in hot rural areas, where storing the seed and inoculum under sufficiently cool conditions is hard and surface soil temperatures are high. However, improved methods of seed marketing and quality control are now attracting renewed public attention in India.

Farm machinery is especially important for soybeans on vertisols. Most cultivation is done using ploughs and tillage equipment made in the village and oxen. Researchers at the International Crops Research Institute for the Semi−Arid Tropics (Awadhwal and Smith 1989), the Central Research Institute for Dryland Agriculture (Mayande and Katyal n.d.), and the Central Institute of Agricultural Engineering in Bhopal, Madhya Pradesh, have made important improvements to the design of traditional implements, but these designs have not been effectively transferred or explained to village blacksmiths or small mechanical industries. Apparently none of these research institutions is well place to assist and support financially the local−level testing, training, and developmental work that would be required. The institutes also have had difficulty in transporting prototype machinery to locations in India where it might be most useful to farmers. In Ethiopia, it has been reported (ILCA 1993) that much greater success has been achieved in introducing simple, locally made ox−drawn equipment for preparing broadbeds and furrows.

During the past few decades tractors have been introduced into many dryland farming districts, and in some villages as much as 25 percent of plowing is done by tractor. Some harvesting and threshing has been mechanized, but it is still mostly done by hand. Since soybean pods tend to shatter during harvesting, crop losses in the field are generally higher with hand harvesting than with mechanical harvesting in which the whole pod may be collected before it opens.

Institutions and Investments

The public sector was galvanized into paying attention to agriculture by the 1870 famine, which led to major investments in flood control and irrigation schemes. The sector paid less attention to rainfed farming until the early years of the twentieth century. At first investigators focused on plant improvement, but as early as 1909 researchers laid out a long−term agronomic trial at Coimbatore, Tamil Nadu, and started a second one of better design at the same station in 1925. Both these trials are still being recorded.

One of the earlier research institutes was the Central India Holker State Institute of Plant Industry (IPI) at Indore. This evolved into the present College of Agriculture. It was at the IPI that Howard and Wad (1931) developed the Indore Compost System and many of the resource management systems now associated with the term organic farming. Howard's *Agricultural Testament* (1940) summarized his long experience with Indian agriculture, and emphasized the need to pay more attention to dryland agriculture and the key importance of soil organic matter in all farming systems.

Dryland research was organized in a more systematic way in 1934/35, when five dryland research centers were established (Bijapur, Hagari, Raichur, Rohtak, and Solapur). In 1954 eight soil and water conservation centers were established, but without being given a mandate for crop improvement or general agronomy. From the mid−1960s, nearly all sectoral public resources were directed toward promoting and facilitating the green revolution with HYVs of rice and wheat under irrigated conditions. However, in 1970/71 some attention reverted to dryland farming when the Indian Council of Agricultural Research of the government of India formed the All India Coordinated Research Project for Dryland Agriculture, which initially linked twenty−three centers of research in all rainfed farming regions. Subsequently the All India Coordinated Research Project on Agrometerology was formed in 1983, and in 1985 the Project Directorate of the All India Coordinated Research Project for Dryland Agriculture was upgraded to the Central Research Institute for Dryland Agriculture (CRIDA), conveniently located close to the International Crops Research Institute for Semi−Arid Tropics (ICRISAT) near Hyderabad, Andhra Pradesh.

The state departments of agriculture, working in collaboration with the local agricultural ministries, have been the main providers of agricultural extension services. However, in the state of Madhya Pradesh, the farmers' cooperatives and the Soybean Processors Association of India (SOPA) have also provided important support for soybean growers by supplying seed and technical advice to cooperatives and their members.

Cooperative and mutual help associations have been common in rural areas of India for many centuries, but it was not until the early twentieth century that the concept of specialized cooperative societies was introduced for credit and marketing. At best, the performance of the cooperative societies was uneven, and at worst it was disastrous. The success of the Amul pattern of self−sustaining milk producers' cooperatives under the overall supervision of the National Dairy Development Board gave new life to the cooperative movement. When the government decided that it had to make a concerted effort to regain India's self−sufficiency in edible oil, it used the dairy experience as a model. Oilseed grower farmers' cooperative societies were promoted in several states. These were linked together into apex oil federations at the state level. These federations provided the societies with technical support to establish seed grading plants and directly invested in and managed some oilseed processing industries. The oil federations also arranged financial advances from cooperative banks and the official banks to societies to enable them to purchase soybeans from their members. Under current arrangements, societies sell their soybeans at township auctions at which private oil mills bid against each other and the officially set floor price at which federations must buy. In 1992/93 the Madhya Pradesh oil federation processed less than 20 percent of the state's soybean output, but this was sufficient to provide a secure planning base for farmers, their cooperatives, and the oil milling industry.

In the state of Madhya Pradesh, an autonomous Regional Soybean Processors Cooperative Union was formed in 1982, which by 1993 comprised the 364 village cooperative societies of the Malwa region. This cooperative union has been effective in providing technical support services to its member cooperatives, but it ran into major financial problems in 1986/87, primarily because its new solvent extraction plant could not achieve more than 52 percent of its supposed design output. The state oil federation helped resolve the plant's problems, and by February 1993 the plant was achieving 85 percent of its installed capacity. Oil federation mills are working at a higher level of technical and financial efficiency than most private industries claim to achieve, because they build up large inventories of soybeans shortly after harvest to allow processing to continue for ten months a year.

The Indian railway system is one of the most extensive in the world, and is particularly important in the export of soybean meal, which is mainly through the Port of Bombay. As the volume of exports has increased, complaints by oil millers about the lack of timeliness and assured availability of railway wagons, referred to as "racks" of 100 wagons, have also increased. The port authorities are unable to promise to allocate shipping berths because of the uncertainty about when racks loaded with soybean meal will arrive. As a leading exporter, N.N. Jain (1993, p. 48), put it:

For example, take a premier market like Japan. They want to not only know the day of delivery of material, but also the time of day when it would reach their doorstep, whether it will be morning or afternoon, whereas, we cannot even give guarantee for a month.

While the oil processors complain that they have double the crushing and extraction capacity currently required and that many of them are not making a profit, this is largely a consequence of their own investment and financial management decisions. The main reason is the privately−owned industries' unwillingness to build up and carry sufficient stocks of soybeans after harvest to keep their plants operating for more than six months a year. This leads to a concentration of output at particular times that exceeds the capacity of the rail system. The cooperatively−owned plants do rather better,

and as already noted, some operate for as long as ten months a year. The private oil processors believe that cooperative plants receive priority in the allocation of racks of wagons, but this is hard to verify.

The location of the existing 110 soy oil processing plants in India is far from optimum. They are clustered together, which places a heavy burden on local utilities, particularly those supplying water, and few, if any, are directly linked to the main railway line. All transport of beans and meal is in sacks by truck to the railhead, which entails several stages of rebagging and manual labor before the meal is loaded onto ships. India has many more vertisol areas where soybeans could be grown, but persuading industrialists to invest in plants in these areas may be difficult until their existing plants are operating closer to full capacity. Transporting soybeans from distant areas is bound to lead to much lower local auction prices and much heavier congestion on the roads.

Factors and Systems of Soybean Production on Vertisols

Soybeans were grown in parts of India as early as 1717 (Bhatnagar 1990a). In 1932, according to Shroff and Gaikwad (no date), the records of the Institute of Plant Industry report that thirty varieties of soybeans of Manchurian and Chinese origin were introduced and tested to determine their suitability for conditions in central India. This led to the selection of Punjab White, which was further tested in several central Indian states. By 1936 investigators concluded that several soybean varieties were suitable for growing as a main or sole crop, or in association with the usual crops grown in the Kharif season. The highest bean yields were obtained from the black−seeded Otootan variety, and seed of this variety was multiplied on fifteen farmers' fields in 1935. Some seed was used for domestic consumption, but agriculturists knew little about the usefulness of soybean plants as fodder or of the seeds as a source of oil. They did, however, advocate that soybeans plants be used for green manuring instead of sun−hemp.

Field and pot trials with *Rhizobium* cultures imported from the United States were carried out in 1932 and 1933. Imported soybean varieties, such as Biloxi from the United States, responded to seed inoculation, while local varieties such as Punjab White produced higher yields with either phosphatic fertilizer or seed treatment with *Rhizobium*, but not both. For several decades further work with *Rhizobium* was dropped because of the difficulty of growing soybeans without inoculation. In 1942 during World War II, a yellow−seeded variety, Easy Cook, was released and became popular because of its publicly perceived medicinal value.

Until 1964 there was little interest in further soybean research because of a lack of domestic demand for either soybeans or soybean products (oil and meal), and because the organization and processing infrastructure to develop and export trade were insufficient. Several advocates urged that soybean protein should be used to improve the nutritional quality of the public's diet, particularly for infants and nursing mothers, but developing this market proved difficult because of traditional consumption habits and the low incomes of those in greatest need of protein supplements (Bhatnagar 1986c).

Until the 1970s, India was self−sufficient in edible oils, including both crops and dairy products, therefore the authorities had little interest in soybeans as a source of edible oil. However, from 1965 work resumed on varietal selection by comparing the improved varieties from the United States (Bragg, Lee, Clark 63, Hardee, and Improved Pelican), of which Bragg (100 to 105 days maturation) and Clark 63 (90 to 95 days maturation) were the first to be recommended by farm extension agents, but because of the rapid loss of viability of the seed of these varieties, they could not find much favor with the farmers.

With the renewed interest in soybeans as a source of edible oil from 1970, much greater attention was paid to variety improvement. During 197075 researchers compared varieties introduced from China, the United States, and several other countries, leading to the selection of Punjab 1 (yellow−seeded), which had a better germination performance than the U.S. material. However, on black cotton soil the local black−seeded soybean performed better, although it required 120 to 120 days to mature. In 197680 the oil crushing industry began to show interest in soybeans, but insisted on yellow−seeded beans such as T−49, which is a nonshattering variety, but is not well suited to growing on black cotton soils. Therefore the Indore College of Agriculture in Madhya Pradesh started a special soybean breeding program, which led to the development of a series of varieties better adapted to local soil and climatic conditions. By 1987 the area under black−seeded soybeans in Madhya Pradesh was no more than 10 percent of the total (personal communication with G.P. Saxena, joint director of agriculture, Indore, 1993).

With the formation of the National Research Center for Soybean in 1987, also at Indore, a collaborative program for soybean improvement by the College of Agriculture and the National Research Center for Soybean has led to major improvements in soybean varieties, including the recently released JS 335 and NRC−2 varieties. JS 335 matures in 95 to 100 days. It is resistant to bacterial pustules *(Xanthomonas campestris),* bacterial blight, green mosaic virus, and alternaria; tolerant to soybean mosaic virus and stem fly *(Melanagromyza sojae* and *Ophiomyia phaseoi)* attack; has a yield potential of 2,500 to 3,000 kilograms per hectare; and a germination percentage of around 85 percent. It is recommended for the whole of Gujarat, Rajasthan, and the Bundelkhand areas of Madhya Pradesh and western Maharashtra. NRC−2 matures in 95 to 102 days. It has some tolerance for bacterial pustules and alternaria and a yield potential of 2,500 to 3,000 kilograms. It is recommended for all parts of Madhya Pradesh. This variety is a mutation induced by irradiation (Bhatnagar and Tiwari 1991).

A continuing problem is the tendency of the pods of improved soybean varieties to open or shatter just before or during harvesting, one factor that limits the yield of the harvested soybean crop. Breeding for nonshattering characteristics is continuing, meanwhile the farm extension services are paying more attention to advising growers on the best time for harvesting, which may be while some pods are still slightly green.

The Madhya Pradesh state extension service is continuing to give high priority to improving arrangements for production of foundation seed; production, safe storage, and distribution of certified seed; distribution and procurement at the village−level; seed procurement and distribution; and promotion of outlets selling farm inputs in small towns and villages. A soil testing service is available,

but in other respect the extension service seems to give insufficient priority to land and water management strategies and practices. Soybean yields in Madhya Pradesh have improved only gradually since 1964/65 despite the substantial progress with varietal improvement (Table 8−10). Advances in field management have not kept pace with the release of higher−yielding varieties of soybeans. Seed germination is frequently uneven leading to gaps between crop plants that allows rapid growth of weeds. There are two reasons for this: first, the variable quality of the seed; and second, the high soil temperatures and the uneven seed bed because of difficulties in tillage just before or in the early weeks of the monsoon rains.

Table 8−10. Soybean Area, Production, and Yields, Madhya Pradesh, Kharif Season, Selected Periods, 1964/651992/93

Season	*Average annual area (thousands of hectares)*	*Average annual production (thousands of tons)*	*Average yield (kilograms/hectare)*
1964/651968/69	3.8	1.2	315
1969/701973/74	7.6	3.4	447
1974/751978/79	85.4	38.2	447
1979/801983/84	376.0	232.7	619
1984/851988/89	1,219.8	870.9	714
1989/90	1,878.0	1,497.0	797
1990/91	2,149.0	2,183.0	1,016
1991/92	2,296.0	1,887.0	822
1992/93 a /	2,600.0	2,100.0	808

a / *Provisional.*

Source: *Personal communication with G.P. Saxena, joint director of agriculture, Indore (1993).*

ICRISAT researchers have developed improved management systems for vertisols in India through trials laid down in 1976 on two small watersheds on the research station at Patancheru, Andhra Pradesh (ICRISAT 1987). These systems were initially adopted by some small−scale farmers in Begumgunj, Madhya Pradesh (Foster and others 1987). The land shaping was adapted from the practice of laying out cambered beds and deep drains used in many countries for large−scale, mechanized sugarcane production on vertisols. The ICRISAT system is described as broadbed and furrow laid out at intervals of about 1.5 meters (1.2 meters of bed and 0.3 meters of furrow). Oxdrawn equipment has been adapted or designed to prepare the land, sow seeds, apply fertilizers, and weed (see Awadhwal and Smith 1989 for a description). Mayande and Katyal (n.d.) have designed an

ox−drawn drill plough suitable for use under a wide range of conditions, including the broadbed and furrow system.

The ICRISAT trials clearly demonstrated the advantage of the broadbed and furrow system on a vertisol for several crops, although soybeans were not included in the trials. However, the BBF system is not used to any noticeable extent in Madhya Pradesh. Apparently, however it is proving more popular in Ethiopia (ILCA 1993). The reason for their slow adoption in India seems to be that all the farmers in a small watershed of anything from 100 to 500 hectares can rarely, if ever, agree on planning and constructing field and community drains in an integrated manner, landscaping to fill in the minor depressions common on vertisols, laying out the broad beds according to a uniform plan, and digging all furrows with a gradient of 0.4 to 0.8 percent. An integrated layout is essential to allow the safe discharge of surplus water in the Kharif season and the option of having supplementary irrigation in the following Rabi season. Katyal (1992) has pointed out that a farmers corps, village *sangha*, or village−level watershed corporation is imperative for watershed development, and insists that some form of corporation is indispensable for improved dryland management where landholdings are small and highly fragmented. Until organizing some form of communal landscaping becomes possible, the possibilities for improving the drainage of seasonally surplus water seem to be limited. Until this is achieved, it will continue to be difficult to secure an even germination and rapid early growth of soybeans or any other crop grown in the Kharif season. An early and vigorous growth by crop plants is essential to avoid excessive weed growth.

The other lessons drawn from the ICRISAT watershed trials have proved directly applicable and have contributed significantly to the rapid extension of the area of soybeans grown on vertisols in India even without the use of the BBF system of land management. The researchers found the following practices to be important, and they are incorporated into the training of farm extension agents:

Cultivating the land immediately after the previous post−rainy (Rabi) season crop has been harvested, while the soil contains some moisture and is not too hard;

Dry sowing or early sowing of rainy (Kharif) season crops;

Improving the placement of seeds and fertilizer;

Providing timely plant protection.

During the past twenty years tractors have gradually become available, even in the dryland, black cotton soil areas, where they have supplemented the traditional oxpower used for cultivation. However, as the number of oxen has been reduced, the availability of farmyard manure has also declined, while the need for additional organic matter for cropped soils has rapidly increased. The College of Agriculture, Indore, has been at the forefront of organic farming since the 1920s, when Howard (1940) emphasized the need for quick recycling of organic wastes, for which he and his associates had developed the first aerobic technique for compost making at IPI, known as the Indore Compost Method (Howard and Wad 1931).

Some agriculturists gave renewed attention to organic farming practices at Indore in the 1970s and 1980s (Shroff 1992a, b). This included studying the importance of vesicular arbuscular

mycorrizha (VAM) soil−borne fungi to improve the availability of phosphorus, and possibly to control some soil−borne pathogens. Investigators have found that VAM reinforce the effectiveness of *Rhizobium* treatment of soybean seeds and improve phosphorus nutrition, unless phosphorus is also applied as a fertilizer. This work was extended to phosphorus solubilizing bacteria (PSB), and in 1991 investigators produced a biofertilizer for field application that consisted of an organic carrier with various combinations of *Rhizobium*, VAM, and PSB applied fifteen days after emergence in granular and pelleted forms on either side of the young plants. These treatments reduced the need for chemical fertilizers.

Recommendations for fertilizer use for soybeans in the 1991/92 season were as follows:

	Nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)	Sulfur
Kilograms/hectare	20	80	40	20

No reliable surveys of how much fertilizer soybean farmers actually apply are available. However, the sales of phosphorus−containing fertilizer for the Kharif season in Madhya Pradesh followed the increase in soybean area between 1974/75 and 1987/88 fairly closely (Table 8−11). During the Kharif season soybeans are now the main crop receiving phosphatic fertilizers.

Table 8−11. Soybean Area and Phosphatic Fertilizer Sales, 1974/75 1987/88

Season	*Average annual area (thousands of hectares)*	*Sales of phosphatic fertilizer (thousands of tons)*
1974/751978/79	85.4	13.5
1979/801983/84	376.0	33.2
1984/851987/88	1,156.0	77.0

Source: *Department of Agriculture records.*

In an overview of the literature on production technology currently available for augmenting soybean productivity in India, Prabhakar, Tiwari, and Bhatnagar (1992) emphasize that phosphorus is the critical input that can help increase soybean yields, and that sulfur is essential for oil synthesis in plants, although field evidence of responses to sulfur application are not conclusive (Sharma and Gupta 1992). A number of trials have shown significant responses to modest applications of nitrogenous fertilizers. The authors note that in Madhya Pradesh the soil has sufficient potassium, but still they advocate 20 kilograms of potassium (K_2o) per hectare. It is possible that in these heavy clay soils some potassium may be too heavily bound to the soil to be available to plants, but this is an area that needs

careful investigation to avoid the unnecessary use of potassium−containing fertilizers on black cotton soils.

In view of the great importance of soybeans to the state and national economy, and considering that almost all production is on small−scale farms with limited financial resources, much closer analysis of the current fertilizer recommendations is advisable. Phosphorus is clearly needed, but can the rate of application be reduced by better placement in the soil, or possibly by applying vesicular arbuscular mycorrizha or phosphorus solubilizing bacteria treatments to the phosphate application in alternate years? Is nitrogen application necessary once a good population of *Rhizobia* has been established in the soil and the soil structure has been improved? How can soil organic matter be increased, particularly while the availability of farm−yard manure is declining? Could more crop residues be left in the field for incorporation into the soil, while improvements are made to grazing land and more forage crops are grown to feed livestock?

Soybeans are susceptible to attack in the field and in storage by a wide range of pests and diseases. Throughout the tropics and subtropics pests and diseases of legumes are commonly the main factors limiting production. For soybeans in India integrated management recommendations are available for the most common pests (Bhatnagar 1990b) and are followed by many growers. Nevertheless research has to be continued to introduce more resistance into the soybean varieties and a decreased reliance on agrochemicals for pest and disease control.

The hydrological balance in Madhya Pradesh is a matter of increasing concern as the population increases and urban and industrial development advances rapidly. In many parts of the Malwa region, where the main soybean development has taken place, the premonsoon groundwater level dropped by more than four meters between 1981 and 1990, although the average premonsoon level has risen in a few districts, for example, Jhabua, Ratiam, and Shajapur (V.K. Jain 1993). At first some agriculturists thought that by replacing fallow land and substituting soybeans for some typical Kharif season crops, the total evapotranspiration would be increased, and thus the recharge of groundwater reserves would be reduced. This view is almost certainly erroneous, because during the rains the fallow land is mostly covered with freely transpiring vegetation, and even though the total moisture transpired by soybeans during a season may somewhat exceed that transpired by, say, maize, the improved soil texture and absence of surface soil capping under a heavy cover of soy foliage will allow a higher rate of water infiltration and less surface runoff and evaporation from water on the soil surface.

Certainly further work on plant:water balances would be useful; however, the drop in groundwater level is much more likely to be the result of the introduction of more than 200,000 bored wells fitted with India Mark II hand pumps in 67,040 villages with water supply problems throughout Madhya Pradesh (V.K. Jain 1993). In addition, extension agents report that many farmers whose family incomes have risen substantially through the production of soybeans have used their savings to sink and equip additional, often unregistered, tube wells. They use the water obtained in this way to irrigate their Rabi (dry season) crops, to meet their domestic needs, and in some cases to sell tanker loads of water to industrialists in urban areas where the municipal water supplies are inadequate.

Thus, while the success of the introduction of soybeans in substantially raising farm family incomes and reducing year to year fluctuations in farm income has probably indirectly accentuated an existing major problem of water resource management, the solution should not be to restrict soybean production, but to evaluate the sinking of tube wells better. In addition, state authorities should give higher priority to the artificial recharge of groundwater in the region's basaltic and sedimentary aquifers. In a black cotton soil region this is particularly difficult, because after the first few rain storms the soil material swells and inhibits the downward movement of moisture. Intensive cropping with additions of organic matter from crop waste and farmyard manure can substantially improve the surface soil structure, but it is unlikely to increase deep percolation of water. Therefore, investigating further methods for injecting surplus water in the Kharif season directly into the strata below the layer of black cotton soil would be a worthwhile activity and, in any case, a system of water pricing that reflects its scarcity value is urgently required.

Commentary

Deliberate public policy decisions led to the ten fold expansion of soybean production in India in the 1980s. The main policy instrument was to provide an assured market outlet for all soybeans produced. The private sector industrialists were encouraged to invest in oil mills and refineries and to seek export markets for soybean meal. For the industrialists the soybean meal exports secured foreign exchange resources and provided the profit margin on the whole enterprise of milling and processing soybeans. The public policy objective was achieved through the production of soy oil to restore India's self−sufficiency in edible oils. Weakness in public policy regarding water resources and their pricing have led to excessive extraction of water from underground sources for domestic and industrial use, as well as for irrigation of crops after soybeans have been harvested. The location of the many new oil mills and refineries has not followed any strategic plan to optimize the use of existing roads and railways or to make use of limited ground water supplies rationally.

Many years of somewhat fragmented research underlie the substantial advance in soybean production from the vertisols of central India. Strong government action in the 1980s provided the framework for development through:

Integrating research and extension efforts;

Providing a guaranteed support price;

Maintaining a variable, but declining, subsidy of fertilizer prices.

The extensive planting of soybeans in large contiguous areas presents the possibility of massive attacks by one or more insect pests or diseases. In addition, the planting of the same crop on the same field each Kharif season may lead to the proliferation of weed species that effectively compete with the crop. In the medium term there is also the possibility of a build up in the population of soil nematodes that can attack soybeans. Agronomic and economic research is advisable on crop rotations that include several crops throughout the soybean area and a greater development of mixed cropping is advisable in the Kharif season.

The government of India's deliberate and concerted effort to reawaken interest in soybeans and to stimulate economic growth in the impoverished areas of Madhya Pradesh has been remarkably

effective over a relatively short period. Based upon the experience and improved varieties already available, there is no doubt that the area and yields of soybeans could be substantially increased by incorporating districts far from the present core production area. A constraining factor may be that the oilseed processors are reluctant to move to new areas while their existing plants are operating at only about 50 percent of capacity.

To increase yields within the collection area of the existing oilseed processing plants, substantial improvements in land management are essential to provide better growing conditions in which the high yield characteristics of the improved varieties can be fully expressed. Some farmers have already achieved this, and they can lead the way for others. However, before any substantial increase in average yields is achieved, more collective, village−level action is necessary to coordinate land drainage patterns. This is likely to be a slow process, but the sooner it is started the better.

In view of these structural constraints, the rate of increase of soybean production may well slacken, but it is likely to keep pace with the increasing domestic consumption of oil. In the longer term, protein exports may decline as domestic purchasing power increases and the demand for concentrated livestock feed increases substantially as a greater number of consumers can afford a diet containing more protein.

9—
Kenya:
Tea Development

The development of what became British East Africa was a direct consequence of the British Parliament's decision to fund a railway from the Indian Ocean port of Mombasa, initially to Lake Victoria. The political pressure for this project came from the antislavery lobby, which sought improved access to Uganda for military forces to stamp out Arab slave raids and trading. After much debate, the "lunatic line" was approved, and eventually reached Lake Victoria in 1901. Even before it was approved, people were asking what freight the line would carry, as it passed mainly through unpopulated regions. In time, this situation led to the promotion of settlement schemes, at first for families from all over Europe, and then after World War I for demobilized military personnel. The early settlers and the missionary services tried many temperate, subtropical, and tropical crops and livestock in the contrasting ecological zones of what became Kenya in the 1920s. Coffee was one of the first crops shown to be a potentially important export crop, and the British East Africa Agricultural Department's annual report (Department of Agriculture 1920) for 1916/17 noted the wartime restrictions on coffee shipments for export, but made no mention of tea. The 1923 and 1924 annual reports of the new Kenya Department of Agriculture mentioned tea briefly as a possible crop, but expressed doubts about the year−round availability of pluckers to harvest the crop, as the need for such workers could conflict with essential work on small−scale farms, such as sowing, weeding, or harvesting food crops.

Several of the settlers had grown tea in Assam, India, and started planting tea in Kenya in the early 1920s. By 1925 farmers had planted 382 acres (155 hectares) and shipped the first exports of 1,341 pounds (0.6 tons) of made tea (made tea refers to the final marketed product containing 3 to 4 percent moisture). Even more significant, reported imports of tea seed totaled 43,480 pounds (19.7 tons). By 1928, made tea exports totaled 86 hundredweight (4.4 tons), farmers had received favorable reports on tea quality from the tea brokers in London, and people were less concerned about the availability of labor for plucking. During the next few years tea planting increased rapidly, and by February 1931, the time of the twelfth agricultural census, which included tea for the first time, Kenya had 10,052 acres (4,068 hectares) of tea estates as reported to the International Institute of Agriculture in Rome, Italy. During this period, tea planting was also proceeding rapidly in Nyasaland (now Malawi).

The worldwide economic depression in the 1930s checked, but did not halt, tea planting in Kenya. It did, however, bring to a head the long−standing fight for world market shares for tea between the government of the Netherlands, which was promoting tea planting in the Dutch East Indies (now Indonesia), and the British government on behalf of the tea plantations of India and Ceylon (now Sri Lanka) (it did not yet view East African tea as a major competitor). The International Tea Committee was formed in 1933 to provide a forum to prevent an all−out tea trade war and to administer the International Tea Agreement (ITA). According to Wickizer (1951), British African territories were issued ITA standard export or quota amounts from 1938/39 to 1942/43, but apparently exports from Kenya never came close to these authorized levels.

World War II provided another check to the expansion of the area under tea, and yields stopped their steady rise after 1942, and indeed remained remarkably steady at around 1,000 kilograms of made tea per hectare (plus or minus 200 kilograms) until the mid−1950s. The area of estate−grown tea continued to rise steadily thereafter, reaching 10,000 hectares by 1959, 20,000 hectares by 1970, and approached 30,000 hectares in the early 1990s. Yields from estate−grown tea resumed their increase from the late 1960s, reaching 1,500 kilograms per hectare in 1969, 2,500 kilograms per hectare in 1979, and more than 3,000 kilograms per hectare by 1990.

People's experience of tea growing in Asia convinced most of them that tea was not a crop suitable for growing by smallholders "because of the high cost of factories and the difficulty of collecting green leaf from numerous, scattered peasants (see Table 9−1 for a summary of the development of tea estates and small holders). Nevertheless, every effort must be devoted to developing sound and practical peasant tea−growing schemes in suitable areas" (Swynnerton 1955, p.18). In 1953 planning to intensify the development of African agriculture in Kenya began. This was to incorporate many partially implemented projects and to provide temporary employment for 20,000 to 30,000 members of the Kikuyu tribe displaced by the recent "Emergency." The plan's main purpose was stated to be "to improve the economy of the country which is largely based on agriculture." This was to be achieved through "raising the productivity of the land or its human and stock−carrying capacity and the standards of African farming" (Swynnerton 1955 p. ii). The plan covered both lands of high potential and semi−arid pastoral areas. For the high potential areas, the plan developed specific area targets for a wide range of cash crops, of which the most ambitious for 1968 were for coffee (71,500 acres), pyrethrum (48,000 acres), sugarcane (45,000 acres), pineapples (25,000 acres), and tea (12,000 acres). At that time Nyeri District had only 35 acres of tea planted as the first step of a 500−acre smallholder scheme managed by the African Land Development Board (ALDEV). The Swynnerton Plan envisaged that eventually Kenya might have some 71,000 acres (28,733 hectares) of smallholder tea, but held the target for the first fifteen years to 12,000 acres to allow time for pilot schemes to show if "tea can be grown successfully as a peasant crop; whether the relatively low return per acre will induce Africans to grow tea in sufficient acreage; and whether the establishment of expensive factories for scattered peasant plots is economically sound"(Swynnerton 1955 p. 19).

Smallholder tea development proceeded much faster than expected, and by 1968 12,233 hectares were in the ground (252 percent of the original Swynnerton Plan). By 1971, the area of smallholder tea almost equaled the area of estate−grown tea, and by 1988 the quantity of smallholder−grown tea exceeded total estate production for the first time. However, smallholder yields, 2,000 kilograms per hectare in the early 1990s, averaged only about two−thirds of average estate yields of more than 3,000 kilograms of made tea per hectare. As Figures 9−1, 9−2, and 9−3, and Table 9−2 show, developments in the growth pattern of the tea estates and smallholder tea growers have been comparable.

Table 9−1. Phases of Development of Kenya Tea Estates and Smallholders

Phases of development	*Estates*	*Smallholders*
Initial buildup phase: increasing yields as the rate of planting slows and the tea bushes mature	1925 to 1942	1955 to 1970
Second phase: stable yields	1943 to 1966	1971 to 1980
Third phase: increasing yields mainly in response to nitrogenous fertilizer applications	1967 to date	1985 to date

Source: *See annex (page 147).*

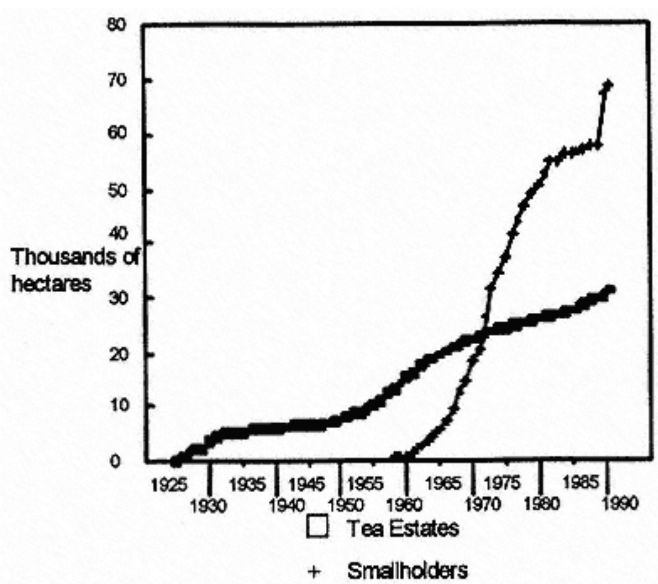

Figure 9−1.
Planted Areas of Tea on Estates (KTGA) and by Smallholders
Source: 192530: Department of Agriculture Annual Report −(various issues); 193162: International Tea Committee Bulletin of Statistics −(various issues); Smallholder 1958 Commonwealth Development Corporation (195963) and Special Crops

Development Authority (1963) Annual Reports ; 196392 The Tea Board of Kenya except US$ value of exports from the International Tea Committee and data for 1992 and for local sales 196374.

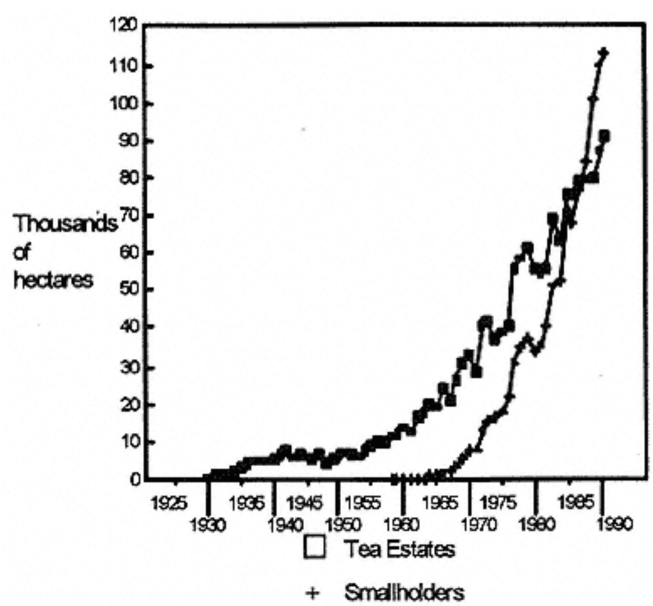

Figure 9−2.
Tea Production (metric tons) for Estates and Smallholders
Source: 192530: Department of Agriculture Annual Report −(various issues); 193162: International Tea Committee Bulletin of Statistics −(various issues); Smallholder 195862 Commonwealth Development Corporation (195963) and Special Crops Development Authority (1963) Annual Reports ; 196392 The Tea Board of Kenya except US$ value of exports from the International Tea Committee and data for 1992 and for local sales 196374.

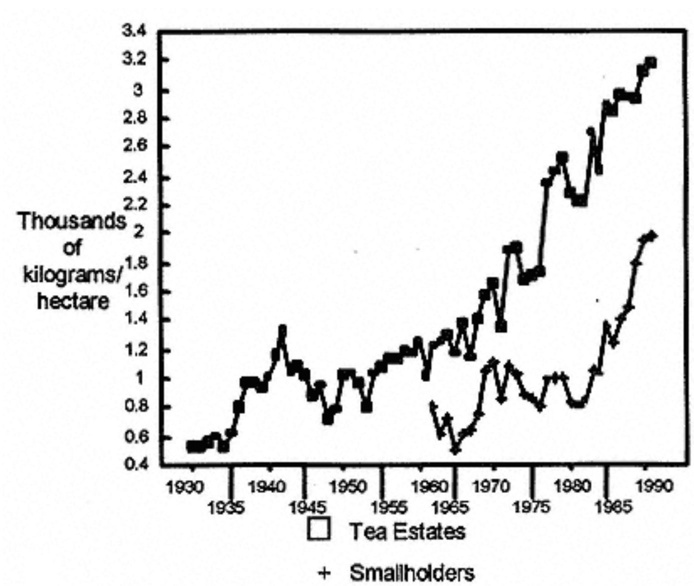

Figure 9−3.
Yields from Harvested Tea (Four Years and More from Year of Planting)
Source: 192530: Department of Agriculture Annual Report −(various issues); 193162: International Tea Committee Bulletin of Statistics −(various issues); Smallholder 195862 Commonwealth Development Corporation (195963) and Special Crops Development Authority (1963) Annual Reports ; 196392 The Tea Board of Kenya except US$ value of exports from the International Tea Committee and data for 1992 and for local sales 196374.

Table 9−2. Tea Area Production and Yields of Made Tea, Selected Years

	Estates			*Smallholders*			*Total*
Year	*Planted area (hectares)*	*Production (tons)*	*Yield (kilograms/ hectare)*	*Planted area (hectares)*	*Production (tons)*	*Yield a / (* kilograms/ hectare)	*national production (tons)*
1930	4,068	422	532	0	0	0	422
1931	4,556	680	533	0	0	0	680
1940	5,833	5,409	1,014	0	0	0	5,409
1950	7,642	6,776	1,031	0	0	0	6,776
1960	15,075	13,631	1,246	862	145	n.a.	13,776
1965	19,327	19,027	1,175	5,429	796	509	19,823
1970	22,289	33,101	1,647	17,985	7,976	1,102	41,078
1975	24,337	38,815	1,700	37,205	17,915	873	56,730
1980	25,850	55,913	2,279	50,691	33,980	821	89,893
1985	27,322	75,755	2,897	56,505	71,339	1,353	147,094
1990	29,979	87,012	3,124	67,041	109,997	1,945	197,008
1991	31,017	90,847	3,184	68,813	112,742	1,982	203,589
1992	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	188,072

n.a. = not available.

a / Yield from tea bushes over four years from field planting.

Sources: *See annex (page 147).*

Local Conditions and Natural Resources

The highland areas of Kenya, where most of the population now lives, account for no more than a fifth to a quarter of the national total area of about 58,000 square kilometers. Much of the highlands are of volcanic origin and lie close to the equator, between latitudes 1 degree north and 1 degree south and longitudes 35 to 38 degrees east (see map of Kenya). The Great Rift Valley divides the highlands into the East of Rift and West of Rift regions. To the west of the Rift Valley the rainfall is generally higher than in the east, and is only slightly bimodal in distribution. As Lake Victoria is the dominant source of precipitation, much of the rain falls in heavy afternoon thunderstorms. In the East of the Rift region the rainfall pattern is sharply bimodal and depends heavily on the northeast and

southeast monsoons from the Indian Ocean. The annual rainfall totals in the tea zone range from 1,500 to 2,200 millimeters.

The early European settlers introduced the first tea into Kenya in 1903 (Othieno 1991), mainly in Limuru, close to Nairobi, east of the Rift Valley and Kericho, west of the Rift Valley. Almost all estate−grown tea has been planted into land freshly cleared from tall rain−forest at an altitude of around 7,000 feet (2,000 meters). In contrast, when the government promoted smallholder tea from 1955, it was planted almost entirely on former cropland or fallow areas that had been cleared of tall rainforest many years earlier.

As part of the long−term studies of the effects of changes in land use in some East African rainfall catchment areas, Kerfoot reported in 1957 (in Pereira 1962) on the initial vegetation of two major valleys near Kericho, where the forest was about to be cleared for estate−grown tea, and in the same report Scott summarized his observations on the soils found in one of these valleys. These studies were initiated because of the concern that further clearing of natural forest might disrupt the regularity, and possibly reduce the stream flow, of the numerous small rivers draining the West of Rift catchment into Lake Victoria, and eventually reduce the outflow to the Nile. The Egyptian government has always been vigilant about any possible interference with the flow of the Nile, particularly since the 1929 Nile Water Agreement and a series of diplomatic exchanges between 1949 and 1952 concerning the Owen Falls Dam in Uganda (Pombe 1958), in which all parties agreed to avoid any actions that might adversely affect the flow of the Nile from Lake Victoria.

The tea around Kericho is grown on very porous, stone−free soils that have developed from a massive, impermeable sheet−flow of hard phonolite lava. Useful amounts of groundwater are seldom available above the phonolite, as the moisture from the heavy local rainfall either drains laterally through springlines into water courses, runs over the surface to the streams, or is transpired through the vegetation. The recording of stream flow and rainfall records in the Kericho trials continued for almost twenty years to 1977, and Blackie (1979) reported the results of the studies of tea planting on one of the two test catchment areas. These showed broadly that the catchment in which tea was planted experienced increased erosion and more erratic stream−flow during the initial three− to five−year development phase. Once the tea canopy had closed over, the long−term mean value of water use by the tea plantation was 84 percent of the potential evapotranspiration (Penman Eo), compared to 92 percent Eo used by the untouched forest. The annual variability in water use was greater for the catchment retained under forest than for the catchment in which 54 percent of the forest had been cleared for tea.

Clearly, therefore, under good land and water management, the conversion of tall rainforest to tea would not adversely affect stream flow variability or totals. Indeed, total stream flow could be greater under tea than from forest under local conditions. This may be because the entire Kenyan highlands are effectively an island of transpiring vegetation receiving additional incoming energy through drying winds from the country's semi−arid regions, as well as the direct energy from sunlight. Later work studied surface runoff and soil erosion on young tea fields (Othieno and Laycock 1977). In the first year surface runoff could be between 1 and 30 percent of incident rainfall, but by the third

year, when ground cover was over 60 percent, only very small amounts of water were lost by surface movement, and no erosion occurred once the tea canopy covered 65 percent of the surface area.

Scott's soil survey results from the Sambret Valley near Kericho (in Pereira 1962) showed that the soils' physical and chemical composition was similar over a wide area and under quite contrasting high forest tree or bamboo cover. The soil pH was acid (5.5 to 5.9), and all the soils were low in total exchangeable bases and had a low saturation status. He therefore concluded that applying fertilizers to obtain the optimum yields may be advantageous. Subsequently, Brown (1963) provided further information on soils in his report on Kenya's cash crop growing potential. This report focused on locations for tea that received high and reliable rainfall without risk of frost. Brown expressed soil requirements in terms of volcanic origin and depth rather than by using specific physical or chemical criteria. In the small−scale farming areas, smallholders often planted tea on previously cultivated land along the margins of untouched forest, where bracken rapidly invades fallow land, and is generally regarded as a reliable indicator of high soil acidity.

More recently (1985), the president of Kenya launched an interesting but problematic program to plant a 100−meter buffer strip of tea along the margin of the forest reserves above the current tea zone. The Nyayo Tea Zones Development Corporation manages this program, whose aim is to preserve the forest zones from human encroachment by growing tea in government forest zones. By 1992 approximately 4,000 hectares of tea had been planted, equivalent to about 40 kilometers of forest buffer zone.

Table 9−3. Rainfall and Average Tea Yields, Driest and Wettest Years

Year	*Rainfall (millimeters/year)*	*Yield (kilograms/hectare)*
Four driest years		
1979	1,671	
1980	1,563	
1984	1,443	
1986	1,341	
Average	1,504	3,157
Four wettest years		
1977	2,053	
1978	2,151	
1982	2,010	
1988	2,030	
Average	2,061	2,949

Source: *Brooke Bond Kenya, Ltd. personal communication (1993).*

In contrast with almost all other farming activities in Kenya, or indeed in most countries, there is remarkably little variation in the year to year tea yields that is attributable to climatic conditions

(Figure 9−3). Years of poorer rainfall do occur, but are less serious in the regions that have been chosen for tea growing, where the rainfall is more reliable and the temperature is cooler than in most of the country. These conditions are also unfavorable to most insect pests of tea, such as mites, which are seldom of economic significance. For example, according to the records of Brooke Bond Kenya, Ltd. from the company's Kericho estates between 1977 and 1992, there is no obvious relationship between annual rainfall and yield, possibly because of improvements in general agronomic management (Table 9−3).

Damage by hail is a common risk, mainly in the west of the Rift tea areas. This can be locally devastating for one or two pluckings. Some valleys seem more prone to hail than others in a particular year. The following year the pattern of hail damage can change remarkably. At one time a program of hail damage mitigation used rocket or aerial seeding of storm clouds with silver iodide or common salt. This proved expensive to sustain and not fully reliable. There is certainly scope for further research into other ways to mitigate the intensity, size, and hardness of hailstones, but for the moment farmers accept hail damage as an important risk, but it probably does not reduce average yields by more than 10 percent, even in the areas most prone to hailstones (Brooke Bond Kenya, Ltd. 1993, personal communication).

The Market for Kenyan Tea

The early samples of tea sent from Kenya in the 1920s received favorable comments from tea tasters in London. This gave the Kenyan authorities the confidence to allow the settlers to proceed with clearing forest for tea planting on small estates in Limuru, near Nairobi, and around Kericho. The authorities did not carry out any detailed analysis of market prospects, but they were aware that Kenyan tea would have to compete with the well−established Ceylonese (Sri Lankan) and Indian teas, and that quality would be important. As the tea estates became more numerous and the areas under tea more extensive, they gradually became integrated into large international corporations, particularly after World War II. Currently the main groups include Brooke Bond Kenya, Ltd., African Highlands Produce, George Williamson, and Eastern Produce Africa. Through these major groups the Kenyan tea industry has kept closely in touch with changes in world market demand.

The type of tea produced in Kenya is described as plain to medium flavor black tea, which indicates that it does not have large amounts of the delicate flavor components found in certain other teas from some other countries during particular seasons of the year. The characteristics of Kenyan tea include strength, brightness, color, and briskness, and in some cases a distinct flavor (TRF−K 1986). However, as Othieno (1991, p. 80) has pointed out based on analytical data from Owuor and others (1987):

Kenya has very high plain tea parameters, ely theaflavins and thearubigins and, in addition, show a high "Flavour Index", strongly indicating that Kenya produces flavoury teas. Indeed, in terms of flavour, the latter was second only to that of Darjeeling tea, suggesting that Kenya teas are among the highest ranked world flavoury teas.

As he further remarks, why the tea trade continues to market the Kenya product as a plain tea is not clear.

Initially, all Kenyan tea was "manufactured" according to the "orthodox" process that is necessary to maintain or produce very delicate flavors. However, at about the time that tea growing by smallholders started in Kenya in the 1950s, a new "cut, tear, curl" (CTC) process was introduced. This yields a product for market that is brighter and brisker and produces more colored infusions, which makes it particularly suitable for use in tea bags and quick brew teas. All smallholder tea in Kenya is now manufactured by the CTC process, and by 1993 only one orthodox factory remained in the estate tea sector. Kenya has been a world leader in the conversion to the CTC process in response to changing market demand.

Kenya's domestic market has never been the demand leader as in China, India, and Turkey. It has, however, grown considerably as the population has increased and the taste for tea has developed. However, it still only accounts for about 14 percent of national production of made tea and does not show much sign of increasing.

Table 9−4. Country Shares of World Production and Trade of Black and Green Teas, 199091 (percent)

	Share of world production		*Share of world trade*	
Country/region	*1990*	*1991*	*1990*	*1991*
China (of which green tea)	21.5 (13.3)	29.5 (12.4)	17.3 (7.3)	17.1 (7.0)
India	21.5	29.5	18.5	18.7
Kenya	7.9	8.1	15.0	16.2
Sri Lanka	9.3	9.6	19.0	19.5
Turkey	5.2	5.5	2.4	0.2
Rest of the world	21.8	21.3	18.0	18.1
Total	100.0	100.0	100.0	100.0

Source: *International Tea Committee, Ltd. (various publications).*

Kenya's tea industry has always been export oriented. Initially, it served an insignificant proportion of the world market for tea. During the 1930s, as market competition between the British (Indian subcontinent) and Dutch East Indies (Indonesia) colonies became serious, little attention was paid during international negotiations to the potential competition from African countries. The International Tea Agreement provided for permitted shares of the international tea market starting in 1933/34. "Except for exports by land from India to Iran, which were not brought under control until

1935, there seems to have been no great difficulty in keeping overseas shipments within the established quotas" (Wickizer 1951, p. 90). During the second period of regulation, 1938/391942/43, four British African territories, including Kenya, participated in the International Tea Agreement. The largest tea producer at that time was Nyasaland (Malawi), closely followed by Kenya, with minor exports expected from Uganda and Tanganyika (Tanzania). For the five years of quotas under the second period, Kenya was allocated the equivalent of 28,300 tons of standard exports, which excluded trade with Uganda and Tanganyika. During the war years, the standard of tea estate management and yields declined, and actual exports for the five years totaled only 23,200 tons, or 82 percent of the allocation.

Some thirty years later, in September 1972, the Food and Agriculture Organization of the United Nations convened an Intergovernmental Group on Tea, which proposed quotas for exports of black tea based on official estimates of export availability. The group agreed that exporting countries would adjust their exports of black tea so as not to exceed these figures. This attempt at market regulation did not constrain Kenya, which during the four seasons covered, 197073, exported 164,000 tons, or 92 percent of the initially agreed export availability. At the time of the group's meeting, Kenya's tea exports were only 6.5 of world black tea exports, which at that time did not include China.

By 1991 Kenya had acquired 19.5 percent of the world market for black tea (excluding China). Exports from China are now included in world trade data, but even with this adjustment Kenya's black tea exports still accounted for 16.2 percent of the world market for black and green tea in 1991, placing it fourth in the world league of tea exporting countries, or third in terms of black tea exports (Table 9−4).

The performance of Kenya's tea industry during this period is quite remarkable, given that during the same two decades exports of all other agricultural crops from Africa were losing a substantial share of world trade. For example, in a few years the exports of palm oil from Malaysia greatly exceeded total palm oil exports from all West Africa. The prospects for Kenya's tea exports continue to be favorable, although world prices are not expected to rise (Table 9−5). This is because Kenya has a climate and soils appropriate for growing tea; the institutional organization that has evolved during the past sixty−five years is diverse and flexible; plant breeding and selection and nutrition research are continuing; so far no important diseases or pests have affected tea; and labor is relatively cheap, however, this will increasingly be the main factor limiting further expansion.

Table 9−5. Long−Term Tea Prices, Selected Years (average prices received for all teas at London auctions in U.S. cents per kilogram of made tea)

	Actual					*Projected*				
Price	1970	1980	1990	1991	1992	1993	1994	1995	2000	2005
Current	110	223	203	184	200	185	192	212	258	310
Constant (1990)	437	310	203	180	188	173	173	186	198	211

Source: *World Bank (1993).*

Long−term tea price projections (1990 constant U.S. dollars) appear fairly stable around 200 cents per kilogram (Table 9−5). From 1980 to 1992 prices dropped sharply from 310 to 188 cents per kilogram, but this may be lower in 1993 and 1994. Current price projections for the year 2000 are 258 cents per kilogram, rising to 310 cents per kilogram by 2005 (World Bank 1993). In the past, Kenya's tea output and yields have shown little obvious response to world market prices, even though Kenya has an entirely open trading system. There is little doubt that tea estates intensified their production in the 1970s and 1980s to maintain profits in the face of rising labor and fertilizer costs, rather than in response to higher product prices. This is likely to be the pattern for the future, both on estates and smallholdings. The availability and cost of labor for plucking tea remain the critical factors, as the Department of Agriculture in 1925 and the Swynnerton Plan in 1953 foresaw.

At current prices individual pluckers on estates cannot harvest more green leaf tea than about the equivalent of US$1 per day. The plucking day is shorter on small−scale farms, as transporting the green leaf (by bicycle or handcart) to the leaf buying center usually takes one to two hours, but several farm family members may help with the plucking. In any event, the daily remuneration is low. It could possibly rise in current prices by 30 percent by 2000 and 50 percent by 2005, but not by much more. The TRF−K is already comparing mechanical and hand plucking and, as expected, has found that all mechanical harvesting treatments significantly outyield hand plucking, but the quality of tea from hand plucked green leaf is superior. During the coming decade, the introduction of machine plucking to Kenya seems inevitable. This will be essential to increase the added value per day's work on both smallholdings and estates.

Institutions and Investments

Private investors led the development of Kenya's tea sector for the first half of the twentieth century with little, if any, direct government support. However, the industry would not have started at all without the construction of the Uganda Railway, which reached Lake Victoria in 1901 and passed through two of the highland forest areas that the early settlers found to be suitable for growing tea. General public policy was supportive of the industry, but until 1950 did not directly affect it.

Until the breakup of the East African Community in 1977, two associations represented estate−scale tea producers and traders in Kenya, Tanganyika (Tanzania), and Uganda. The Tea Growers Association represented its member tea estates in negotiating wages and terms of employment for all tea workers and in other matters of common interest. The Tea Trade Association was made up of East African tea producers (but now also includes small−scale tea growers in Kenya through the Kenya Tea Development Authority), tea brokers and buyers, and others whose activities relate to tea production and marketing. Its functions were to organize and control the Mombasa tea auctions and domestic commercial sales of tea. The association advised the Tea Board on tea marketing since the board's formation in 1950. During the period of the international tea agreements, from 1933/34 until about 1955, and for the purpose of complying with wartime shipping quotas, the East African administering authorities delegated responsibility for complying with standard tea export entitlements and shipping volume permits to the Tea Trade Association.

Table 9−6. Approximate Annual Expenditures in African Areas in 1953 (thousands of pounds sterling)

Department	*Kenya colony funds*	*U.K. development funds*	*Total*
Agriculture	285	290	575
Veterinary	279	144	423
ALDEV	0	297	297
Total	564	731	1,295
Percent	44	56	100

Source: *Swynnerton (1955, p. 4).*

At the end of World War II, U.K. government policies toward British colonies, dependencies, protectorates, and trusteeship territories changed quite sharply. These had hitherto been supposed to be essentially self−financing, without the introduction of public funds from U.K. taxpayers. At this time, however, a fund was established with U.K. public funds for colonial development and welfare that, among many other schemes, funded the ALDEV Program in Kenya (194656). By 1953, more than half the public expenditures in Kenya for agriculture and rural development in small−scale African areas, as contrasted with European farming areas, were derived from U.K. development funds (Table 9−6). In addition, at about the same time, there was substantial public expenditure on land registration and the consolidation of many parcels of land into holdings of one to two hectares. This was an important preparatory step before perennial crops such as tea and coffee could be promoted on smallholdings.

Most of the ALDEV funds were allocated to the semi−arid and pastoral areas of Kenya, where water shortages, severe erosion, poverty, and occasional famines were most serious. Machakos, Kitui, the Masai District, and the Northern Province were major beneficiaries of ALDEV schemes. A few ALDEV projects were in areas of high agricultural potential, and one of these was the Nyeri Tea Scheme, which received £4,700 sterling, or 0.3 percent of total ALDEV expenditures from 1946 to 1952 (£1,633,700 sterling). By 1953 this pilot tea scheme had 35 acres planted on smallholder farms (Table 9−7). Development had been retarded by the State of Emergency, but the initial experience was promising, and led to tea being cautiously introduced into the Plan to Intensify the Development of African Agriculture in Kenya, compiled in 1953 by Swynnerton, who was at that time the assistant director of agriculture. This became known as the Swynnerton Plan, and was initially funded by an interest−free loan to Kenya from the U.K. government of £5 million sterling. In contrast with the ALDEV schemes, the Swynnerton Plan emphasized the phased development of cash crops over the fifteen years 1953 to 1968. The most cautious program was for tea, because of uncertainties about the organization of green leaf collection and tea manufacture from smallholder−grown tea.

Important institutions for the tea industry were established in the 1950s. In the first place under the Tea Act of 1950, a statutory board, the Tea Board of Kenya, was formed with licensing, regulatory, and research responsibilities, but without any direct involvement in tea trading. Current functions of the Tea Board of Kenya are as follows:

Licensing tea growers and tea factories;

Regulating, controlling, and improving the cultivation and processing of tea and the control of pests and diseases;

Controlling the export of tea;

Carrying out investigations and research into all matters relating to the tea industry.

The board is also charged with promoting Kenyan tea in world markets. To this end, it supports promotional campaigns in the major markets for Kenyan teas jointly with the various tea councils. The board acts as a link between the tea industry and the government and represents the government in the various international tea forums. To finance its operations, the board levies a cess on areas of tea planted and on tea production.

Table 9−7. Areas under Tea in Smallholdings, Selected Years

	Swynnerton Plan			
Year	*Acres*	*Hectares*	*Actual (hectares)*	*Percentage of plan*
1953	35	14	14	100
1958	2,000	809	400 a /	49
1963	6,000	2,428	3,527	145
1968	12,000	4,856	12,233	252

a / Estimate.

Source: *Swynnerton (1955); Kenya Tea Development Authority (various reports).*

The Tea Research Institute of East Africa (TRI−EA) was formed at the initiative of the Tea Growers Association, which represented estates in Uganda and Tanganyika as well as in Kenya. The TRI−EA was first registered in Kenya in 1951 as a company without share capital serving the three countries, with its headquarters near Kericho. Registration of the institute in Uganda and Tanganyika soon followed. The institute was to be concerned with all aspects of tea, from site selection and land preparation to plucking, but tea manufacture and economics were notably absent from its terms of reference. The TRI−EA gradually developed into one of the world's leading tea research institutes, and laid the foundations for the rapid increases in tea productivity in the 1970s and 1980s. In addition to numerous research papers and regular annual reports, the TRI−EA published the *Tea Growers Handbook* in 1965 (subsequently reissued in 1966, 1969, and 1986), which has provided one important technical basis for tea growing in East Africa.

The TRI−EA's structure proved impossible to maintain following the disintegration of the East African Community in 1977. The Tea Research Foundation of Kenya (TRF−K) was therefore incorporated in January 1980 as a private company limited by guarantee, without capital, supported by the Tea Board of Kenya. This structure is similar to that of the Coffee Research Foundation of Kenya formed in the late 1960s, whose structure was in turn based on that of the Rubber Research Institute of Malaysia. The main objective of the TRF−K is stated to be:

To promote research into, and investigate all problems relating to tea and such other crops and systems of husbandry as associated with tea throughout Kenya, including the productivity, quality and suitability of land in relation to tea planting; and on matters ancillary thereto (TRF−K 1985).

The TRF−K's annual report for 1991 (TRF−K 1992) shows that it is actively pursuing these very broad terms of reference through agronomic, botanical, chemical, environmental, and plant protection investigations and a small field advisory service. Since the TRF−K's main source of funds is a share (about 50 percent) of the Tea Board's cess on the volume of exports, it has been well funded during the period of rapid increase in export volume, but clearly this rate of increase will not continue much longer, and the mechanism for funding the TRF−K will require revision. One of the TRF−K's strengths is that its staff members regularly submit technical papers to international scientific journals, and it is in regular communication with scientists in tea research institutes in other producing countries, including Japan. This international networking is particularly important in maintaining the quality of research output. Unfortunately, it is not common among developing countries, particularly in Africa.

In September 1960 a Crops Development Authority took over from the regular Agriculture Department and ALDEV staff the responsibility for promoting some crops new to smallholders, particularly tea and horticultural crops. The other crops being promoted under the Swynnerton Plan—coffee, pyrethrum, sugarcane, and sisal—already had their statutory organizations or specialized government units. Initial progress with smallholder tea fell behind the plan's targets for area planted, mainly because of the difficulty of raising sufficient tea seedlings and distributing them safely to farmers. Furthermore, initial levels of interest were even less than the Swynnerton Plan had hoped for (Table 9−7). When the Crops Development Authority was formed, there were about 900 hectares of smallholder tea, and a factory at Ragati. It was planned to increase this to 3,642 hectares (9,000 acres) on 9,000 farms by 1965, and thereby be on track for the Swynnerton Plan's target of 12,000 acres by 1968. Through the Crops Development Authority's effective work, the tea target for 1965 was almost attained by 1963 (3,527 hectares), but inevitably the heavy attention to tea led to the neglect of other crops. Therefore early in 1964, the Kenya Tea Development Authority (KTDA) replaced the Crops Development Authority, and at a later date a Horticultural Crops Development Authority was established.

Even before the creation of the Crops Development Authority, in February 1960 the Commonwealth Development Corporation had entered into a partnership arrangement with the government of Kenya and the Meru County Council to establish and manage a 500−acre (202−hectare

nucleus tea plantation and 700 acres (312 hectares) of outgrowers, to be called the Nyambeni Tea Company, Ltd. By 1964, 88 percent of the estate area and 54 percent of the smallholder tea had been planted, and the first 90 tons of made tea had been produced from Nyambeni. The Commonwealth Development Corporation helped launch the Crops Development Authority with a loan of £900,000 sterling, guaranteed by the government, to finance access roads to tea areas, field staff housing, and some operational expenditures. The Commonwealth Development Corporation continued to support the Crops Development Authority, and later the KTDA, in financing the construction of tea factories at Chinga (Nyeri), Mataara (Kiambu), and other locations. The pattern of responsibility was established that the Crops Development Authority and later the KTDA was responsible for delivering fresh green leaf of good quality to the factory gate. All tea manufacture and delivery to the Mombasa tea auctions was then the responsibility of factory managing agents such as James Finlay, Ltd., with long experience in tea manufacture. Experience soon showed that this division of responsibilities led to a high quality product from small−scale tea growers, often superior to the quality from Kenyan tea estates. More recently the KTDA has taken over direct management of the factories and has begun a further step to form local boards of directors to be responsible for overseeing the factory management.

With the formation of the KTDA early in 1964, the smallholder tea area targets for the First Five−Year Plan period to 1965 were raised from 9,000 acres to 11,100 acres (4,047 hectares), and an additional 14,400 acres (5,828 hectares) were included for the Second Five−Year Plan period, resulting in a target of 25,500 acres (10,320 hectares) by 1970. However, by that date the area of smallholder tea had reached 17,985 hectares, or 174 percent of the second plan's targets. Clearly the tentative steps taken in the 1950s had led to major progress in the 1960s, during which the KTDA rapidly developed the competence of its field staff. The Swynnerton Plan had estimated that eventually smallholder tea could extend to 71,000 acres (28,733 hectares). This area was exceeded in 1973 (31,161 hectares), and by 1991 the area of smallholder tea in Kenya had reached 68,813 hectares, or over 170,000 acres, about 100,000 acres more than the maximum area envisaged in the Swynnerton Plan. However, this area was well within the total of 800,000 acres of land considered to be suitable for smallholder tea by Brown (1963), although it was envisioned that only a tenth of this area would be used for tea growing. This rapid expansion was possible because of the sound technical basis provided by thirty years of experience on Kenyan tea estates, the investigations of the TRI−EA and the TRF−K, and an effective public and private sector partnership in implementing the tea expansion program of the Crops Development Authority and the KTDA.

The Nyayo Tea Zones Development Corporation was established in the 1980s, the first 15 hectares of tea were planted in 1985, and by 1993 the area had reached about 4,000 hectares. The corporation reports directly to the Office of the President, and is responsible for preserving forest zones from human encroachment by planting a buffer strip of 100 meters of tea just inside the government controlled national forests. All green leaf is delivered to the nearest KTDA tea factory. Problems have arisen because the corporation has not been adequately financed and organized to maintain and pluck the tea to the KTDA's standards, which small−scale tea growers have adopted fairly uniformly. However, the factories are required to accept all leaf from the Nyayo zones. A related difficulty is that the Nyayo zones suffer from a serious shortage of labor, because nearly all the nearby residents are fully occupied, even overextended, by the labor requirements of their own tea and food crops. The original idea of a tea buffer zone is attractive for environmental protection reasons, but details of the scheme need urgent revision. One possibility could be to lease strips across the buffer for environmental protection reasons to the nearest tea grower to operate as part of one farm unit, but this would not solve the problem of the shortage of pluckers.

Messrs. Brooke, Bond for many years received tea from Kenya, Uganda, and Tanganyika (Tanzania) for packaging and wholesaling on the East African domestic market. The Kenya Tea Packers, Ltd. evolved from this arrangement and, until very recently, held a monopoly in the domestic tea market. It is jointly owned by members of the Kenya Tea Growers Association and the KTDA and blends, packs, and distributes tea for sale on the local market. Recently, individual tea factories have been licensed to sell directly on the local market.

Public investment in both main roads and rural roads has been an important feature of tea development in Kenya. Immediately after the country became independent in December 1963, it entered into an innovative arrangement with an international civil engineering firm to bring the main road to Kericho up to a reliable all−season standard. This was financed by the contractor for ten years. The Commonwealth Development Corporation and the World Bank (International Development Association) funded a major tea roads program in the 1960s that was crucial for the prompt delivery of green leaf tea to the tea factories. However, this program did not keep up with the rapid expansion of smallholder tea planting in the 1970s and 1980s.

A detailed survey of the needs for rural road maintenance and construction requirements in the smallholder tea growing areas has recently been completed for the government of Kenya. A substantial new tea roads program is clearly required, as the poor condition of many tracks sometimes causes serious delays in the delivery of green leaf to KTDA factories. In the estate sector, the companies effectively construct and maintain their own internal roads, but recently some of these have become access roads to the Nyayo scheme areas and higher altitude tea districts, but the county councils are unwilling or unable to contribute to road maintenance. Consequently, there is currently a serious problem with roads in both the smallholder and estate tea growing areas.

The commissioning of KTDA tea manufacturing factories lagged quite seriously behind the rate at which new smallholder tea areas came into production during the 1980s. Congestion at the green leaf buying stations led to crop loss at this stage and, at peak seasons, overloading the manufacturing capacity of some factories had a deleterious effect on the quality of the final output. In the early 1990s the KTDA accelerated the factory building program, and was thus able to moderate the problem of congestion during peak periods of green leaf production.

Factors and Systems of Tea Production and Output

Tea is made from the young leaves and growing points of the plant *Camellia sinensis*, formerly known as *Camellia thea* or *Thea sinensis.* As the scientific name indicates, it originates from China, principally in the southern forests bordering India and Myanmar. More than 100 years ago, tea seed was smuggled from China through Hong Kong to several parts of the Indian subcontinent, including Ceylon (Sri Lanka), and to Burma (Myanmar). This was the basis of the major plantation industries

that were established in the region during the nineteenth century. Estate management practices developed in this period provided the basis for the initial management of tea in the Dutch East Indies, and later in the British territories in Africa, particularly Nyasaland (Malawi) and Kenya.

As tea is almost entirely cross−pollinated, there is an enormous diversity of forms and large differences in productivity between plants. The standard of care at planting and during the formative first few years of growth affects the productivity of a tea plant for the rest of its life, which can exceed 100 years. Until the 1960s, virtually all tea gardens in Kenya were planted with seedlings, but much earlier observant tea estate managers had begun to propagate on a small−scale vegetative cuttings from apparently high−performing bushes. This was a slow process as they had to distinguish carefully between genetically−based differences and differences resulting from management (or between nature and nurture). According to the *Tea Growers Handbook* (TRF−K 1986), only one seedling in 200 or 300 has suitable vigor, and of these, one in 200 to 300 has suitable tea making properties for a clone that is acceptable for large−scale planting. Thus, on average, only one seedling in every 40,000 to 90,000 is likely to be selected to be the parent for a first−class clone.

The many years of observation and selection on tea estates were followed by careful comparative clonal performance trials by the TRI−EA and many estates, so that by the time smallholder tea growing was being promoted, widespread use of clonal material was a possibility to consider. The research and development work done on vegetative propagation methods at the TRI−EA was of great importance to the later rapid expansion of tea planting in Kenya. The use of plastic sheet covers and plastic tubes for individual cuttings of a section of a branch and one leaf provided a means for the rapid multiplication of clones most adapted to local conditions. In the smallholder program, the KTDA initially ran the tea seedling and later clonal nurseries; however, the vegetative propagation technique is now so well established that individual small−scale farmers operate their own tea nurseries, and some also sell rooted clonal cuttings to their neighbors.

During the period of rapid expansion of smallholder tea in Kenya, smallholders paid insufficient attention to the quick filling in of gaps caused by the death of plants that failed to take root. As the surrounding tea bushes mature, establishing young tea among them is difficult. Many smallholder tea gardens, and notably the Nyayo tea buffer strips along the forest, have gaps that lead to a loss in overall productivity.

Kenya's tea estates currently face a dilemma. About half of their area of tea is grown from seedlings, because only since 1960, when the area under tea was 15,075 hectares (compared to 31,017 hectares in 1991), has all new planting been with vegetatively propagated material. Replacing the unevenly performing seedling material with high−performing clonal material is now advisable. However, this means an inevitable increase in costs and a serious loss of income during the several years needed for uprooting, preparing the land, replanting, and bringing the new tea garden into full production. One estimate (Brooke Bond Kenya, Ltd. personal communication) indicates that reestablishing a positive cash flow position could take twelve years. Farmers have found it difficult to establish young tea immediately on fields recently cleared from tea. This problem has received the TRF−K's attention since 1983 in field trials to rehabilitate old tea, as well as to study the effects of soil amendments and the use of food and nonfood cover crops on soil conditioning and the establishment of

clonal teas on old tea fields. Meanwhile, at least one estate group (African Highlands Produce) is moving ahead quite aggressively to convert its estates to clonal tea. After the old tea is uprooted, the land is terraced and sown to one crop of oats before planting the clonal tea. This conversion appears to be proceeding well

Tea requires acid soil conditions, preferably in the range pH 5.0 to pH 5.6, but it tolerates much more severely acid conditions. Values as low as pH 3.5 have been recorded under apparently healthy old tea. With such highly acid conditions, there is a severe reduction in bases (calcium, magnesium, and potassium) and phosphorus in the rooting zone and a corresponding increase in aluminum and manganese levels. Tea can continue to grow well under these conditions as long as appropriate fertilizer applications are provided. Farmers replacing old tea with another crop would probably experience considerable difficulty; however, little research has been carried out in this area. Nevertheless, it may now require study, particularly since some small−scale farms have planted more than half their land to tea, but may at a future date wish to replace tea with other less labor−demanding farming operations.

The early tea plantings in Kenya were all with shade trees, often *Grevillea robusta* (Australian Silky Oak), as this was the practice in India and Ceylon. It was not until the 1950s, following relatively extensive field studies of soil moisture and nitrogen balances, that investigators concluded that under Kenyan conditions, shade trees reduced total tea vegetative production potential. However, without shade, nitrogen fertilizer applications were essential to achieve higher yields. In East Africa, no significant yield response has been recorded to phosphatic and potash fertilizer applications, although potassium is known to help tea recover from pruning (Owuor and others 1987).

During the late 1950s and 1960s, the killing of shade trees and the application of nitrogenous fertilizers proceeded rapidly on tea estates, and from about 1968 the average yield of estate tea (from plants four years old and older) started to rise sharply for the first time since 1942. At about the same time (1965) the KTDA started bulk procurement of fertilizers for distribution to smallholders on credit, but the average yields of smallholder tea did not begin to rise sharply for a further twenty years, having remained remarkably stable since 1971, the end of the first fifteen years of rapid area expansion (Figure 9−1).

On the tea estates, rates of fertilizer applications at first increased rapidly, with farmers in some cases applying as much as 400 kilograms of nitrogen per hectare annually. Gradually fertilizer application rates stabilized from the early 1980s at around 200 kilograms of nitrogen per hectare annually applied all at one time, as supported by TRF−K trials and advice. Lower amounts of phosphorus, potassium, and sulfur were included in a mixed fertilizer specially prepared for Kenyan tea and used by many estates and by the KTDA.

In 1983, the KTDA systematically laid out fertilizer demonstration plots on a nationwide basis. The results were so obvious that from 1984, adoption of the practice of fertilizer (20.5.5.5 [sulfur]) application was rapid and widespread. The KTDA fertilizer distribution system worked so efficiently that a considerable number of farmers decided to apply more than the recommended annual application of some 200 kilograms of nitrogen per hectare. Average yields increased immediately, but the

harvested crop was only about two−thirds of the yields achieved on estates growing generally inferior seedling tea with lower yield potential than the small−scale farmers' clonal teas

Farmers traditionally brought tea into bearing by pruning back the vertical growth of branches, first to 20 centimeters, later to 40 centimeters, and finally to 60 centimeters from the ground. This led to progressive closing of the gaps between tea plants and the formation of a level plucking table, initially at 60 centimeters. In 1965 the KTDA introduced a much simpler more laborious, but quicker way to form a plucking table. When the first shoots reach 45 to 60 centimeters they are bent outward and pegged to the ground so as to cover the ground surface evenly. Shoots then grown upwards to form an initial table usually cut back ("tipped−in") to 45 centimeters above the ground. This method can advance the first plucking from field planting from three years to less than two years.

Where moisture is adequate, the frequency of plucking depends on the ambient temperature, defined as the cumulative total of the average day and night temperatures over ten days. In the Kenya highlands it normally takes eight to nine days for a young shoot to expand fully from a bud. A young growing shoot with one leaf and a tip takes about the same time to reach a pluckable stage of two leaves and a bud. One of the most important skills of managing tea is to pluck as fast as a new crop of shoots reaches the two and a tip stage, and to ensure that pluckers maintain a level table for the most efficient use of the sun's energy and the ease of future plucking. Typically this may range from plucking once a week in warm weather to intervals longer than twelve days at the coolest time of the year.

Under normal, well−managed plucking the table rises about 20 centimeters a year. Once the table attains 120 to 150 centimeters in height plucking becomes much more difficult, and is therefore slower and generally of poorer quality. This is the time to prune back the whole growth to 60 centimeters once more. Formerly farmers removed prunings from the field, often for fuel, but agriculturists now recognize that this large bulk of vegetative material provides a rich source of organic matter and nutrients, and also protects the newly exposed soil from the damaging direct impact of sunshine and rainfall. Prunings are now generally left to decompose in the tea gardens of smallholders and estates.

Special care is necessary to avoid serious erosion during the establishment and rehabilitation phases of tea management, and at all times from roadways and built−up areas. Sound water management practices are now fairly standardized in the estate sector. In the smallholder areas, the tea gardens usually provide excellent ground cover, particularly now that prunings are retained in the field. The buildup of soil organic matter and regular fertilizer application improves general soil fertility conditions. One possible issue is that if heavy rainfall occurs just after a heavy dose of fertilizer has been applied, surface wash may lead to contamination of water courses. In addition, repeated heavy applications of nitrogenous fertilizer may lead to contamination of water draining through the soil profile to the streamlines.

One possible explanation for the lower yields harvested from clonal tea on small−scale farms than from mostly seedling tea on estates while applying the same amount of fertilizer, is that on small−scale farms plucking is not frequent and thorough enough to check the inevitable rise in the table.

Smallholders often lack sufficient farm family labor to keep up with the growth of tea bushes, particularly if they have applied high rates of fertilizer. Furthermore, one of the main periods of tea "flush" coincides with essential work for food crop production (Carr 1993). Not only is there an immediate loss of green leaf harvest if some of the young branches pass the optimum plucking stage, but also if the plucking table level rises fast, because of partial harvesting, then pruning back becomes necessary more quickly, for example, every four years instead of every five years.

Kenyan tea is remarkably free of pest or disease problems, although several do occur locally and occasionally. Agriculturists have identified several mites, including red spider mite, *Oligonychus coffee,* and red crevice mite, *Brevipalpus phoenicia,* and the yellow tea thrips *(Schirothrips kenyensis)* has attacked some tea. In general, however, in Kenya's relatively cool, high altitude tea growing areas the damage seldom becomes economically significant, and parasites and predators keep the pest species populations in check.

Armillaria root rot *(Armillaria mellea)* continues to be an important problem for new tea plantings. This disease can cause serious loss of plants in the early years of tea establishment, and may be one factor that has led to frequent gaps remaining in smallholder tea gardens. The only effective and practical control continues to be to remove all medium and large pieces of old roots during land preparation.

Blister Blight, which is a major disease of Asian tea, has not yet been identified in Africa. Therefore checking on the tolerance or resistance of Kenya clonal material to this disease has not been possible. As a precaution, estates and the KTDA usually recommend planting new tea gardens with a mixture of five or six of the best clones, hoping that if and when Blister Blight or some other as yet unknown pathogen appears in Kenya, one or more of the clones will exhibit at least some tolerance to the new disease. An interesting potential problem is that smallholders operating their own vegetative propagation units are tending to narrow the genetic range of clones by reproducing material only from the one or two clones that are visually the most outstanding.

Commentary

Kenya's tea output has more than doubled each decade from 1950 to 1990 while maintaining a high quality product, and its exports now place the country among the world's top three or four tea suppliers. Kenya tea is the only agricultural product for which an African country is among the top four producers in the world. By 1989, tea had overtaken coffee as the principal agricultural product, and was second only to tourism in terms of foreign exchange earnings for Kenya. Most of the tea in Kenya is planted in formerly highland forest areas, and all of it is grown as an intensive monoculture on both estates and smallholdings. What are the reasons for this success? Is it a sustainable system?

The location of Kenya's tea zones is narrowly defined, based on many years of practical experience. They are in areas where the climate is relatively cool and soil moisture conditions are favorable for most of the year. The government has closely regulated and limited the extent of forest removal for tea estates to maintain the integrity of the water catchments rather than biodiversity.

Investigators found that a closed tea canopy transpires less than high forest, thus a tea−covered catchment basin will yield more stream flow than natural forest cover.

The government has never intervened in tea marketing, but has provided the transport infrastructure (railways and roads) and established an appropriate institutional framework that embraces private sector associations of tea growers and traders. The public agencies charged with promoting smallholder tea growing were given considerable authority and adequate financing, except for the Nyayo Tea Zones Development Corporation. For most of the period covered in this review, Kenya maintained a realistic exchange rate although the tea industry pressed for devaluation in the late 1960s, and the modest volumetric export tax was channeled through the Tea Board for research and market promotion for the benefit of the tea sector as a whole.

Many individual estate managers carried out their own agronomic research long before the authorities established a formal research institute in 1951. The TRI−EA, and later the TRF−K, have served the tea industry well, even though there was a period of uncertainty and weakness in the late 1970s. As a whole, the industry has benefited greatly from the diversity, continuity, and international networking of its research workers. An interesting point is that all the important advances have been at least as important to small−scale farmers as to tea estates, for example:

Tea clones and vegetative propagation

Shade tree removal and nitrogenous fertilizer application

Pruning and the retention of organic matter

Soil conservation and grass strips

The CTC process for tea manufacture.

Some important subjects remain that require attention, some of which are already been looked into, including:

Mechanical harvesting;

Surface soil management and leaching of nitrates to water courses;

Farm economics, particularly as concerns labor availability.

Kenya's tea farming systems are currently viable, but they will have to keep evolving if they are to continue to be sustainable. While they are technically sustainable, they will have to adapt rapidly to continue to be socially and economically sustainable as well. The tea industry in Kenya is a clear example of a farming system that is productive and adaptable, though not very flexible.

Annex: Kenya Tea Statistics 19251992

Year	Estates (KTGA) Planted Area (ha)	Production (metric ton)	Yields (kilograms)	Smallholders (KTDA) Planted Area (ha)	Production (metric ton)	Yields (kilograms)	Total Estates and Smallholder Planted Area (ha)	Production (metric ton)	Exports (metric ton)	Value (thousands) (K£)	(US$)	Local Sales (metric ton)
1925	155						155		0.6			
1926	793 e						793					
1927	1,276						1,276		0.5			
1928	1,946						1,946		4			
1929	2,263						2,263		69			
1930	4,068	422	532				3,410	422	73			
1931	4,556	680	533				4,556	680	161			454
1932	4,870	1,098	564				4,870	1,098	318			685
1933	5,047	1,369	605				5,047	1,369	887			354
1934	5,124	1,826	449				5,124	1,828	1,124			553
1935	5,185	2,858	627				5,185	2,858	2,292			435
1936	5,332	3,906	802				5,332	3,906	3,409			367
1937	5,529	4,903	971				5,529	4,903	4,158			626
1938	5,537	4,924	961				5,537	4,924	4,278			527
1939	5,663	4,928	950				5,663	4,928	4,502			358
1940	5,833	5,409	1,014				5,833	5,409	4,451			943
1941	5,750	6,454	1,167				5,750	6,454	4,704			1,706
1942	6,197	7,375	1,332				6,197	7,375	5,225			2,109
1943	6,336	5,940	1,049				6,336	5,940	4,322			1,665
1944	6,359	6,257	1,073				6,359	6,257	4,190			2,064
1945	6,552	5,907	1,027				6,552	5,907	4,321			1,642
1946	6,572	5,569	899				6,572	5,569	4,060			1,579
1947	6,697	6,071	958				6,697	6,071	4,348			1,801
1948	6,920	4,553	716				6,920	4,553	2,697			1,846
1949	7,189	5,197	793				7,189	5,197	3,161			2,019
1950	7,642	6,776	1,031				7,642	6,776	4,704			2,195
1951	8,042	6,952	1,038				8,042	6,952	4,707			2,300
1952	8,507	6,708	969				8,507	6,708	4,889			1,837
1953	8,803	5,864	816				8,803	5,864	3,550			2,281
1954	9,476	7,933	1,038				9,476	7,933	5,457			2,191
1955	10,146	8,645	1,075				10,146	8,645	5,987			2,749
1956	10,939	9,648	1,134				10,939	9,648	7,718			2,118
1957	12,134	9,990	1,135				12,134	9,990	8,429			1,960
1958	13,110	11,371	1,200	400 e	50 e		13,510	11,421	9,526			2,204
1959	14,159	11,940	1,177	500 e	100 e		14,659	12,640	10,872			2,068
1960	15,075	13,631	1,246	862	145		15,937	13,776	11,871			2,232
1961	16,194	12,421	1,024	1,563	220		17,751	12,641	11,202			2,096
1962	17,372	16,109	1,229	2,521	319	798	19,893	16,428	14,807	5,800	16,239	2,046
1963	17,921	17,770	1,255	3,527	312	624	21,448	18,082	15,354	5,013	14,036	3,143
1964	18,591	19,616	1,301	4,471	625	725	23,062	20,241	16,422	5,665	15,862	3,729
1965	19,327	19,027	1,175	5,429	796	509	24,756	19,823	16,823	6,056	16,982	3,642
1966	20,102	23,846	1,373	7,238	1,572	624	27,340	25,419	23,283	8,714	24,399	3,681
1967	20,809	20,564	1,147	9,269	2,248	637	30,078	22,812	18,116	7,396	20,709	3,866
1968	21,329	26,360	1,418	12,233	3,403	761	33,562	29,762	27,839	10,041	28,119	4,309
1969	21,840	30,333	1,569	14,685	5,777	1,064	36,525	36,111	32,952	11,271	31,599	4,436
1970	22,289	33,101	1,647	17,985	7,976	1,102	40,274	41,078	33,851	12,705	35,574	5,443
1971	22,838	28,222	1,356	20,528	8,068	870	43,366	36,290	30,073	10,844	30,363	5,698
1972	23,268	40,193	1,884	26,493	13,129	1,073	49,761	53,322	49,484	16,442	46,037	5,900
1973	23,635	41,505	1,900	31,161	15,073	1,026	54,796	56,578	50,528	16,975	48,493	6,366
1974	24,087	37,259	1,672	34,648	16,180	900	58,735	53,440	49,617	19,403	54,328	7,058
1975	24,337	38,815	1,700	37,205	17,915	873	61,542	56,730	52,633	22,970	62,561	7,472
1976	24,539	40,521	1,741	41,412	21,463	810	65,951	61,984	59,154	31,769	75,938	8,068
1977	24,859	55,554	2,350	43,641	30,737	986	68,500	86,291	75,258	71,780	173,453	9,578
1978	25,159	58,552	2,431	46,910	34,821	1,005	72,069	93,373	80,791	63,193	163,513	11,004
1979	25,424	61,641	2,533	48,876	37,634	1,012	74,300	99,275	88,985	62,815	168,140	12,462
1980	25,850	55,913	2,279	50,691	33,980	821	76,541	89,893	74,799	58,003	156,338	13,640
1981	26,153	55,138	2,218	52,743	35,804	820	78,896	90,941	75,501	61,093	135,049	14,492
1982	26,283	56,087	2,229	54,698	39,916	851	81,082	96,003	80,371	77,882	142,611	13,980
1983	26,567	68,774	2,705	54,969	50,964	1,043	81,536	119,738	100,645	123,420	185,434	15,172
1984	26,863	63,464	2,455	56,499	52,708	1,040	83,372	116,172	91,198	189,478	262,910	14,390
1985	27,322	75,755	2,897	56,505	71,339	1,353	83,827	147,094	126,086	191,410	232,971	17,014
1986	27,854	75,192	2,861	56,546	68,125	1,245	84,400	143,317	116,456	172,789	212,982	17,702
1987	28,529	78,875	2,969	56,891	76,933	1,400	85,420	155,808	134,779	163,354	198,552	17,322
1988	29,109	79,338	2,953	57,693	84,693	1,499	86,802	164,030	138,201	185,264	208,781	17,712
1989	29,539	80,033	2,929	57,934	100,567	1,780	87,473	180,600	163,188	271,835	564,270	17,569
1990	29,979	87,012	3,124	67,041	109,997	1,945	97,020	197,008	169,586	314,981	274,915	17,883
1991	31,017	90,847	3,184	68,813	112,742	1,982	99,830	203,589	175,555	381,625	277,466	17,538
1992			0					188,072	166,518			15,465

e = estimate.

Source: 1925-1930 Department of Agriculture Annual Report - various issues; 1931-1962 International Tea Committee - Bulletin of Statistics - various issues; 1958-1962 Commonwealth Development Corporation (1959-1963) and Special Crops Development Authority (1963) Annual Reports; 1963-1992 The Tea Board of Kenya except US$ value of exports from the International Tea Committee and data for 1992 and for Local Sales 1963-1974.

10—
Malaysia:
Oil Palm Development

Malaysia covers about 330,000 square kilometers in two distinct geographic areas. Peninsular Malaysia, which lies south of Thailand, accounts for 40 percent of the country and includes the eleven states and the Federal Capital Territory. The other area consists of the two states of Sabah and Sarawak, which constitute East Malaysia and share the island of Borneo with Brunei and the Kalimantan province of Indonesia.

A little more than 100 years ago forest covered almost all of present−day Malaysia. Most of the population of less than 1 million lived along the coast and the many river estuaries, where they had a productive subsistence economy based on fishing and small plots of rice. The population of Peninsular Malaysia increased rapidly in the late 1800s and early 1900s, largely because of the influx of Chinese, who came to work the rich tin deposits, and Indians, who were bought in to work on the coffee and later the rubber estates (Ooi 1976). By 1991 the population had reached 18.2 million, of whom 14.9 million (82 percent) lived in Peninsular Malaysia (Ministry of Primary Industries 1992).

The initial foreign investment in the mining sector, and later in rubber development, in Peninsular Malaysia was supported by several publicly−financed railway lines leading from the interior to the coast, and linking the coastal plains with sea ports. This infrastructure provided the framework for much of the subsequent development of Peninsular Malaysia (Arope, Nor, and Tan 1983).

In contrast with many tropical rain forest regions of the world, forest clearing in Malaysia has not been mainly by small−scale farmers. Initially the country had ample coastal and riverine areas to provide subsistence for the small indigenous population of Malay and Orang Asli communities, and as the population increased, the government was able to promote more intensive food crop production in areas where the indigenous population was concentrated. More recently some erosion has been caused by shifting cultivation by small−scale farmers. Forest areas were progressively licensed for plantation development, initially mainly to foreign investors. These areas were first cut for marketable timber, and then much of the area was planted with rubber, which rapidly became Malaya's main agricultural export. However, even by 1981/82, according to Brown and others cited by Vincent and Yusuf, (1993), 6.6 million hectares of forested land remained in Peninsular Malaysia, accounting for 50 percent of the total area.

The rubber industry developed initially from a few seedlings grown from seeds collected in Brazil by Wickham in 1886. The seeds were passed through Kew Gardens in London to Ceylon (Sri Lanka), from where twenty−two seedlings were sent to Singapore, of which seven to ten were taken to Penang, now part of Malaysia. The period of most rapid annual area expansion (49,000 hectares per year) was between 1904 and 1932, principally on estates, as the official policy was to discourage small−scale farmers from growing rubber, and thereby neglecting food production. Nevertheless, by 1932, despite policies that discriminated against them, smallholders accounted for 40 percent of the area under rubber in Peninsular Malaysia. By 1961 the area of rubber on smallholdings exceeded the

area on estates (Vincent and Yusuf 1993) and by 1991 smallholdings accounted for 81.3 percent of the area of rubber grown in Malaysia (Ministry of Primary Industries 1992). Barlow (1978) provides a comprehensive account of the history of the development of the rubber industry.

The rapid expansion of rubber plantations on recently cleared, undulating to hilly, low altitude, tropical rain forest led to considerable soil erosion in the early years. However, with the introduction of leguminous plants for ground cover in the 1920s, this form of land degradation was gradually controlled. In the early years of the Rubber Research Institute−of Malaysia, land use management received considerable attention. The results of the institute's work were also applicable to and valuable for the later development of other long−term crops, including oil palm and cocoa.

Natural rubber exports continue to be important, but are in third place following palm oil and palm products in terms of export value. Crude petroleum products, liquid natural gas, and forest products are of higher value. The Rubber Research Institute−of Malaysia was established in 1925 and soon gained a reputation as one of the world's leading tropical agricultural research stations. It has maintained a high standard of performance largely because of its strong financial base and close identification with the industry's needs. The area of rubber plantations is continuing to decline slowly, and the institute believes that in 1993 more than 300,000 hectares were not being tapped because of low world market prices and the shortage of tappers; others believe that double this area may now be untapped. Reduced tapping frequency from every two days to each three to four days using latex stimulants is already practiced in Malaysia, but apparently still less extensively than in some other rubber producing countries. The Rubber Research Institute is continuing research into reduced frequency systems and also into automated tapping equipment; however, no one believes the latter will become of widespread practical significance for many years.

Oil palms were introduced to Malaysia initially as ornamental plants. According to Hill (1982), the first commercial plantation was established in 1917 on Tennamaram estate, but almost fifty years passed before there was much interest in extending the area of this crop, and by 1966 only about 0.1 million hectares of oil palm plantations had been established, compared with 1.8 million hectares of rubber. This chapter focuses on oil palm rather than the other two perennial tree crops that have been important in Malaysia—rubber and cocoa—because the oil palm production systems now appear to be as sustainable over the long term as natural rubber production has been in the past.

Rubber plantations on estates or smallholdings proved their technical sustainability once the initial problem of soil erosion had been resolved; but the domestic shortages of labor to tap the rubber trees and the continuing weakness of the worldwide demand for natural rubber raise serious doubts about the long−term sustainability of rubber in Malaysia. However, the industry has pioneered many field management and organizational forms that have been of importance worldwide, and have no doubt contributed substantially to the subsequent rapid development of oil palms and cocoa (Table 10−1). Cocoa has developed even faster than the other two tree crops. While it has provided a major additional source of foreign exchange for Malaysia and has radically altered the world market structure, it is now facing serious problems of insect and disease attack, and as it requires considerable labor inputs, it is even more sensitive to the rapidly increasing shortages of rural labor than rubber or oil palm plantations.

Table 10−1. Areas, Production, and Export Value of Natural Rubber and Cocoa and their Products, Selected Years

	National area (thousand of hectares)					*National production value of exports*			
Product and year		*East Malaysia*					*Value of exports*		
	Peninsular Malaysia	*Sabah*	*Sarawak*	*Total*	*Rate of annual change*	*Production (thousands of tons)*	*Ringgi million*	*Exchange rate*	*US$ million*
Natural rubber									
1980	1,697	102	200	1,999	−10	1,530	4,618	2,18	2,121
1985	1,663	78	208	1,949	−23	1,470	2,971	2.48	1,156

1990	1,536	90	208	1,834	−12	1,292	3,028	2.70	1,119
1991	1,517	91	214	1,822	−.	1,253	2,690	2.75	978
Cocoa									
1980	57	58	9	124	+36	37	202	2.18	93
1985	−	−	−	304	+20	108	545	2.48	219
1990	138	206	60	404	−4	247	756	2.70	279
1991	142	201	57	400	−	230	720	2.75	262

− not available

Note: *Cocoa area is the maincrop equivalent, to allow for mixed cropping.*

Source: *Ministry of Primary Industries* (1986, 1988, 1989, 1990, 1991, 1992).

Table 10−2. The Agricultural Sector's Share of Gross Domestic Product and Employment, 1980 and 1991

	1980		*1991*	
Economic indicator	*Agriculture a /*	*Manufacturing*	*Agriculture a /*	*Manufacturing*
Share of GDP (%)	23.0	20.0	17.3	28.7
Employment (thousands)	1,800.5	748.8	1,834.8	1,374.1
Percentage of total employment	37.2	15.5	26.8	20.1

a / Includes livestock, forestry, and fisheries.

Source: *Ministry of Primary Industries (1992).*

During the 1980s the proportional contribution of agriculture, livestock, forestry, and fisheries to GDP declined rapidly, although in absolute terms GDP grew strongly at 8.7 percent per year between 1980 and 1991. The relative importance of manufacturing increased rapidly (Table 10.2).

This sharp structural change and the currently low international prices for commodities have substantially altered the relative attractiveness of activities in the agricultural sector. Essentially, less labor−intensive systems are more likely to be financially attractive. Fore example, even though total employment in the agricultural sector held steady at about 1.8 million between 1980 and 1991, the number of those employed in the rubber subsector, (in Peninsular Malaysia), dropped from 152,000 to 88,000, while oil palm employment rose from 93,000 to 115,000 (information from East Malaysia is incomplete). Perennial tree crops continue to be important, although their relative importance changed rapidly in the 1980s (Table 10−3).

Table 10−3. Perennial Tree Crops: Area, Production, Yield, and Exports, 1980 and 1991

	1980				*1991*			
Commodity	*Area (thousands of hectares)*	*Production (thousands of tons)*	*Yield (kilograms/ hectare)*	*Exports (thousands of hectares)*	*Area (thousands of hectares)*	*Production (thousands of tons)*	*Yield (kilograms/ hectare)*	*Exports (thousands of tons)*
Natural rubber	1,999	1,530	1,108 *a* /	1,525.6	1,002	1,253	1,002 *a* /	1,131.8
Palm oil, palm oil products	1,023	2,793	2,518 *b* /	2,270.2	2,068	7,887	2,970 *b* /	7,302.0
Cocoa, cocoa products	138	37	268	34.8	400	230	575	205.5
Coconut oil	355	−	−	62.5	316	−	−	41.9

− *not available.*

a / The yield of rubber from mature, tapped areas.

b / Palm oil only.

Source: *Ministry of Primary Industries.*

Local Conditions and Natural Resources

There is an extensive literature on the natural conditions and resources of Peninsular Malaysia, much of it cited in a recent valuable contribution by Vincent and Yusuf (1993). This section draws substantially from that source.

Peninsular Malaysia lies between the South China Sea to the East and the Andaman Sea and Malacca Straits to the West, approximately between 100 and 104 degrees west longitude, close to 1 degree north (see map of Malaysia) latitude at the frontier with Singapore, and just short of 7 degrees north along the frontier with Thailand. East Malaysia occupies the northwestern part of Borneo island, excluding Brunei, lying between approximately 1 and 7 degrees north latitude and 110 and 119 degrees east longitude. The whole of Malaysia is thus within the equatorial zone, and none of the peninsula is more than about 140 kilometers from the coast. For a comprehensive discussion of the country's physical, climatic, and ecological environments see Cranbrook (1988).

The combination of an equatorial location, proximity to the sea, and low altitude results in a climate that varies relatively little during the year or within the peninsula. Most of the peninsula receives more than 2,400 hours of bright sunshine per year. The mean annual temperature ranges from 26.0 to 27.2° centigrade, and is highest in the lowlands, just inland from the west coast. Mean annual rainfall ranges from less than 1,800 millimeters to more than 3,600 millimeters. The wettest regions are the foothills near the east coast and the northwest coast. The peninsula has a weak monsoonal climate. The northwest monsoon occurs during November−March and the southwest monsoon during MaySeptember. In much of the peninsula the heaviest rain falls in the intermonsoonal periods, and there are no prolonged dry periods in the areas of oil palm production (Vincent and Yusuf 1993).

The mining industry and the expansion of the tree plantation crops led to substantial removal of the tropical rain forests, especially along the coastal areas up to the escarpment that marks the rise to the central highlands. Once the natural forest had been replaced by mature plantation crops, a new, stable land use had resulted, but one that was much poorer in diversity of plant and animal species. In the abstract to an earlier publication Vincent and Yusuf (1991) had concluded:

Deforestation in Peninsular Malaysia during the twentieth century illustrates that shifting cultivation is not a necessary ingredient for extensive conversion of forests in the humid tropics. It also illustrates that the existence and adoption of sustainable agriculture systems are not, on their own, sufficient to forestall the expansion of agriculture into undisturbed forests. Deforestation in Peninsular Malaysia has been caused primarily by expansion of tree−crop plantations: rubber and oil palm. For the most part, expansion of plantations has been driven by inherently high financial or economic returns, not unduly favorable government policies.

Although the plantations appear to provide sustainable uses of converted forest land, they might have expanded too far due to the

failure of markets and project appraisals to account for environmental impacts − soil erosion, degradation of water systems, and loss of biological diversity. As in the United States in the early part of this century, the period of deforestation in Peninsular Malaysia is rapidly coming to a close due to the combination of agricultural sustainability and the creation of off−farm sources of employment, which leads to stabilization of the rural population. This is in spite of severe deficiencies in economic policies related to the forest sector.

While initially the expansion of some plantation crops was apparently unsustainable from the natural resources point of view, in 1981/82 forests still covered about half of Peninsular Malaysia, but half of this had been logged−over at least once. Nevertheless, many reports have drawn attention to serious economic distortions that threaten the remaining forest land of the Peninsula and East Malaysia (see D'Silva and Appanah 1993 for a summary of the issues). Conversion of forests to agricultural use has slowed dramatically in Peninsular Malaysia, to the point where stabilization of the agricultural area is in prospect, but rapid conversion continues in the less developed states of Sarawak and Sabah.

Market Demand for Oil Palm Products

While Malaysia's oil palm industry is focused on the world edible oil market, it also supplies the local market. World trade in edible oils increased by 50 percent between 1980 and 1990, while exports of palm oil and palm oil products from Malaysia increased by 127 percent during the same period. At the same time, the share of oil palm products in the world trade in vegetable oils increased from 33 to 44 percent. Between 1980 and 1992 the annual total production of Malaysian oil palm products increased by 157 percent and the annual export volume rose by 148 percent (Table 10−4). There is a sizable oleo−chemical industry in Malaysia based on the oils (palm and kernel), which deflects some palm oil from the edible oil market. This recent development is being driven by international manufacturers and conglomerates that have factories in Malaysia. One of the main products of the industry is detergents that, as a chemical group, have largely displaced phosphate detergents which, are harmful to waterways and the environment. Another important product is glycerin, which is the starting point for many industrial applications. In addition, experts have developed several pharmaceutical products and other minor, but valuable, products from the residue produced during the initial extraction of crude palm oil from the fresh fruit.

Planners expect the rate of output increase in Malaysia to decline as earlier plantings cease to be economic and need to be replanted after twenty to twenty−five years. However, production is expected to continue to increase (Table 10−5) to 8 million tons in 1995 and 11 million tons by the year 2005. The fast pace of production increase in several countries that produce vegetable oil at low cost, especially Argentina and Brazil (for soybeans) and Indonesia and Malaysia (for oil palm) is expected to continue. Demand growth is likely to remain robust, especially in many populous countries in Asia. Vegetable oil and meal prices are expected to continue to be volatile, although the diversification of production in recent decades has helped to ease the effects of weather on global production levels (World Bank 1993).

Table 10−4. Malaysia's Share of the World's Edible Oil Market, Selected Years (thousands of tons)

	1980		1985		1990		1991		1992
Fats and oil commodities	*Production*	Exports	Production	Exports	Production	Exports	Production	Exports	Productior
Soybean oil	13,382	3,300	13,932	3,574	16,040	3,805	15,886	3,628	—
Palm oil	4,543	3,811	8,925	5,780	10,943	8,582	11,414	8,894	—
(of which Malaysia)	(2,576)	(2,207)	(4,133)	(3,215)	(6,095)	(5,827)	(6,141)	(5,423)	(6,373)
Palm kernel oil	571	364	945	638	1,448	908	1,460	867	—
(of which Malaysia)	(222)	(219)	(512)	(430)	(827)	(680)	(782)	(610)	(812)
Other vegetable oils	21,252	5,097	23,614	6,154	31,940	8,429	33,024	8,098	—
Subtotal of all vegetable oils	39,748	12,572	47,416	16,146	60,371	21,724	61,784	21,487	—
Animal oils and fats	17,934	5,189	19,742	5,264	20,083	5,003	19,462	5,083	—
Total	57,682	17,761	67,158	21,410	80,454	26,727	81,246	26,570	—
(of which Malaysia) Percent	4.9	13.7	6.9	17.0	8.6	24.4	8.5	22.7	

— not available.

Sources: *1980, 1990, 1991: Ministry of Primary Industries (1992); 1985: Ministry of Primary Industries (1987); 1992: Er Malaysia, Office of the Science Attaché, Washington, D. C., personal communication (1993).*

Table 10−5. Area, Production, and Export Value of Palm Oil and Products, Selected Years

Category	*1970*	*1975*	*1980*	*1985*	*1990*	*1991*	*1992*
Area (thousands of hectares)							
Peninsular Malaysia							
Sabah	261	569	907	1,292	1,698	1,728	—

Sarawak	29	59	94	153	276	285	—
Total	1	14	22	23	55	55	—
	291	642	1,023	1,468	2,029	2,068	—
Annual change in area							
	+70	+76	+89	+112	+39	—	—
Production (thousands of tons)							
Crude palm oil	431	1,258	2,576	4,133	6,095	6,141	6,373
Palm kernels							
Kernels	—	—	550	n.a.	1,845	1,785	1,874
Oil	—	—	222	512	827	782	812
Cake	—	—	277	—	1,038	955	984
Value of exports							
M$ millions	—	—	2,982	4,812	5,507	5,865	—
Exchange rate	3.06	2.40	2.18	2.43	2.70	2.75	2.55
US$ millions	—	—	1,370	1,938	2,036	2,133	—

— not available.

Sources: *Ministry of Primary Industries (1988, 1992); Embassy of Malaysia, Office of the Science Attaché, Washington, D. C., personal communication (1993).*

Institutions and Investments

The Federal Land Development Authority (FELDA) was formed in July 1956 as part of the government's effort to develop new land for agriculture for the settlement of the rural poor, and to stabilize the rural community. In contrast with the Swynnerton Plan initiated two years earlier in Kenya (chapter 9), which sought to intensify agriculture where the rural population was already living, the FELDA settlement schemes opened up lowland, rain forest land, and provided much stronger central control over development. A few years later in the late 1960s, Kenya's settlement schemes more closely resembled those of FELDA in Malaysia; however, the Kenyan schemes involved settling Africans on farms already developed by non−Africans, some of which had originally been excised from highland forested areas.

All FELDA schemes have been strongly managed centrally, although part of the land has been allocated and sold to settlers. The settlers have been organized into groups that benefit from the same technical and financial systems as the estate operations of FELDA on which labor and management are paid by the authority. This institutional and social structure has been accepted by the Malay settlers, but might not be so feasible with other communities.

Until 1966 the FELDA schemes were based mainly on rubber as the principal cash crop, but by 1991 oil palm plantings had become important, and accounted for 29 percent of the national total oil palm area (Table 10−6). At the end of 1990 about three−quarters of the area planted with oil palm on FELDA schemes was allocated to individual farm families (or settlers as they are commonly called). The remaining area is managed directly by FELDA on a commercial basis by hiring workers. The settlers' land ownership system under overall FELDA management has been modified at various times since 1956. Up to 1985 and again since 1989, smallholders with about 10 acres (4 hectares) per family have received titles to their land after paying off their loans for land purchased and development. In the intervening period the FELDA had tried various systems, including the "share system," but these were not well received by the settlers. By the end of 1990 the FELDA had settled 119,180 families, of whom 13,419 had received land titles. Of the total number of families 76,494, or 65 percent, depended mainly on oil palm production for their livelihood.

The FELDA has established corporations in seven production units and six service units. Since 1971 it has also become a partner in eight joint ventures related to its settlement activities throughout the country, and in which, by 1990, it held 50.7 percent of the equity through its Palm Kernel Corporation and FELDA−Johore Bulkers Sdn. Bhd.

Table 10−6. Distribution of Area Planted with Oil Palm, 1991 (hectare)

		East Malaysia			
Management system	*Peninsular Malaysia*	*Sabah*	*Sarawak*	*Total*	*Percentage of total*
Individual smallholder a /	176	7	1	184	9
FELDA	515	89	8	612	29
Federal Land Consolidation and Rehabilitation Authority	126	0	0	126	6
Rubber Industry Smallholders Development Authority	34	0	0	34	2
State schemes and government agencies	102	53	29	184	9
Subtotal	953	149	37	1,140	55
Private estates	775	136	17	928	45
Total	1,728	285	55	2,068	−−−
Percentage	84	14	2	n.a.	100

a / Holdings of less than 100 acres.

Source: *Ministry of Primary Industries (1992).*

The Federal Land Consolidation and Rehabilitation Authority was established in 1966 to take over failed state (as opposed to federal) land development schemes and to help smallholders develop economically viable holdings under overall FELCRA management. By 1991 had developed some

247,000 hectares with tree crops, of which about half were oil palm plantations (Table 10−6). In 1992 the World Bank approved a loan for a third Federal Land Consolidation and Rehabilitation Authority land development project.

In 1973 the Rubber Industry Smallholders Development Authority was formed to help small−scale rubber growers replace old, low−producing trees with improved clones. As some of these farmers converted at least part of their land to oil palms, Table 10−6 includes the Rubber Industry Smallholders Development Authority. About 10,000 hectares of the oil palm areas under RISDA are operated as estates under the authority's direct management.

Several state settlement and land development schemes have been implemented during the past decade, but in aggregate they account for no more than 9 percent of the national area of oil palm plantations. They are relatively more important in East Malaysia, where they account for almost as great an area of oil palms as the FELDA schemes. Private estates include about 45 percent of the total national area of about 2 million hectares of oil palm plantations (Table 10−6).

With few exceptions, companies that had originally developed Peninsular Malaysia's rubber industry also developed the large−scale palm oil estates. In addition, the Unilever oil palm plantation company, Pamol, has been established for more than forty years, and by 1991 had 15,000 hectares of oil palm plantations throughout Malaysia. Several of the companies formed their own oil palm research units or broadened the mandate of the research units they had established earlier for rubber. For example, the first commercial oil palm planting began in 1917 on Tennamaram estate, now managed by the Sime Darby Plantations, which established a research station at Ebor in 1978, and the Guthries research station dates back to 1929, when its main priority was to test locally rubber management recommendations based on earlier field research in the Dutch East Indies (Indonesia), although Guthries, first planting of oil palms was as early as 1905.

Various public sector units carried out some research on oil palm selection and management until these activities were brought together in 1969 under the Malaysian Agricultural Research and Development Institute, which became operational in 1971. In 1979 the Palm Oil Institute of Malaysia (PORIM) was founded and funded through a cess on the volume of oil palm products collected at mills (of which there were 261 in 1991) or refineries (42 in 1991). The PORIM's design was based on the successful performance of the industry−based Rubber Research Institute of Malaysia, which was also the model for Kenya's coffee and tea research foundations.

The PORIM has grown remarkably quickly into one of the world's leading research institutions for tropical agriculture. By 1993 it had 680 staff engaged in research into field production, oil extraction, refining, by−products, nutritional values, and international marketing. It has a liaison office in Hertford in the United Kingdom and regional technical advisory offices in Washington, D.C., United States; Karachi, Pakistan; and Hong Kong.

The PORIM has been at the forefront of research to respond to a public campaign in the United States to halt the use of tropical oils for human consumption. Elson (1992) has reviewed the nutritional and scientific issues supporting the U.S. Department of Agriculture's (USDA 1979)

conclusion, that palm oil should be clearly distinguished from palm kernel oil and coconut oil because it has a lower level of saturated components, with no significant content of capric, lauric, and myristic acids. It is now clear that while palm kernel oil and coconut oil should be avoided for human consumption, there are positive indications in favor of using palm oil for cooking. This work sponsored by the PORIM has benefited oil palm growers throughout the world (MOPEC 1990).

The oil palm industry now has a strong structure with a central, industry−financed, vertically integrated technical institution (PORIM), and also several research units run by private companies that focus mainly on applied research, including plant selection and multiplication, crop agronomy, field management, and primary oil extraction from fresh fruit bunches. Over the years many useful and practical results have been obtained from these research units that have benefited not only the firm concerned, but also the Malaysian oil palm industry as a whole. There has been increasing discussion about combining and simplifying the FELDA, the Federal Land Consolidation and Rehabilitation Authority, and the Rubber Industry Smallholders Development Authority organizations into one public sector entity to provide smallholders with services that private firms cannot provide more efficiently,

Factors and Systems of Oil Palm Production and Processing

Malaysia's first oil palm plantations had a narrow genetic base, and were exclusively of the dura type, being the progeny of four seedlings imported from Africa to Bogor, Dutch East Indies (Indonesia). From 1917 to the late 1950s, Malaysian farmers planted only dura palms, whose oil extraction rate was 15 to 16 percent. Crossing with a pisifera type from the Congo (now Zaire) led to tenera, a hybrid palm with an oil extraction rate of 20 to 25 percent. Since the late 1970s, work has been in progress to develop vegetative propagation techniques to multiply rapidly progeny from selected high−yielding palms. However, in 1986 researchers found that many palms grown from plantlets had abnormal flowers, possibly because of the use of hormones, or the efforts to maximize the number of plantlets, or both. About ten laboratories in Malaysia are now working on this problem, but the widespread use of clonal material is unlikely for another five to ten years. However, seed production from selected palms is already a standard practice. According to one estimate (Dr. Ho, Sime Darby, personal communication 1993), the current yield level of crude palm oil per hectare under good management could be raised from 4.5 to 8.0 tons using known clones, provided the incidence of abnormal floral structures could be brought to a low level. According to Dr. Halim Hassan, former director general of the PORIM (personal communication 1993), the problems of tissue culture for vegetative propagation are partly genetic and partly physiological. The combination of culture, medium, and protocol needs to be adjusted. A liquid medium is probably better than a solid medium for propagation. Clones differ considerably in the occurrence of floral abnormalities, and some abnormalities are also found in inflorescences of seedling oil palms.

Few male inflorescences are produced on young oil palms. Therefore when extensive areas are planted at one time, there is insufficient pollen to fertilize all the female flowers. This proved a seriously limiting factor during periods of rapid expansion of the area of oil palms in isolated locations, as there were too few old palms to produce sufficient pollen. Initially farmers mitigated this problem by manual collection of the pollen and individual application of the pollen to female flowers. However, this is a skilled operation and obviously very labor intensive. In the early 1980s

entomological surveys in the Cameroons in West Africa showed that several insects live in the inflorescence of wild oil palms and move pollen as they travel from flower to flower. Researchers tested several of these insects in Malaysia, which led to the release of the small weevil *Elaedobius kamerunicus*. By 1983 the weevil was widespread and efficient in pollination, with no apparent harmful side effects. Some observers think the subsequent increase in the rat population was because rats thrived on the larvae of the weevil in the male inflorescence, but this has not been proven. Nevertheless, the number of rats in oil palm plantations has increased. At high infestations they are controlled with Warfarin, but the common barn owl is reported to be effective at controlling smaller rat populations. One nesting box per five or ten hectares seems enough to attract the owls and keep them on rat control duty. The general experience has been that fewer rat bait rounds are needed when owls are present in oil palm plantations.

Oil palms are extremely sensitive to competition for soil moisture, as rooting is mainly in the top meter of soil, therefore the density of palm planting and the type of ground cover are both important considerations affecting productivity. Currently triangular spacing is recommended to give 136 palms per hectare in coastal regions and 148 palms per hectare for inland areas. On broad−based terraces the spacing between rows may be somewhat greater than within rows to allow the passage of small tractors that may be used to collect fresh fruit bunches, and later to return the empty bunches as organic mulch, for which fallen palm fronds are also important.

Since the early 1940s Malaysian farmers have used legume ground cover crops widely and successfully, initially in rubber plantations, and later with oil palms. The main species used at planting are *Calopogonium mucunoides, C. caeruleum*, and *Pueraria javanica* sown at 5 to 10 kilograms of seed per hectare. Recently investigators have found that vetiver grass *(Vetivaria zizanoides)* is useful in preventing surface soil erosion when planted in a narrow row along the lips of terraces on steep slopes. The use of legumes for ground cover in young plantations not only reduces erosion, improves moisture infiltration, and supplements the nitrogen supply, but also improves the soil's physical conditions throughout the rooting zone and the nutrient uptake by the palms.

Oil palms in Malaysia are grown mainly in the lowlands, where special drainage works are necessary in many low lying areas, particularly for peat and acid−sulphate soils, which occur in some coastal areas. Peat soils are used mainly for pineapples and Robusta coffee, but if they are less than 3 meters deep they can also be used for oil palms. If the peat soil layer is deeper, subsidence can be a problem.

Since 1983/84 the PORIM has adopted a sequential environmental suitability system of analysis of soils for oil palm planting. This was developed from the U.S. Department of Agriculture's Soil Taxonomy and includes soil acidity (usually pH 4.1 to 4.5), soil organic matter (range 1.5 to 2.5 percent), slope, drainage conditions, presence or absence of an impervious layer, and the soil's potassium content. So far this system has not been widely used.

Under mature oil palms, the initial vegetative ground cover is replaced by more shade−tolerant species. Weeding is minimal to protect the soil surface from the impact of raindrops or drips from high palm fronds that can have a damaging effect on the surface soil structure, thereby reducing moisture infiltration into the soil profile and increasing surface soil erosion, particularly on steep terrain. The surface soil needs to be protected by spreading fallen and pruned fronds in the inter−row spaces, as well as oil mill residues, including empty fruit bunches, close to the palms.

One estate company (Guthries) uses locally adapted breeds of sheep to graze between the rows of young oil palms to keep down weeds. However, herbicides (paraquat and glyphosate) are more widely used for spot−spraying patches of weeds in the immature plantations. Careful ground cover management is necessary in mature plantations to minimize soil loss by water erosion.

Forty years ago fertilizing was confined to small applications of muriate of potash or bunch ash (from burnt empty fruit bunches) and occasional dressings of ground rock phosphate. The first field−scale applications of nitrogen were made in the mid−1950s, and from the late 1960s more substantial applications were made of fertilizer mixtures that included nitrogen, phosphorus, potassium, and magnesium (Davidson 1991). Potassium remains the most important nutrient, as the element is heavily exported through the harvested fruit bunches. The amount applied as a fertilizer can be substantially reduced by the return of empty bunches from the oil mills to the field plantations. Fertilization of mature oil palm is essential for good production. Foliar analysis is a standard practice in the industry for fertilizer application on a field by field basis. The use of fertilizers for oil palms now varies according to the age of the palms. In mature plantations between 10 and 12 kilograms of fertilizers per palm are applied annually (1,480 to 1,776 kilograms per hectare at 148 palms per hectare), including 3 kilograms of ammonium sulfate, 3 kilograms of muriate of potash, and 1 kilogram each of kieserite and rock phosphate per palm.

Methods of milling to extract the crude palm oil from the fresh fruit bunches have changed little since 1964, but the procedures, equipment, and control methods have been substantially modernized. There have been improvements in labor efficiency at the mills, which for Pamol's Kluang Estate Davidson (1991) estimates to be equivalent to an 8 percent increase in yield between 1951 and 1991. The main changes in field and mill operations have almost all been aimed at improving the value added per day of work. For example, during a six−year period Pamol was able to:

Increase by 3.0 percent annually the weight of fresh fruit bunches harvested per worker by labor specialization, centralized harvesting, and mechanization (tractors, crane and net loading, and so on);

Increase by 4.5 percent annually the area of plantation per field worker by mechanization of fertilizer and herbicide application;

Increase by 13.5 percent annually the volume of palm oil extracted and processed per mill worker by improved mechanization, automation, and bulk storage facilities.

By 1975, the crude palm oil industry had become the worst source of water pollution in Malaysia. The government estimated that in 1980 the pollution caused by the organic wastes from palm oil and rubber mills was equivalent to the pollution generated by a human population of more than 10 million. A National Division (later Department) of Environment was founded in 1975 to implement the 1974 Environmental Quality Act. From July 1977 the department issued regulations, set a license fee that increased as the level of pollution increased, and set standards that were mandatory after the first year with annually declining levels of pollutants that could be tolerated from

1978 to 1984. Vincent (1993) has reported fully on the apparently remarkable success of the department's program to reduce biological oxygen demand in water of levels of rivers to low values while the crude palm oil industry's daily output tripled. These strong environmental control measures have had no impact on the international competitiveness of the industry as the oil mills recovered their costs by reducing the price paid for fresh fruit bunches. Considerable advances have also been made in the use of effluent and empty fruit bunches from rubber factories and palm oil mills to recycle nutrients back to oil palm plantations, which has permitted considerably reduced application of some fertilizers.

Lim, P'ng, and Chan (1991) reported on an eight−year study of the recycling of palm oil mill effluent to oil palm plantations, and showed that mature oil palms treated with palm oil mill effluent yielded up to 16 percent more in weight of fresh fruit bunches than areas that received only the normal fertilizer applications. Soil fertility and the soil moisture status was improved with the application of palm oil mill effluent. At controlled levels of application there was no accumulation of heavy metals following eight years of treatment, and analysis of surface water and groundwater in the surrounding area indicated that applications of palm oil mill effluent had a negligible effect on the environment,

Commentary

The role of government in the development of the oil palm industry has been critical, but selective and focused. In several respects there are parallels between the policies underpinning palm development in Malaysia and tea development in Kenya (chapter 9). There are, however, some important differences related to contrasting social and geographic contexts. The scale of the oil palm industry in Malaysia is far greater than that of Kenya's tea industry, and several other important differences between the industries exist, but they also have some interesting features in common. In both cases initial government involvement was to promote the construction of railway system, and later a network of main roads. The initial railway network in Malaysia was for the mining and rubber industry, but it later became important for general development, including the oil palm industry. All government sponsored oil palm development schemes have been accompanied by essential access road programs to deliver inputs and allow transport of fruit bunches to the oil mills.

In both countries the private sector initiated plantation development on land cleared from indigenous forest; highland forests in Kenya for tea, and lowland rain forests for rubber and later oil palms in Malaysia. Also in both countries the government progressively restricted the alienation of forest areas for plantation development. Since the late 1980s little or no forest has been cleared in Malaysia except in East Malaysia, where extensive deforestation has continued, although clearing is being more strictly limited.

Initially the government released natural forest land for−large scale rubber estates, but discouraged smallholders from growing perennial cash crops, because it was believed that this could reduce their self−sufficiency in food production. In fact, smallholders soon entered into rubber production and initially delivered their product to estate rubber factories. From the 1950s a series of public institutions was established to help landless and poorer families to benefit from growing perennial tree crops for which the natural conditions were most suitable: −− rubber, cocoa, and oil

palm. Each of these development programs was based on strong central leadership, control, and management by the corresponding authority. Smallholders were associated in groups, which proved successful in Malaysia, but was in sharp contrast with the policy followed in Kenya for smallholder tea development on individually−managed farms.

In Malaysia, the government set up the Federal Land Development Authority in 1956 to promote smallholder settlements on newly cleared land. These were mainly for perennial crops, initially rubber, and later oil palm. These were on about 4−hectare plots per family aggregated into plantation−scale operations managed by the FELDA, which also provided extension, milling, and marketing services. In Kenya, smallholding tea developed from a pilot scheme started in the mid−1950s on existing individual smallholdings. This led in a few years to the Special Crops Development Authority (1960), and later to the Kenya Tea Development Authority (1964). These agencies provided the necessary planting material and technical advice, and also the green leaf collection and delivery system to the tea manufacturing factories. For many years specialist private companies managed the factories for the Kenya Tea Development Authority. This model of perennial crop development for smallholders provides an interesting contrast to the FELDA's direct management of all aspects of development. Recently the FELDA has begun to sell its oil extraction mills to cooperatives of settlers, which remain under the overall supervision of the FELDA.

The limiting factor for both smallholder tea farmers in Kenya and oil palm growers in Malaysia is the availability of farm labor. This is particularly serious in Kenya, as tea has to be plucked almost daily throughout the year. The tea area per family of 0.5 to 1.0 acre is too large to manage entirely with family labor, but is insufficient to provide as high a standard of living as originally envisaged. The much larger−scale holdings of oil palm in Malaysia provide à reasonable prospect for substantial increases in the standard of living, particularly once farmers have paid off their initial loans. Furthermore, the Malaysian strategy for smallholder involvement in perennial crop production facilitates the continuing transition of the national economy from an agricultural and forestry−led structure to an industrialized economy in which agriculture will continue to release labor to other sectors.

The legislative and administrative procedures used in Malaysia to control serious water pollution by rubber factories and palm oil mills provide an excellent example that could be adapted to conditions in many other countries.

Finally, both in Malaysia and Kenya the government did not tax the perennial crop industries unduly, and maintained the exchange rate of the domestic currency against the currency of its main trading partners at a realistic level for many years. Malaysia has kept an extraordinarily stable exchange rate against the U.S. dollar since 1980 (Table 10−1).

In both Malaysia and Kenya early plant selection and agronomic research was undertaken on private estates. Later the ministries of agriculture provided some research support, and then the industries themselves financed special research institutes governed by joint private sector and public sector boards of directors. The Tea Research Institute of East Africa was registered in Kenya in 1951, while the Palm Oil Institute of Malaysia was established in 1979 to take over responsibility for oil

palm research from the Malaysian Agricultural Research Department Institute. In both cases the Rubber Research Institute of Malaysia served as an institutional model.

There is a strong scientific and technical basis for the oil palm industry in Malaysia, which is widely recognized as the world leader in this field. Similarly the tea industry in Kenya has developed a high degree of technical competence through the enterprise of the private estates and on the public tea development authority, which jointly support a specialized research institute, as does the oil palm industry in Malaysia.

The prospects for further substantial increases in the yield of palm oil appear to be stronger than for seasonal oil producing crops. The main advance will be through the commercial production of clonal palms. After many years of research and field testing of progeny raised through tissue culture, the rapid, large−scale reproduction of clones of high−performing palms is likely to become commercially viable in the next five to ten years. As was the case with tea in Kenya (chapter 9), the production of uniform high−yielding clones will have a major effect on the profitability of the oil palm industry. All palms in a clonal plantation will have the same genetic potential to respond to improvements in agronomic management, such as the application of fertilizers and organic by−products from the mills. Clones vary in their adaptability to soil moisture, stress, and other local environmental conditions, therefore by using clonal material farmers will be able to match−local conditions with the most appropriate clone. This will, of course, require much wider−scale testing of clones than has been carried out with seedling material.

Once a fully practicable system of vegetative propagation is available, researchers will be able to give more attention to producing what Davidson (1991) has called designer bunches. These would ripen more uniformly and the color of the fruit would change abruptly as it ripened to improve the efficiency of harvesting at the optimum stage. Long bunch stalks and narrower frond butts could also be used as selection criteria to facilitate harvesting.

Malaysia currently has about 2 million hectares of oil palm plantations, much of which will be ready for replanting in the 1990s and the early years of the twenty−first century. The annual area to be replanted will be around 100,000 hectares, or about the rate of new planting in the 1980s (Table 10−5). Provided that these replanting are with clonal material, the prospects for substantial increases in productivity in the early years of the next century are good.

There is also considerable scope for improving the efficiency of oil extraction, as currently 8 to 10 percent of oil and 3 to 4 percent of kernels are not extracted during milling. Although major advances have been made in the use of liquid and solid by−products from mills, more efficient boiler design and more effective use of by−products could result in more efficient generation and use of energy (Davison 1991).

The world market for edible oils is continuing to expand, particularly in Asia, where both population and family incomes are increasing rapidly. The prospects for palm oil and palm oil products are reasonably good, provided the costs of production do not increase substantially as the general availability of rural labor decreases, and consequently the cost of labor increases. Seasonal oilseed crops such as soybeans and rapeseed can be grown and harvested with a low labor input, and furthermore produce by−products for livestock feed as well as edible oil. World oil and meal prices often do not move in unison, so the total farm income for producers of seasonal oilseed crops is liable to smaller fluctuations than those palm oil producers experience. In addition, Malaysia is rapidly developing a major oleo−chemical industry based on palm oil as an important complement to the edible oil industry.

The oil palm industry of Malaysia is thus well placed to continue to evolve as a viable sector of the economy, because of its strong technical basis, and a structure that appears capable of further adaptation to changing socioeconomic conditions.

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Chapter 8—
India: Soybeans on 'Black Cotton' Soils

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Montevideo, URUGUAY
Telephone: (59 82) 49.94.58
Fax: (59 82) 48 61 74

Colombia: Associated Cropping in Antioquia

CENICAFE
Centro Nacional de Investigaciones de Cafe.
FEDERACAFE.

DNP
Departamento Nacional de Planeacion
Calle 26, no 13−19 piso 7°
Santafe de Bogata, Colombia
Telephone: (57 2) 824055

FEDERACAFE
Federacion Nacional de Cafeteros de Colombia
Calle 73, no 8−13
Apartado Aereo 57534
Santafe de Bogota, Colombia
Telephone: (57 2) 170600
Fax: (57 2) 171021
Telex: 44723 FCAB CO

Nigeria: Associated Cropping in the Forest Zone

FACU
Federal Agricultura Coordinating Unit Federal Department of Agriculture
Federal Ministry of Agriculture and Natural Resources.
1416 Ilaro Street, Bodija
PMB 5517
Ibadan, Nigeria
Telephone: (2349 681896
Fax: (2349) 234−0945

NRCRI
National Root Crops Research Institute.
Umudike, Nigeria

West African Farming Systems Network
Ouagadougou, Burkina Faso

Brazil: The "Cerrados" Region

CPAC
Centro de Pesquisa Agropecuaria dos Cerrados.
Km. 18, BR−020
Cx. Postal 70/0023
CEP: 73.300
Planaltina, DF, Brazil
Telephone: (061) 596 1171

CNPAF
Centro Nacional de Pesquisa de Arroz e Feijao
Goiania, GO, Brazil

EMBRAPA
Empresa Brasileira de Pesquisa Agropecuaria.
Ministerio da Agricultura e Reforma Agraria
SAIN − Parque Rural
W/3 Norte Final
C.P. 040315
70770 Brasilia, DF, Brazil
Telephone: (61) 347 2061
Fax: (61) 347 1041

EMGOPA
Empresa Goiana de Pesquisa Agropecuaria
Rua 58 no 94 − Centro
Caixa Postal: 49
74130 Goiana GO, Brazil
Telephone: (062) 225 4111
Telex: 62.1519 EGPS BR

Associaçào Brasileira para a Pesquisa da Potassa e do Fosfato
Associacao de Plantio Direto no Cerrado
M.U.D.B. Conj. 9
Lote 5, Brasilia D.F.
Brazil 71600
Telephone: (55 61) 366 1984

Fundaçao ABC
Rodaria PR 151
Km 155, Parana 84165−700
Campinas SP, Brazil

India: Soybeans on "Black Cotton" Soils

AICARP
All India Co−Ordinated Agronomic
Research Project (ICAR)

CIAE
Central Institute of Agricultural Engineering
Shri Guru Tegh Bahadar Complex
T.T. Nagar. Bhopalu
Madhya Pradesh 462003
Telephone: (0755) 75616, 75171
Telex: 0705 273

CRIDA
Central Research Institute for Dryland Agriculture
Santoshnagar
Hyderabad, India
Telex: 425−6252 DARP IN

ICAR
Indian Council of Agricultural Research
Krishi Bhawan
New Delhi 110 001 India
Telephone: 385233
Telex: 031−62249 ICAR IN

NRCS
National Research Centre for Soybean (Indian Council of Agricultural Research)
Khandwa Road
Indore 452 001

MP, India
Telephone: (91 755) 65653

SOPA
Soybean Processors Association of India
Scheme No. 53 Near Malviya Nagar
A.B. Road
Indore 452 008
India
Telephone: (0731) 440765
Fax: (0731) 443254
Telex: 0735−308 SOPA IN

Agricultural and Industry Survey
Vidya Mila Media Pvt Ltd
Additional office No. 14
Shankar Mutt Road Sankarpuram
Bangalore 560 004
Telephone 625973

Agricultural Situation in India
Directorate of Economics and Statistics
Dept. of Agriculture & Cooperation
Ministry of Agriculture
The Controller of Publications
Civil Lines
Delhi 110 054

Ministry of Agriculture, Forestry and Fisheries and Rural Development

Ministry of Water Resources
412 Shram Shakti Bhavan
Rafi Marag
New Delhi 110 001
Telephone: 371 0305
Fax: 371 0253

National Bureau of Soil Survey and Land Use Planning
Nagpur: 4400 10
Telephone: 532 386
Telex: 0715 262 NBSL IN

Trade Fair Authority of India
Pragati Bhavan
Pragati Maidan
New Delhi 110 001
Telephone: 331 8143

Kenya: Tea Development

KTDA
Kenya Tea Development Authority
Rahimtulla Trust Tower, Moi Avenue
P.O. Box 30213
Nairobi, Kenya
Telephone: (254 2) 21441
Fax: (254 2) 339356
Telex: 22645 CROPS K

TRF−K
Tea Research Foundation of Kenya
PO Box 820
Kericho, Kenya

International Tea Committee Ltd.
Sir John Lyon House,
5 High Timber Street, London EC4V3NU
ENGLAND
Telephone: (0) 71.248.4672
Fax: (0) 71.248.3011

The Tea Board of Kenya
Ukulima Co−op House
Haile Selassie Avenue and County Road
P.O. Box 20064
Nairobi, Kenya
Telephone: (254 2) 220241/220643
Fax: (254 2) 331650

Malaysia: Oil Palm Development

FELDA
Federal Land Development
Authority − Headquarters
Jalan Perumahan Gurney
54000 Kuala Lumpur MALAYSIA
Telephone: 03 293 5066
Fax: 03 292 0087
Telex: FELDA MA 32159

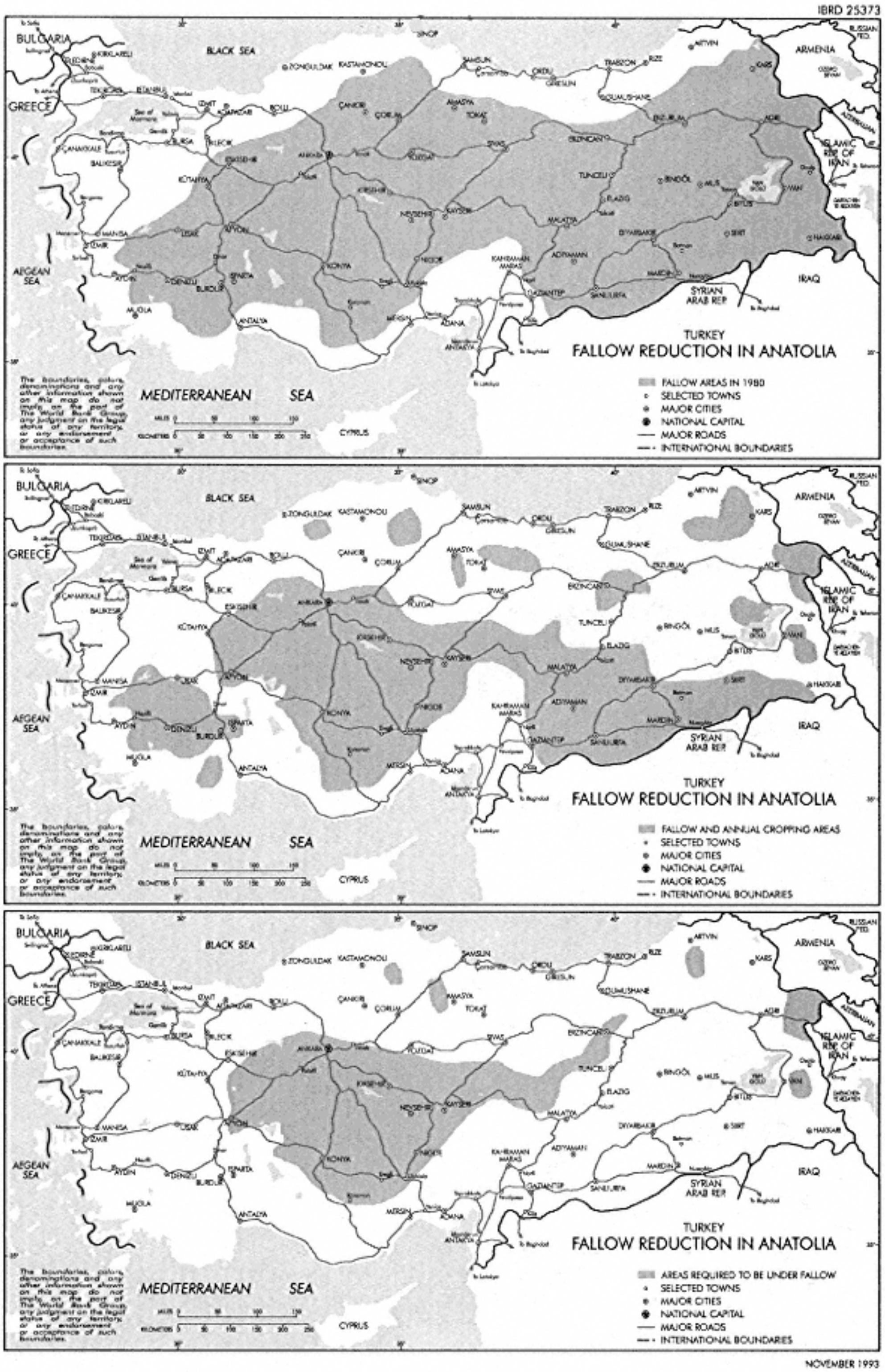
Kumplan Guthrie Berhad
Guthrie Research Chemara
Jalan Perpateh.Locked Bag No: 28
70990, Seremban, Negeri, MALAYSIA
Telephone: 06−725 361
Fax: 06 727 864
Telex: GEALCO MA 638 78

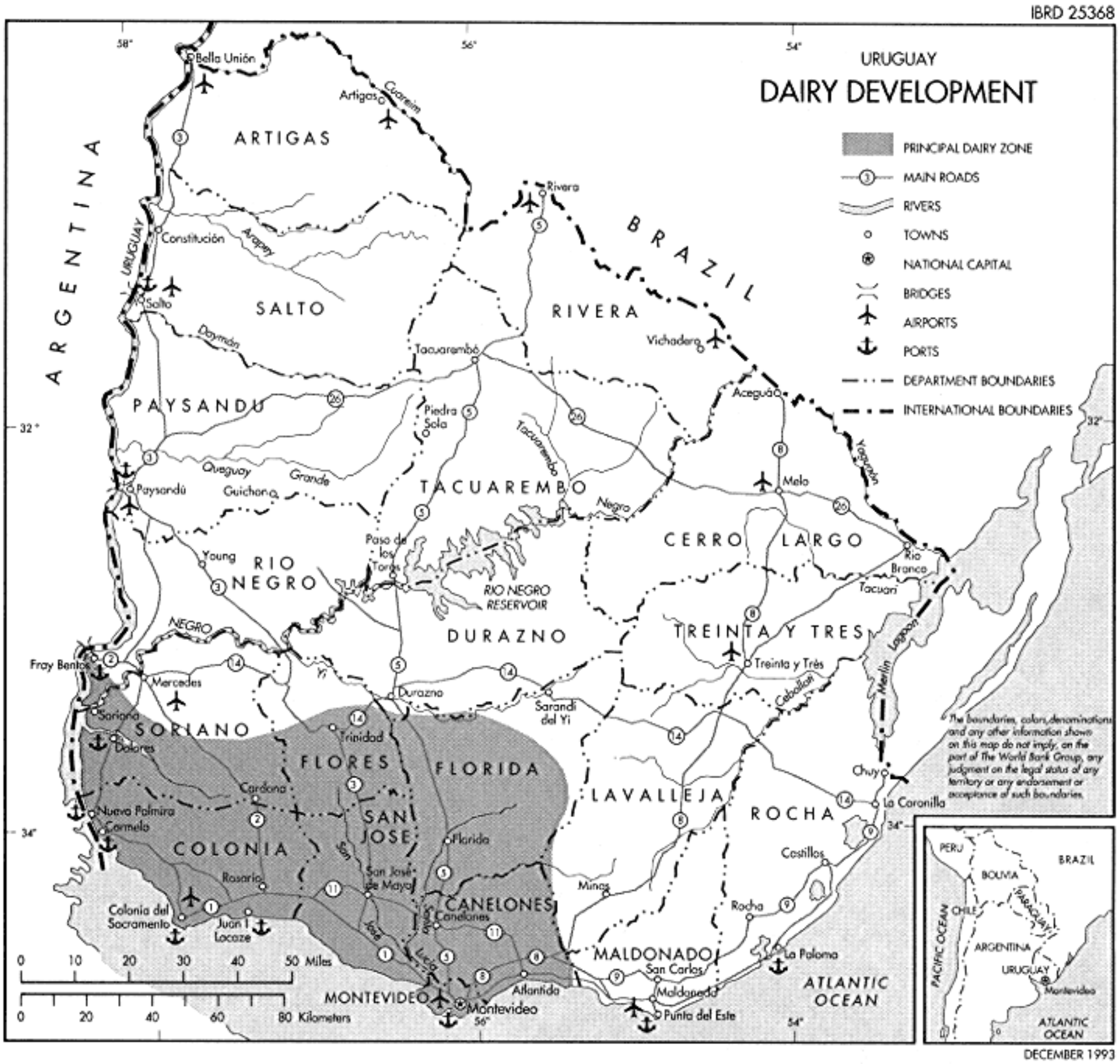
MPOPC
Malaysian Palm Oil Promotion Council
1st Floor, Bangunan Getah Asli
148 Jalan Ampang
50450 Kuala Lumpur, Malaysia
Telephone: 03−2481075
Fax: 03−2422935

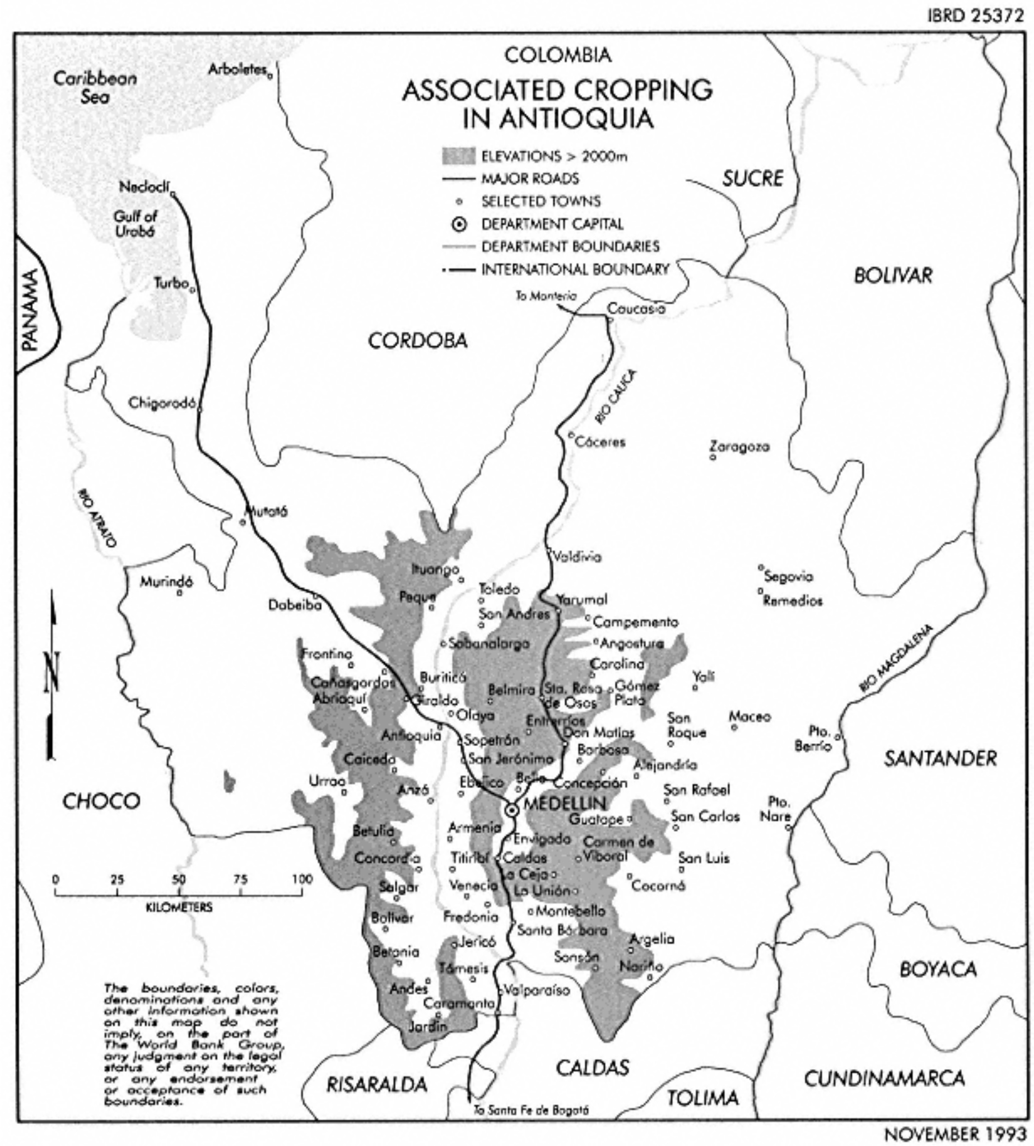
PORIM
Palm Oil Research Institute of Malaysia
P.O. Box 10620
50720 Kuala Lumpur, Malaysia
Telephone: 03−8259155
Fax:03−8259446
Telex: MA 31609

RRIM
Rubber Research Institute of Malaysia
PO Box 10150
50908 Kuala Lumpur, Malaysia
Telephone: 03−4567033
Fax: 03−4573512
Telex: RRIM MA 30369

Sime Darby Plantations
Ebor Research
Peti Surat 7202
40706 Shah Alam, Selangor, MALAYSIA
Telephone: 5590137
Fax: 5503728
Telex: SDPHO MA 33503


IBRD 25373
BULGARIA
GREECE
BLACK SEA
ARMENIA
AZERBAIJAN
ISLAMIC REP. OF IRAN
IRAQ
SYRIAN ARAB REP.
AEGEAN SEA
MEDITERRANEAN SEA
CYPRUS
TURKEY
FALLOW REDUCTION IN ANATOLIA
FALLOW AREAS IN 1980
SELECTED TOWNS
MAJOR CITIES
NATIONAL CAPITAL
MAJOR ROADS
INTERNATIONAL BOUNDARIES
TURKEY
FALLOW REDUCTION IN ANATOLIA
FALLOW AND ANNUAL CROPPING AREAS
SELECTED TOWNS
MAJOR CITIES
NATIONAL CAPITAL
MAJOR ROADS
INTERNATIONAL BOUNDARIES
TURKEY
FALLOW REDUCTION IN ANATOLIA
AREAS REQUIRED TO BE UNDER FALLOW
SELECTED TOWNS
MAJOR CITIES
NATIONAL CAPITAL
MAJOR ROADS
INTERNATIONAL BOUNDARIES
NOVEMBER 1993


IBRD 25368
URUGUAY
DAIRY DEVELOPMENT
PRINCIPAL DAIRY ZONE
MAIN ROADS
RIVERS
TOWNS
NATIONAL CAPITAL
BRIDGES
AIRPORTS
PORTS
DEPARTMENT BOUNDARIES
INTERNATIONAL BOUNDARIES
ARGENTINA
BRAZIL
ARTIGAS
SALTO
PAYSANDU
RIVERA
TACUAREMBO
RIO NEGRO
DURAZNO
CERRO LARGO
TREINTA Y TRES
SORIANO
FLORES
FLORIDA
LAVALLEJA
ROCHA
COLONIA
SAN JOSE
CANELONES
MALDONADO
MONTEVIDEO
ATLANTIC OCEAN
RIO NEGRO RESERVOIR
The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.
0 10 20 30 40 50 Miles
0 20 40 60 80 Kilometers
DECEMBER 1993


IBRD 25372
COLOMBIA
ASSOCIATED CROPPING
IN ANTIOQUIA
ELEVATIONS > 2000m
MAJOR ROADS
SELECTED TOWNS
DEPARTMENT CAPITAL
DEPARTMENT BOUNDARIES
INTERNATIONAL BOUNDARY
Caribbean Sea
Arboletes
Necloclí
Gulf of Urabá
Turbo
PANAMA
Chigorodó
Mutatá
RIO ATRATO
Murindó
Dabeiba
CORDOBA
SUCRE
BOLIVAR
To Montería
Caucasia
RIO CAUCA
Cáceres
Zaragoza
Valdivia
Segovia
Remedios
Ituango
Peque
Toledo
San Andrés
Yarumal
Campemento
Angostura
Sabanalarga
Frontino
Cañasgordas
Abriaquí
Buriticá
Giraldo
Olaya
Belmira
Sta. Rosa de Osos
Carolina
Gómez Plata
Yalí
RIO MAGDALENA
Antioquia
Sopetrán
San Jerónimo
Entrerríos
Don Matías
Barbosa
San Roque
Maceo
Pto. Berrío
SANTANDER
Caicedo
Urrao
Anzá
Ebéjico
Bello
Concepción
Alejandría
San Rafael
CHOCO
MEDELLIN
Guatape
San Carlos
Pto. Nare
Betulia
Armenia
Envigado
Carmen de Viboral
Concordia
Titiribí
Caldas
San Luis
Salgar
Venecia
La Ceja
La Unión
Cocorná
0 25 50 75 100
KILOMETERS
Bolívar
Fredonia
Montebello
Santa Bárbara
Jericó
Argelia
Betania
Sonsón
Nariño
Támesis
BOYACA
Andes
Caramanta
Valparaíso
Jardín
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RISARALDA
CALDAS
TOLIMA
CUNDINAMARCA
To Santa Fe de Bogotá
NOVEMBER 1993


IBRD 25371
NIGERIA
ASSOCIATED CROPPING
IN THE FOREST ZONE
VERY HUMID ZONE
RIVERS
STATE CAPITALS
NATIONAL CAPITAL
STATE BOUNDARIES
INTERNATIONAL BOUNDARIES
NIGER
CHAD
Lake Chad
BENIN
CAMEROON
Gulf of Guinea
SOKOTO
KATSINA
KANO
JIGAWA
YOBE
BORNO
KEBBI
KADUNA
BAUCHI
NIGER
ADAMAWA
KWARA
ABUJA
PLATEAU
TARABA
OYO
OSUN
KOGI
BENUE
ONDO
OGUN
EDO
ENUGU
LAGOS
ANAMBRA
IMO
ABIA
CROSS RIVER
DELTA
RIVERS
AKWA-IBOM
NOVEMBER 1993


IBRD 25365
BRAZIL
CERRADOS AREA
COLOMBIA
VENEZUELA
SURINAME
FR. GUIANA
GUYANA
Boa Vista
RORAIMA
AMAPÁ
Macapá
ATLANTIC OCEAN
Belém
Manaus
São Luís
Fortaleza
AMAZONAS
PARÁ
MARANHÃO
Teresina
CEARÁ
RIO GRANDE DO NORTE
Natal
PARAÍBA
João Pessoa
PIAUÍ
PERNAMBUCO
Recife
ALAGOAS
Maceió
SERGIPE
Aracaju
Porto Velho
ACRE
Rio Branco
Miracema Do Norte
TOCANTINS
BAHIA
Salvador
PERU
RONDÔNIA
MATO GROSSO
GOIÁS
Cuiabá
BRASÍLIA F.D.
Goiânia
ATLANTIC OCEAN
BOLIVIA
MINAS GERAIS
PACIFIC OCEAN
MATO GROSSO DO SUL
Campo Grande
Belo Horizonte
ESPÍRITO SANTO
Vitória
SÃO PAULO
PARAGUAY
São Paulo
RIO DE JANEIRO
Rio de Janeiro
CHILE
PARANÁ
Curitiba
STA CATARINA
Florianópolis
RIO GRANDE DO SUL
Porto Alegre
ARGENTINA
URUGUAY
CERRADOS
PAVED ROADS
NATIONAL CAPITAL
STATE CAPITALS
STATE BOUNDRIES
INTERNATIONAL BOUNDRIES
0 500 1000 KILOMETERS
0 200 400 600 MILES
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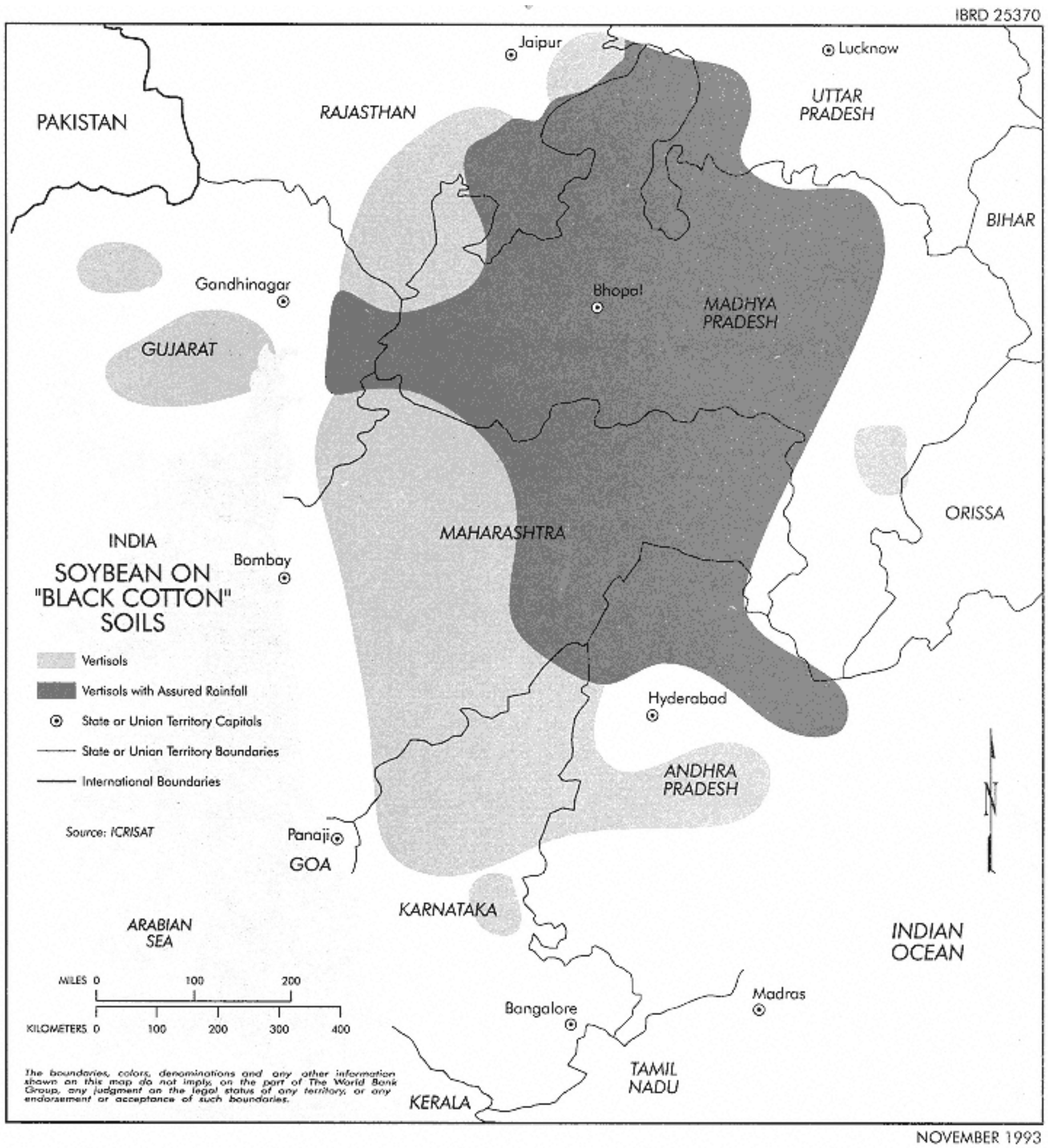
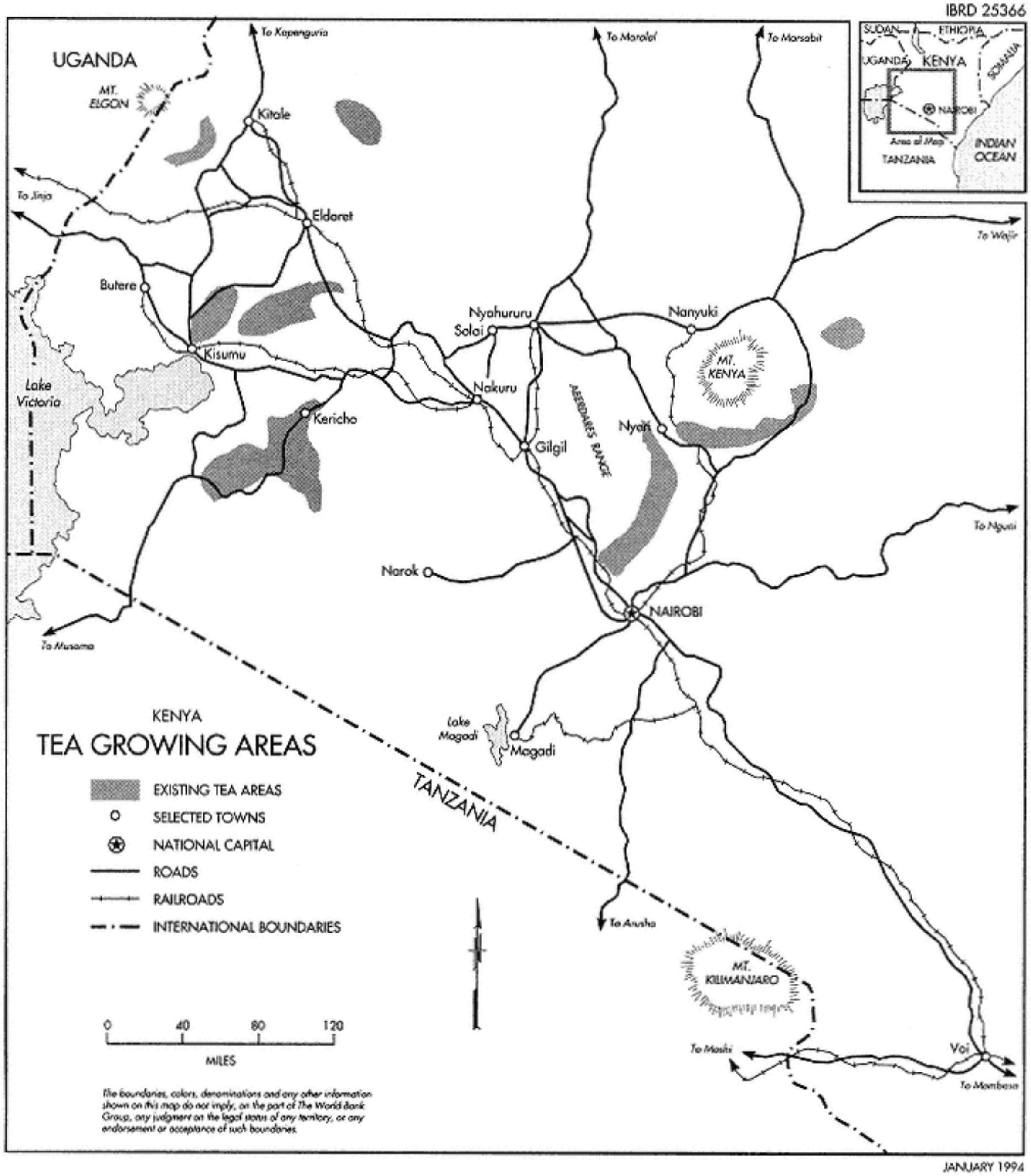
JANUARY 1994


IBRD 25370
Jaipur
Lucknow
PAKISTAN
RAJASTHAN
UTTAR PRADESH
BIHAR
Gandhinagar
Bhopal
MADHYA PRADESH
GUJARAT
ORISSA
MAHARASHTRA
INDIA
SOYBEAN ON "BLACK COTTON" SOILS
Bombay
Vertisols
Vertisols with Assured Rainfall
State or Union Territory Capitals
State or Union Territory Boundaries
International Boundaries
Hyderabad
ANDHRA PRADESH
Source: ICRISAT
Panaji
GOA
KARNATAKA
ARABIAN SEA
INDIAN OCEAN
N
MILES 0 100 200
KILOMETERS 0 100 200 300 400
Madras
Bangalore
The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.
TAMIL NADU
KERALA
NOVEMBER 1993


IBRD 25366
KENYA
TEA GROWING AREAS
EXISTING TEA AREAS
SELECTED TOWNS
NATIONAL CAPITAL
ROADS
RAILROADS
INTERNATIONAL BOUNDARIES
0 40 80 120
MILES
UGANDA
MT. ELGON
Kitale
Eldoret
Butere
Kisumu
Lake Victoria
Kericho
Nyahururu
Solai
Nakuru
Gilgil
Nanyuki
MT. KENYA
Nyeri
ABERDARES RANGE
Narok
NAIROBI
Lake Magadi
Magadi
TANZANIA
MT. KILIMANJARO
Voi
To Kapenguria
To Maralal
To Marsabit
To Jinja
To Wajir
To Nguni
To Musoma
To Arusha
To Moshi
To Mombasa
SUDAN
ETHIOPIA
SOMALIA
INDIAN OCEAN
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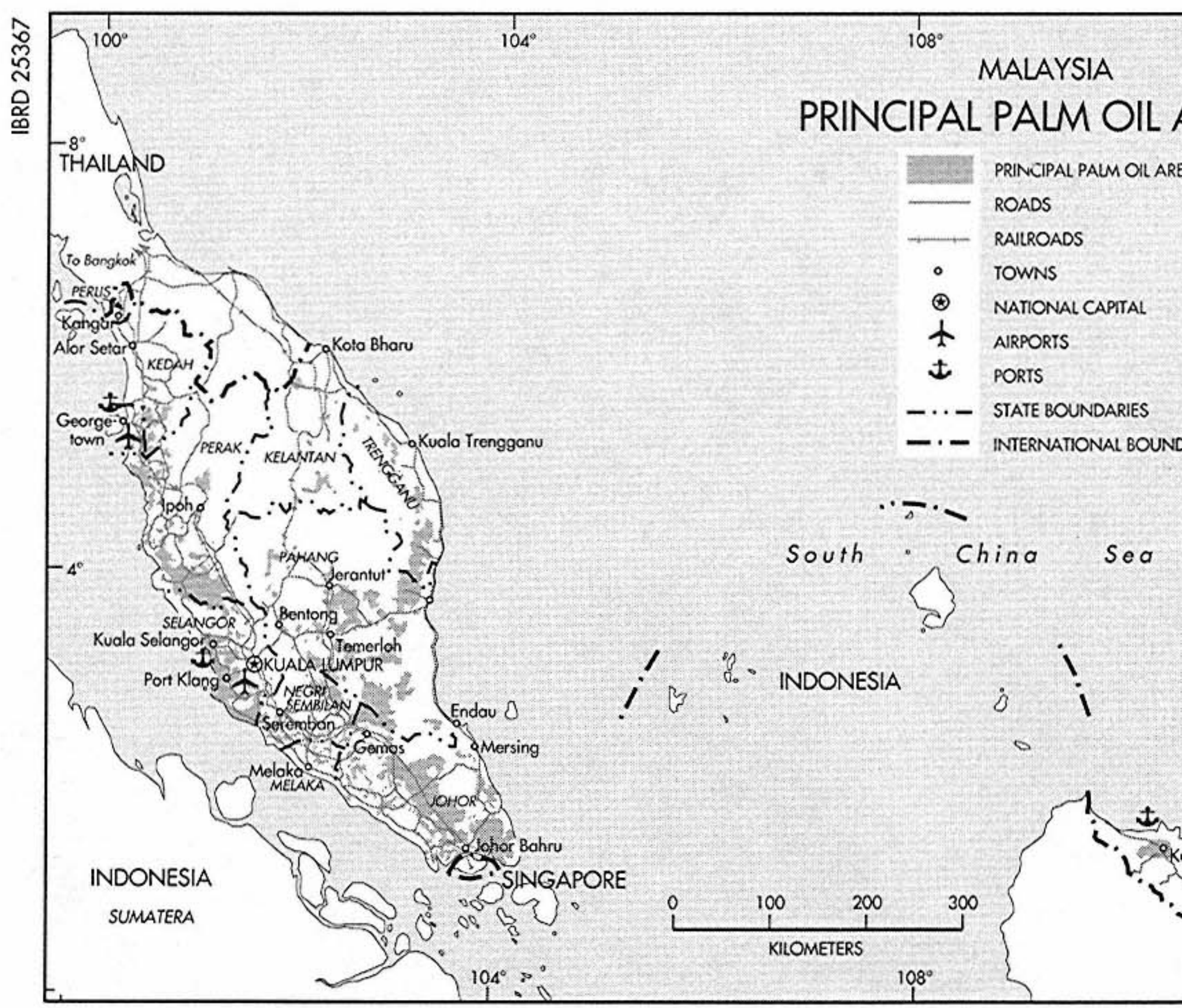
JANUARY 1994



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