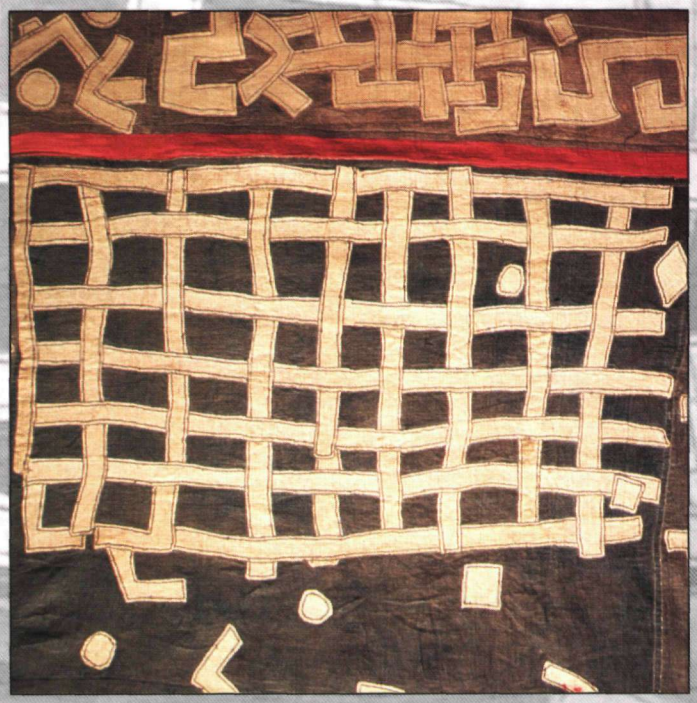
REPÈRES

Agricultural Research and Innovation in Tropical Africa

Pierre-Marie Bosc, Ellen Hanak Freud



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CIRAD SPAAR

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Table of contents

Preface

Over the past four years, SPAAR *(the Special Program for African Agricultural Research)* has launched and closely followed an in-depth review of the organization and programming of agricultural research activities in Africa. This review, and the activities generated by it, have focused on research at both the national and international levels. The first initiatives took place in the subregions of Southern Africa and the Sahel.

This book is the result of a study undertaken as a contribution to the review of research in the humid and subhumid zones of West and Central Africa. The review process concluded with an overall framework for action for the revitalization of research in this region.

By combining commodity and production system approaches, the authors propose an evaluation of the contributions of research to agricultural growth and development in the region, drawing on a large base of empirical studies conducted for this purpose. They question two widespread images of Africa, and of its agriculture and agricultural research in particular.

One conclusion is that this region of Africa has been the site of strong dynamics in agricultural growth over the past three decades. An analysis of the data concerning production and local markets contradicts the widely held assumption that Africa is incapable of feeding its own people. Despite the doomsayers, the expected collapse has not occurred, and to a certain extent production has kept pace with demographic growth.

A second conclusion, again contradicting the conventional wisdom, is that agricultural research has played a significant role in this growth process, both in the traditional and modern sectors. Many of the remaining challenges must be met by the principal actors – the farming communities of the region.

These producers have already proven their strong capacity for innovation each time that the institutional and economic structures and the instruments of technological progress have been appropriate. The position and role of agricultural research should be seen and evaluated as an instrument of assistance indispensable to this transformation.

My work with SPAAR has shown that, putting aside the institutional questions, the national and international research systems have skills that are invaluable if research is to fulfill its central role. The hope of SPAAR is to contribute, however modestly, to the synergism of these skills for the benefit of a research system highly responsive to the technical and socio-economic needs of the producers.

Moctar Toure
Executive Secretary of SPAAR

Introduction

The economic recovery predicted by the World Bank[1] for sub-Saharan Africa will depend, among many other measures, on the intelligent mobilization of research in the service of agriculture, which remains the surest resource for overall development. *Agricultural Research and Innovation in Tropical Africa,* written by Ellen Hanak Freud and Pierre-Marie Bosc, thus arrives at a most auspicious moment. The book provides a much needed focus on the state of research today – its potential and the challenges facing it – and on the modalities existing to effectively implement necessary changes. This work is all the more important in that it is the result of a long and fruitful collaboration with many persons, inspired by SPAAR *(Special Program for African Agricultural Research),* and may thus be seen as a key element in an action plan that can be consulted by the decision-makers of the countries concerned.

Yet, in the aftermath of the profound crisis in the world markets and the severe economic adjustments that have followed, two major elements must be taken into account in order to make the best use of research: the consequences of urbanization and the changing role of the state.

Urbanization and the concentration of a constantly growing population in the coastal zones of sub-Saharan Africa, in West and Central Africa in particular, are without doubt among the most important events of the century in this part of the world. Yet, paradoxically, until now several factors have combined to hinder the rapid transformation of agriculture in the region. These include the availability of unused farmlands, which have high output potential when newly cleared,[2] the low revenues from a fledgling industrial sector, thin urban markets, and the easy access by ports to the cheap (subsidized) foodstuffs arising from the structural surpluses of developed countries' agriculture. The transformation is nonetheless underway, giving rise to a richly diversified and productive agriculture that is at times replacing the traditional export-oriented model. Research must give priority to this emerging agriculture, both to raise its productivity and to enable it to better respond to the requirements of urban markets. This inevitable transformation would be better understood today if we had access to relevant statistical information for tracking agricultural output and yields and, in particular, if we could determine the magnitude and evolution of the role of commercialization in food crop production.

1. In *Le Monde,* April 20, 1995. The growth rate announced for the next five years for sub-Saharan Africa is 3.8% per annum, compared to 3.3% for the world as a whole, and higher than for all other developing regions, with the exception of Asia.

2. It should be recalled that the average yields on newly cleared lands using traditional techniques are approximately the same in this region as those in France in the 1950s, both for tubers (5 to 10 tons per hectare) and cereals (1 to 2 tons per hectare).

In effect, a common characteristic of countries witnessing significant growth and development is the rapid rise in the share of agricultural output destined for the market. A precondition for adapting agricultural research to the needs of the evolving domestic market is thus the updating and adaptation of agricultural statistics.

It is, however, without doubt the transformation in the role of the state vis-à-vis the economy – that is, its withdrawal and the implementation of policies of liberalization and privatization – which requires the most attention in order to understand the consequences for the success of agricultural research. Indeed, experience in both developed and developing countries has shown that research can be highly effective in the service of well-organized production, at the level of a product, a sector, or the national economy.

In Africa, the withdrawal of the state as a direct actor in the principal agricultural export subsectors marks the end of what has been known as state capitalism. Privatization has already begun to submit these commodity systems to the sole criterion of international competitiveness. Yet their modes of organization, characterized by a high degree of vertical integration, are not likely to change much. Research will have an important role to play in improving their competitiveness, and will need to adapt in order to take into account the acceleration of internationalization.

What, then, will be the role of public sector national research? National governments, though no longer direct economic actors in the commodity systems, still remain the most legitimate of partners. They will need to maintain the means to negotiate necessary compromises, and to impose, if necessary, measures to ensure the best distribution of profits along the commodity chains – profits being, of course, the gauge of their efficiency. They will also need to impose the measures deemed necessary to ensure that the commodity systems contribute to overall development. Governments must also continue to provide certain services. Among them, a redefinition of the role and objectives of research clearly seems warranted.

In any foreseeable circumstances, public sector research will continue to be the principal, if not sole, vehicle for assisting agriculture's adaptation to the requirements of the domestic market or, in other words, for raising the productivity of the agricultural labor force, which continues to decline in relation to the growing number of mouths to feed. In contrast to the situation of export-bound products, there exist today no organizations strong enough or sufficiently well organized to argue convincingly for the needs of research in this area. In the meantime, it will be necessary to provide dynamic and competent public services, acting on well-defined policies, and attentive to the preoccupations of consumers, producers and their intermediaries.

Privatization imposes an additional burden of organization, service and competence for the vigorous development of a market economy. Research

alone, as competent and well organized as it may be, cannot ensure a green revolution. Indeed, it must be said – and said again – that the now-legendary green revolutions in Asia were the result above all of the application of clearly defined agricultural policies, implemented, at times, against the advice of international experts. This was possible in great part because of the existence and support of highly developed agricultural administrations. The sub-Saharan countries today have an impressive number of highly qualified engineers and other agricultural specialists. It is thus possible for these countries to put into place effective administrations, a precondition for successful research.

Appropriate statistics based on a solid understanding of the transformations underway in agriculture, unambiguous agricultural policies, and well-functioning administrations are therefore all necessary if research is to be effective. In this context, research itself must acquire an operational strategy grounded in the knowledge of two particular aspects of African agricultural development: the determinants of geographical concentration and the nature of agricultural intensification required.

The geographical patterns of agricultural output result from three complementary phenomena, which combine in various ways to result in the distribution observed in a given country, at a given period. The first is the progressive colonization of lands by a population searching to feed itself. This is the dimension of history, constantly changing with the development of new techniques and infrastructure. The second phenomenon results from the development of production for exportation and depends directly on the available lands and labor migration policies. These latter are often decisive in the acceleration and intensification of production. The geographical concentration of a labor force that accompanies these export-led dynamics, as long, as is often the case, as it is available in the favorable periods for foodcrop production, can lead to the formation of veritable zones of potential surplus production. Numerous examples show how these zones have been able to respond within a short time to a rapid growth in demand. The third phenomenon determining production zones results directly from the increase in demand from the urban markets. This appears most strikingly for new products: production develops as close as possible to consumption centers or along transport routes. Taking into account these phenomena, and the types of farmers and products which correspond to each case, is essential to orient research efforts. The priority must always be given to situations which enable agriculture to respond to market demand.

To be effective, research needs to approach the objective of intensification with a great deal of discernment. Yield maximization continues to be the only criterion of a great number of agricultural scientists. Here we have a magnificent example of the transfer of this single criterion of productivity increases, justified by the state of European agriculture (and more generally of situations where agricultural land is limited), in the period prior to the

accumulation of surpluses under the Common Agricultural Policy.[3] In Africa, in the majority of cases, it is rather the labor force and capital that are limited; it is thus in terms of improvements in the productivity of these two scarce factors that priority must be given. Beyond the short and medium term, however, it seems realistic to expect that increases in the production per hectare of accessible agricultural land will be inevitable.

Indeed, available indicators of production systems within the Region suggest that the process of intensification, accompanied by a tendency toward sedentarization, is almost everywhere underway. Instead of juxtaposing a high-performance intensive system – only mastered on the research station – and a poorly understood extensive system, often caricatured, it may be wiser for agricultural research to develop the means to observe, describe, and understand the mechanisms of intensification and sedentarization that are actually underway, including their impact on the environment. These evolutions are at times quite slow, but they are often more rapid where commercial production is developing. In any event, science-based improvements adapted to local settings have the best chances of success. The veritable revolution in European agriculture in the last half-century bears witness to this. So, too, do the examples of green revolution in the agriculture of the developing world.

Jean Chataigner
INRA, France

3. In the wake of recent reforms, the Common Agricultural Policy is now intended to encourage more land-extensive practices. The methods to achieve this are still far from clear, so much has the paradigm of intensification dominated agricultural sciences.

Authors' note

This book is the outcome of a study undertaken for the regional initiative on the revitalization of agricultural research in the humid and subhumid zones of West and Central Africa under the auspices of the Special Program for African Agricultural Research (SPAAR) and the Conference of Ministers of Agriculture of West and Central Africa. The research was jointly financed by CIRAD, the French Ministry of Cooperation, and the SPAAR secretariat.

In the context of this initiative, the Region has been defined to include the following fifteen countries: Guinea, Liberia, Sierra Leone, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Central African Republic, Congo, Gabon, Zaire, and Sao Tome; throughout the text, the proper noun "Region" is used to refer to this grouping.

The objective of the study was to provide a synthesis of the challenges for technology development and transfer in the Region, related to the constraints operating within the farming systems and the various crop subsectors, or commodity systems (filières). To do so, we drew from a wide range of technical and socioeconomic literature, complemented by interviews with researchers and persons involved in technology transfer activities within the Region. An initial document entitled *Economic and Technical Factors Influencing Regional Research Priorities in the Humid and Subhumid Zones of West and Central Africa* was issued in October 1993 and submitted for review to a large number of researchers, whose remarks have enabled us to make substantial improvements.

We are grateful to the many persons who have helped us in conducting this research. In particular, we thank the directors and staff of the agricultural research systems in Nigeria and Ghana who met with us during a brief fact-finding mission to these countries, and the numerous researchers at CIRAD and IITA (International Institute of Tropical Agriculture) who granted us interviews. A special thanks is due to Ms. Antonia Obeya of the SPAAR secretariat, who accompanied us on the visit to Nigeria, and to the resident missions of the World Bank, who organized our visit to the two countries. For guidance and suggestions on the overall conduct of the study, we thank Mr. Moctar Toure, executive secretary of SPAAR, and the members of the SPAAR Regional Task Force for the initiative, Messrs. Ajibola Taylor, Bakary Ouayogode, Yunusa Yusuf, Gerard Boukambou, and Mohammed Danihya.

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Responsibility for the interpretations, and for any errors or omissions that may remain, rests entirely with the authors. The views expressed herein do not necessarily represent those of either SPAAR, CIRAD or the Ministry of Cooperation.

Résumé

Recherche agricole et innovation en Afrique tropicale propose une réflexion sur les apports de la recherche agricole au développement en Afrique de l'Ouest et du Centre. Contrairement à nombre d'idées reçues, cette région a été le lieu de plusieurs dynamiques successives de croissance agricole, dans lesquelles la recherche a joué un rôle déterminant. Cependant, en dehors des plantations agro-industrielles, l'adoption globale des propositions d'innovation de la recherche agricole reste un phénomène rare. Les processus d'innovation observés traduisent au contraire des phénomènes d'adoption non conformes aux prévisions de la recherche, mais qui mettent en évidence les lignes de force des contraintes auxquelles doivent faire face les petits producteurs : déficit en force de travail, accès limité au capital et combinaison des risques économique et agricole. Durant ces phases de croissance, les politiques économiques ont présenté des configurations incitatives contrastées d'un pays à l'autre, avec notamment des niveaux très variables d'intervention étatique. Au-delà des différences contextuelles, la sécurisation des rémunérations des producteurs en aval et l'assurance en amont de la disponibilité en intrants et en matériel végétal amélioré constituent les constantes de ces configurations incitatives. Reste que ces agricultures tropicales doivent faire face à des défis auxquels elles ne peuvent espérer répondre sans un effort important des systèmes de recherche nationaux et internationaux. Au premier rang de ces défis se situent ceux de la compétitivité des productions africaines sur les marchés internationaux et nationaux, dans un cadre où devront être mieux pris en compte la durabilité des systèmes de production et les contraintes agroéconomiques des producteurs.

N.B. Une version française de l'ouvrage est disponible dans la même collection.

Objectives, Approach and Scope

The Economic Challenges for Agricultural Research

The ultimate goal of agricultural research is to foster economic growth. Conventionally, research's role has been considered to be productivity enhancement: to promote technical change either by enabling farmers to lower their unit costs of production or processing and/or by making techniques available that add value to their output, such as quality improvements. The first is the classic case of "shifting the supply curve downward"; the second is sometimes thought of as "stimulating demand." More recently, an additional research mission, to promote environmentally sustainable technologies, has been increasingly emphasized in light of concerns that some common agricultural practices may be undermining longer-run growth and development prospects.

These broad research goals are applicable to any economy – be it high- or low-income, resource-rich or resource-poor. Yet the magnitude and orientation of the task before agricultural research depends in great measure on the specific development challenges facing individual countries or regions. This depends in part on objective factors: the quality and composition of the resource base, and the options for growth and employment in sectors other

than agriculture, both of which are anchored in the context of international market conditions. And, it depends in part on policy goals for agriculture that may seek to transcend these conditions, such as providing food security, preventing the erosion of farm incomes, or preserving the natural environment. These factors jointly influence the economy's agricultural research priorities, not only in terms of commodity focus, but also in terms of the types of productivity enhancements most needed: yield-augmenting, yield-stabilizing, labor-saving, soil fertility-conserving, on-farm or post-harvest, and so on.

For the humid and subhumid zones of West and Central Africa – a vast area of fifteen countries[1] that extends along the coast from Guinea to Gabon, and inland as far as the Central African Republic and Zaire – the agricultural sector is a major source of employment and domestic food requirements. It is also a major source of export earnings in all but those few countries with important mineral wealth (Gabon, Congo, Nigeria, Zaire and Cameroon).

As elsewhere on the continent, the countries of these agroecological zones have been experiencing severe overall economic difficulties, and stagnating or declining per capita incomes, for at least a decade. While the crisis has most often been triggered by debt repayment obligations and adverse shocks to the terms of trade, it is clear that the underlying economic performance of the countries without major mineral wealth over the three decades since independence has been closely linked to the performance of the agricultural sector. The wealth of Côte d'Ivoire, which experienced exceptional agricultural performance both in terms of overall output growth and introduction of new commodities, stands in contrast to the lack of substantial growth of the economies where agriculture has made little progress since independence, such as the Central African Republic, Guinea and Ghana. Overall, agricultural growth in the Region has been insufficient to substantially raise per capita incomes. Although food production per farmer appears to have risen over time, this has not kept pace with the growth of the nonagricultural population, and food imports have increased. In the industrial/export crops, many countries in the Region have seen their shares in world markets diminish.

Even mineral exporters like Nigeria need to rely on the agricultural sector as they move out of the crisis and regenerate a broad-based development process. The economic challenge for agriculture is multifold: to feed rapidly growing populations, generate foreign exchange, and foster growth in per capita income through the creation of direct and indirect employment opportunities. This challenge is heightened in relation to the past. It comes at a time of increased concerns about the deterioration of the natural resource base under current agricultural practices, and at a time when profitability in most of

1. Guinea, Liberia, Sierra Leone, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Central African Republic, Congo, Gabon, Zaire, and Sao Tome. Throughout the text, the proper noun "Region" is used to refer to this grouping.

the Region's tradeable commodities has been undermined by a protracted period of low international prices, a phenomenon due not only to the worldwide recession, but also in large measure to increased competition from producers in Asia and Latin America. The recent rise in world prices since late 1993 has improved the Region's room for maneuver for a number of products, but African commodity subsectors remain on the whole more fragile than their counterparts elsewhere when facing prospects of the next downturn.

How can the agricultural research system help the countries of the Region to meet this complex challenge? Technical progress in agriculture will be essential to the sustainable development of the sector over the years to come. Yet bold actions will be needed to enable the research system to meet the challenge. Under the current economic crisis conditions, the most apparent dimension of the problem is the system's very ability to conduct research. Financial distress permeates large parts of the system, with dire consequences for the productivity of researchers. This budgetary crisis has helped expose other obstacles to researchers' productivity that are more institutional in nature: incentive structures that do not sufficiently reward dynamic researchers and lack of effective linkages within the scientific community, leading to isolation, lack of "critical mass", duplication of efforts, and so forth. These financial and institutional obstacles to the effective conduct of research have been the subject of regional initiatives on revitalizing agricultural research throughout the continent (SPURLING *et al.*, 1992; WEIJENBERG *et al.*, 1993; CMAWCA and SPAAR, 1994). Creative solutions are needed that tackle them jointly.

The focus of this study is on a set of concerns that may be less apparent, under the current crisis conditions, but just as essential to the ability of the research system to provide the results that are needed to transform the Region's agriculture: the setting of research priorities in line with the needs of the economy. The orientation of research activities, both with respect to commodity focus and to the types of productivity changes aimed for, has increasingly come into question. In part, this stems from the low adoption rates for many of the research results that the system has produced over the past decades – especially those varieties and techniques that substantially augment yields and intensify land use. While a case can be made that adoption is impeded by policy-related factors outside of the research orbit, such as low farmgate prices or poorly functioning marketing and input distribution infrastructure, it seems clear that part of the problem lies in the failure of research to sufficiently take into account the resource constraints that prevent farmers from making use of the results. It also stems from the perception that research has not found answers for some of the Region's most serious problems, such as soil fertility maintenance and productivity increases in some of the major food crops. Although the lack of solutions may reflect the intractability of the problems themselves, there is again reason to doubt that research has given them sufficient attention.

Approach and Scope

For agricultural research to have an important impact on the economy's development, it needs to gear its efforts toward relieving the most pressing technical constraints. What these constraints are will depend on the interdependence of the agroecological conditions of the Region with two interlocking systems: the farming system and the commodity system. By farming system, we refer to the entire range of resources, or factors of production – the natural resource base, labor and various types of capital inputs – which, combined at the farm level, enable the production of agricultural output in line with the economic and social objectives of the farm household. Since it lies directly within their technical competence, agricultural research scientists have most naturally focused on the characteristics of the first of these – climate (temperature, rainfall quantity and distribution), soil quality, and the presence of pests and diseases that determine growing conditions – without considering adequately the role of the other resources. Labor and capital constraints can have a decisive impact on the types of technology that farmers can and will use.

Recognition of this interdependency has been behind the emergence over the past fifteen years of "farming systems research". When applied to the agronomic, rather than socioeconomic, disciplines, this usually refers to adaptive research seeking solutions across combinations of crops and livestock that are raised by farmers, often in association. It is therefore important to emphasize that understanding the resource constraints of the farming systems can provide guidance for the full spectrum of agricultural research, ranging from basic genetic work to input trials on farmers' fields.[2]

Whether or not research can have an impact depends, as well, on the conditions in the wider economy in which producers operate. The level of prices for agricultural outputs and purchased inputs, and the reliability of both of these markets, are key determinants of the profitability of the activity for the farmer. These conditions depend, to some extent, on factors that are given: price movements in international commodity markets set limits on the output price; distance from marketing outlets and poor transportation infrastructure raise the costs of inputs and output marketing margins. But there are clearly areas where government intervention affects profitability: input and output price policy may be the most obvious channel, but "non-price" policies, such as investments in road networks, can be equally important.

2. For French-language literature in this area, see *Les Cahiers de la recherche-développement*. The journal of the Association for Farming Systems Research and Extension (AFSRE/E) *Journal for Farming Systems Research-Extension*, is the counterpart in the English language. See in particular the proceedings of the XII Symposium of the AFSRE/E, held in East Lansing, Michigan, in September 1992, and those of the Symposium on systems-oriented research, held in Montpellier, France, in November 1994.

A useful framework for analyzing this interdependence is that of commodity systems (in French, *filières*): the chain of successive activities from input delivery to the final sale of the output (in local or export markets), including production activities, transportation and, where relevant, primary processing. Information on the structure of costs across the successive activities in this chain, and on the market situation, can reveal the weak points within the system, where changes are needed to increase profitability.[3] For any given commodity, this provides perspective on the relative importance, first, of research versus other actions, such as cutting marketing margins, and second, of various research strategies: reducing production costs or the costs of processing, raising yields versus improving quality, and so on. By helping to identify the best opportunities, this analysis can also help in the decisions pertaining to the allocation of research resources among the various commodities. Too often, the research system has allocated resources without the benefit of this type of perspective.

We draw on these two frameworks to review the nature of agricultural growth in the Region and the contribution of agricultural research to that growth, and to raise issues we consider essential for the future orientations of agricultural research and the supporting policy environment.

Given the great diversity in the agriculture of this vast Region, it has been necessary to limit the focus of the analysis to the commodity systems that are of major economic interest at the regional level; other crops that may have a more local significance are mentioned in passing. By the same token, the treatment of issues relating to the farming systems is illustrative of major tendencies, and is by no means exhaustive. Livestock issues are dealt with only insofar as they relate to the cropping systems, in particular via animal traction and integration of livestock with crops.[4]

There is no perfect overlap between political and agroecological boundaries. Although we consider the Region's countries in their totality in the analysis of global issues such as production and consumption trends and the policy environment, we have used agroecological cut-off points in the discussion of specific issues related to agricultural technology development and transfer. Specifically, we have confined our focus to the two broad agroecological zones, humid and subhumid, described in some detail below, which cover the

3. In this area, the references in the French-language literature are relatively more abundant. *Filière* analysis has been a primary tool for the evaluation of development projects by the French Ministry of Cooperation and Development (Freud, 1988). Several methodological references are CHERVEL and LEGALL (1989), BRIDIER and MICHAÏLOF (1980), and DURUFLÉ *et al.* (1988). In the English-language literature, a commodity systems perspective has been accentuated by researchers at Michigan State University (SCHAFFER, 1973; BERNSTEN and STAATZ, 1993).

4. For specific treatment of livestock in these agroecological zones, see JABBAR (1993 and 1994), D'AQUINO *et al.* (1994) and LHOSTE *et al.* (1993).

majority of the agricultural areas of the countries in the Region. Some of the countries also have drier areas more similar in characteristic to the better-watered areas of the Sahel (northern Nigeria and Cameroon, eastern Central African Republic); issues specific to these areas will not be discussed here.[5] Nor will there be specific treatment of the conditions relating to the small number of high altitude areas within the humid zone (above 1,000 m around the equator, and above 700 m in the wider tropical zone to the north and west) situated in Cameroon, Nigeria and Zaire, where certain crops can be grown that cannot be found at the lower altitudes (arabica coffee, tea) and where agriculture is on the whole quite different. The characteristics of these zones are more germane to those of the high altitude regions of East Africa.

5. For an overview of the agricultural challenges in these zones, see the following synthesis documents: WEIJENBERG *et al.* (1993), BOSC *et al.* (1990), and BOSC *et al.* (1992-94), in particular vol. IV.

The Resource Base and the Dynamics of Agricultural Growth

Since the natural resource base is a primary determinant of the potential of agriculture, we begin with a brief review of its main characteristics, and the potentials and constraints that they impose for the development of the sector. Although these characteristics determine the quality of the land available for agricultural purposes, other elements of the resource base are key for whether and how this land is put to use: (i) demographic patterns, which play a dual role in determining the location of markets and the availability of labor resources for putting the natural resource base to use; and (ii) the state of the physical and communications infrastructure, which affects the degree of ease and the cost of transporting inputs and outputs from production to consumption zones. We next examine the status of these other elements briefly, before looking at the way they have interacted with the overall policy environment and international market conditions to determine the dynamics of agricultural growth.

Characteristics, Potential and Constraints of the Physical Environment

Altitude and Topography

Altitude is the key determinant of temperature variability in the wet tropics. Overall, the Region presents an essentially uniform agroecological context as concerns thermal conditions for growth and development of the main crops. Outside of a few highland areas, one does not find pronounced fluctuation in altitude, with the result that temperature variation is very slight and practically nonexistent around the equator. The high average annual temperatures and the absence of sharp drops in temperature are, on the whole, quite favorable to crop growth. These conditions do pose constraints for those crops whose cycle depends on a lower temperature, such as certain horticultural crops that need low temperatures for seed production.

Although relatively smooth, the Region's relief nevertheless structures the agrophysiological environment. Mildly sloping toposequences create a network of more or less dense zones of valley bottoms with particular hydric and agropedological characteristics. Despite some specific constraints, relating in particular to weed and parasite pressure and to land-use conflicts between farmers and livestock herders, these zones offer a high potential for the development of certain intensive farming practices, for crops such as rice and garden vegetables.

Rainfall

Rainfall appears as the key differentiating factor. Such criteria as whether there is one or two dry seasons, how long each lasts, and the intensity of the rains, are at least as important as the amount of water available. Between the north and the equatorial zone, the rainfall regimes pass from monomodal, in the 800-900 mm isohyet, to rainy regimes without dry seasons or where the dry season is very short and precipitation levels surpass, in some cases considerably, 2,000 mm, via a host of intermediate situations where, for instance, there may be two dry seasons of varying duration and intensity. Schematically, a distinction can be made between a humid zone and a subhumid zone as follows:[6] (See maps.)

6. This section draws on work by the Agro-ecological Studies Unit of the International Institute for Tropical Agriculture (IITA) and the working group on "The Future of the Humid Tropical Zones" of the French-based *Réseau recherche-développement* (especially LABROUSSE, 1993).

The Humid Zone

The humid zone is generally considered to encompass areas with over 2,000 mm of annual rainfall and a maximum dry season of no more than four months. It also includes regions with less precipitation where "dry" seasons receive an average monthly rainfall of 10 to 50 mm or where atmospheric humidity is high enough to offset the effects of the dry season. Within these two broad groupings, it is possible, by drawing on the work of Labrousse (1993), to identify subzones in application of the above-mentioned criteria: a vast zone with generally over 1,500 mm of rainfall, and a zone with relatively little rainfall (800 to 1,500-1,600 mm) and usually two dry seasons.

More than 1,500 mm of Rainfall

A vast zone with generally over 1,500 mm of rainfall corresponds, on the whole, to the "Lowland Warm Humid" zone according to IITA's classification. This can be broken down into three subzones, based on the characteristics of the dry season: a dry season of under two months, a pronounced two- to four-month dry season, and a long dry season that lasts about five months.

A dry season of under two months, or no dry season at all, is found in the Congo River Basin (Congo and Zaire) that extends to the Ogooué Basin in Gabon, along the Cameroonian coast, and in the delta of the River Niger in southern Nigeria. Crops can be grown all year long in such areas, but the moisture and cloud cover conditions can pose important constraints, in the first case for harvesting, since sun-drying is next to impossible, and in the second case for yields.

A pronounced two- to four-month dry season, with annual rainfall of between 1,500 and 2,500 mm, is found in certain regions of Congo, Gabon, Cameroon and Zaire complementary to the regions cited above, as well as in the southern regions of Liberia, Côte d'Ivoire, Ghana, Nigeria, and the Central African Republic. In this subzone, a distinction should be made between two situations related to the sequence of the dry season: those regions with a single dry season lasting three to four months, *e.g.*, the Guinean forest region; and those with two dry seasons whose relative importance can be clearly distinguished, one being called the "short dry season" (one to two months with possibly a little rainfall) and the other the "longer dry season" (two to three months with no rainfall). The distinction is important for the choice of crops that can be grown in each wet season. In the areas with the longer dry spell, short-cycle cereal crops may be necessary in the period preceding it. Roots and tubers, whose yields are less affected than the cereals by a several-month dry spell, generally provide more stability in such areas (Gigou, 1987).

The third subzone is characterized by a long dry season that lasts about five months, but with high precipitation. The isohyet may span from over 2,000 mm to 5,000 mm, as in parts of Guinea and Sierra Leone. In these areas, there

are generalized risks of hydric stress during the dry season, most critical for the young perennials.

800 to 1,600 mm of Rainfall

A zone with relatively little rainfall (800 to 1,500-1,600 mm) and usually two dry seasons of varying duration is found in the south of Togo and Benin, part of Côte d'Ivoire, certain regions in the south of Congo and the northwest of Zaire. In Congo, the shortest of the two dry seasons is sometimes considered to be "capricious" (SAUTTER, 1958) since there may be some slight, randomly distributed rain spells. Although the rainfall levels of these areas correspond to the areas in the subhumid classification, the bimodal distribution contributes to sufficient atmospheric humidity to permit the cultivation of some perennial crops normally requiring higher rainfall levels (particularly various palm trees). In the IITA classification, these areas fall under the "Moist Savanna Zone".

Crop Aptitudes Related to the Rainfall Regimes

The high moisture conditions of the humid zone facilitated the development of the vast tropical forests, and likewise permit the cultivation of a number of perennial tree crops: cocoa, robusta coffee, oil palm, coconut palm, and rubber. As concerns food crops, the conditions similarly favor the cultivation of roots and tubers (cassava, yams, cocoyam, sweet potato), plantains, fruits (sweet banana, pineapple, avocado), and a variety of local vegetables, especially leafy varieties.

The moisture conditions are favorable for various types of rice cultivation in many parts of this zone, ranging from mangrove swamp rice along some coastal areas to valley bottom and upland rice further inland. This is notably the case in the western areas, such as Sierra Leone, Liberia, and Côte d'Ivoire, where rice is a traditional staple. Cultivation of cereals such as maize, which have high light requirements, is more circumscribed: although the high and relatively reliable moisture conditions are favorable, in some cases permitting double or triple cropping cycles within the year, the thick cloud cover screens sunlight necessary for optimal crop development during the dry season in many areas. Too much rain can similarly be a constraint if it falls during the flowering period, another limiting factor for maize in this zone. On the whole, the rains in this Region are accompanied by relatively mild winds, posing less threat of crop damage than in parts of Southeast Asia and some other tropical zones subject to monsoon weather.

The lengthier dry seasons pose constraints to the optimal development of perennials, which are highly sensitive to hydric stress at the nursery stage. This appears to be a particular problem in the "boundary" areas of the zone, which some observers argue have been expanding southward toward the equator as agriculture has replaced forest cover (whence their designation in some classifications as "derived savanna" zones).[7]

The subhumid zone

The subhumid zone, as considered here, corresponds more or less to the "Lowland Sub-Humid" zone in the IITA classification and comprises the zones generally known as the "Guinean Savanna" and "South Sudanian Savanna."[8] Whereas the entire humid zone lies within the fifteen countries of the Region under study, a number of adjacent countries contain areas that would fall into the subhumid classification (the southern areas of Mali, Chad, Burkina Faso and Guinea Bissau). This factor could be important to consider when embarking on multi-country research initiatives; in some cases collaboration with these "Sahelian" countries could prove fruitful.

This zone also has particular conditions as concerns total rainfall and the distribution of the dry spells. A sketchy distinction can be made between the northern zones, where rainfall varies between 800 and 1,200 mm and the dry season lasts from five to six months, and the more southerly zones, with 1200 to 1,500 mm rainfall and two pronounced rainy seasons separated by a period of very low rainfall. In between these two extremes there is a large range of variation, with weather events that are more or less intense. In the center of Côte d'Ivoire, for instance, the first rainy season and the first dry season become gradually more pronounced as one moves westward into an area with a monomodal rainfall pattern. Further to the south, on the other hand, the first rainy season and the first dry season are more pronounced and the rainfall pattern tends to become more decidedly bimodal. The risks associated with rainfall variability increase as one moves from the higher to lower rainfall areas within this zone, although even at its dryer limits, rainfall conditions are considerably more reliable than in the semi-arid zones to the north. At the same time, dryness has its own advantages in terms of plant protection, since the longer dry seasons are a natural aid in the fight against various pests. Post-harvest treatments and storage are also easier to accomplish, and exact lower losses, in the dryer areas of the zone.

Crop Aptitudes Related to the Rainfall Regimes

In the subhumid zone, growing conditions are good not only for roots and tubers, but also for a large variety of cereal crops (maize and sorghum, in addition to upland rice) and legumes (cowpeas, groundnuts). The rainfall conditions generally preclude the cultivation of the perennials traditionally found in the humid zone, except for oil palm in low-lying areas. This limits the range of industrial crops mainly to cotton, with sugar and soybean as minor crops facing marketing problems. This zone is also favorable to some fruit

7. The problem in the eastern cocoa-growing areas of Côte d'Ivoire is noted by Ruf *et al.* (1992); this issue was similarly cited by officials of the Cocoa Research Institute of Ghana (CRIG) for the neighboring area of Brong-Ahafo.

8. The «Moist Savanna Zone» of IITA also includes the wooded savanna and the coastal zones of Eastern and Southern Africa.

trees, notably mangoes. Vegetables such as onions and tomatoes can do well in this zone if cultivated in valley bottoms or with irrigation; in the humid zone, they suffer from many more pest problems.

In West Africa in particular, the last twenty years have been marked by profound climatic changes, about which it is difficult to make definitive assessments. Although these phenomena have been studied in depth for the arid and semi-arid zones (ESPACE, 1987 and 1988), isolated observations concerning the humid and subhumid zones (such as CLEAVER and SCHREIBER, 1992) underscore the need for a systematic study of climatic risks at the Regional level and the implications thereof for agricultural research, including methods of crop management and adaptations of cropping systems, the better to cope with rainfall uncertainty (FOREST *et al.*, 1991; REYNIERS and FOREST, 1989).

The Soils

The Region's soil resources cannot be assessed independently of rainfall. The main soil types are ferralitic in the equatorial zones where there is no dry season and ferruginous in the subhumid zones. Between the two there are intermediary profiles whose evolution depends on rainfall patterns, the canopy cover, and land-use practices.

In the humid zones, where the ultimate stage of pedologic evolution is evidenced by ferralitic soils, rainfall intensity and abundance have caused primary materials to be seriously weathered, and many of the nutrients to be leached away. These biochemical phenomena explain the character of the base-exchange complex: poor capacity to fix nutrient substances because of very limited exchange capacities, along with problems of acidity and high rates of exchangeable alumina.

The ferruginous soils covering much of the subhumid zone are clay-sand to clay-kaolinite type soils of widely varying thickness, depending on the topographic position, the presence or absence of hardpan, and the type of bedrock. The relief is often undulating with generally gentle graded glacis that connect to summits with hardpan mounds and, at the bottom of the slope and in valley bottoms, hydromorphic clay soils. Soil fertility here is affected by the tendency for the structure of the surface horizon to break down and the soil profile to be saturated during the rainy season and compacted during the dry season. Since the degree of soil damage caused by rainfall is highly correlated with its level, the conditions of this zone become more acute and more closely approximate the problems of the humid zone as one moves from north to south towards the equator.

Because these natural handicaps of soil quality in both zones can be compounded quickly when the land is put to agricultural uses, it is fair to say

that soil fertility maintenance and improvement is the Region's predominant agroecological constraint.

Soil Fertility Maintenance in the Subhumid Zone

The problem has been examined at some depth for the subhumid zone, for which a synthesis of results from long-term research experiments now exists (Piéri, 1992). The process of degradation is therefore now well-understood. Cultivation causes the soil surface to suffer serious loss of organic matter, which makes the soil structure fragile, causing pulverulence, crusting, runoff, and topsoil erosion. Although the role of chemical degradation in the reversal of the soil's productive potential should not be underestimated, weed invasion and acidification of the growing layers are the two primary factors at play. On cleared forestlands, yield levels diminish somewhat for 2 to 4 years, then level off for 7 to 8 years before declining sharply after 10 to 15 years of cultivation. On cleared grasslands, the first negative trend seems to be avoided but, after a 3- to 6-year period of stability, the yields drop off.

The synthesis study confirms the often-made observation that farming methods based on long periods of fallow followed by short periods of cultivation can maintain soil fertility at moderate degrees of crop intensification. The fallow favors the development of two fertility-restoring effects in what one might consider the "live" phase of the soil: rooting, which spreads organic matter throughout the profile, facilitates water and gas circulation, and contributes to soil fixation; and biological activity of both the soil's fauna and its micro-organisms, which contribute respectively to humification and mineralization of the soil. But the land requirements of such a system are high: the land held in reserve must be three to four times greater than the land being cropped at any given time. In areas with greater land pressure, the fallowing period becomes too short for this method to be effective, and other systems of fertility reconstitution have to be considered.

In policy discussions of this issue, the focus tends to be on the need to augment the quantity of inorganic fertilizers, presently in very low use in these production systems if compared with agriculture elsewhere in the world. For many crops grown in this zone, ample evidence exists to show that mineral fertilizers can augment the productivity of the soils, thereby enabling substantial yield increases. To wit, agricultural research has formulated reference standards for all of West Africa that provide data on the best quantities, forms, application methods and mineral balances on a crop-by-crop basis. Yet although they may need to be a key component of high-yielding agriculture in this zone, mineral fertilizers alone will not solve the problem of long-term soil fertility decline. If used exclusively, they contribute to acidification of the soils, regardless of the method of soil preparation employed (manual, mechanized, or mixed). For instance, drops in fertility levels in mineral fertilizer-based monocropped systems using cotton-cereals rotations

have been shown to require rapidly increasing amounts of fertilizer applications (by a factor of 4 or 5!) to maintain stable yields (HIEN *et al.*, 1984).

Alkaline amendments present a technical solution to the acidification problem, but one which is costly to implement, and which does not compensate for another dimension of fertility loss under mineral fertilizer use: the loss of organic matter. Organic fertilizers of plant or animal origin exhibit greater restorative properties, and as such represent an important complement to mineral fertilizers. The practices can include cultivation of leguminous crops, recycling of plant residues into the soils, and spreading of manure. Although they do not necessarily require purchased inputs (manure is in fact often sold), these practices are not without costs in terms of both farming time, which can be high in some of the plant associations[9], and transport costs to bring manure to fields (BERGER *et al.*, 1987; BERGER, 1991; CÉSAR and COULIBALY, 1991; LANDAIS *et al.*, 1991).

On the basis of these combined practices, the synthesis study concludes that soil fertility can be maintained in the savanna zones. Given obstacles to implementation of these practices, there remain considerable research challenges to finding suitable techniques to propose to farmers.

SOIL FERTILITY MAINTENANCE IN THE HUMID ZONE

Fertility issues in the humid zone have not benefited from a comparable synthesis on the nature of the problems and the scope for technical solutions. Certain elements of the diagnosis for the subhumid zones also apply here, in particular concerning the phenomena that cause degradation of cultivated soils. Cropping the land in the humid zones degrades the soil's structural properties and negatively impacts the water-holding capacity, causing crust formation, surface layer compacting and poor water infiltration. Mechanization apparently increases these phenomena, particularly because it requires much more radical land-clearing techniques than the traditional methods, which leave trees and stumps in place (LAL and OKIGBO, 1990; LEDUC, 1984). This problem is of course also relevant in the subhumid areas (PELTRE-WURTZ and STECK, 1991; FREUD *et al.*, 1991). As in the subhumid zone, mineral fertilizers alone are insufficient tools for fertility restoration.

The aggressiveness of the climate in this zone compounds the problems of fertility retention that are present in savanna areas. In particular, the forcefulness of the rains leads to serious erosion in annual crop systems. Certain practices seem to make the soil break down more quickly, in particular, sole cropping with short-cycle varieties, which leaves the soil exposed for longer periods. Perennial crops and forest trees therefore play a key role in this zone, as the cover they provide can go a long way toward

9. This is a particular problem in the alley cropping systems which associate leguminous trees and annual food crops, introduced by IITA (CGIAR-TAC, 1990; CARR, 1989).

preventing leaching. Many perennials contribute naturally to regeneration of the organic matter through residue deposits; they also enable the vertical transfer of fertility, by mobilizing and transporting upward by biological means the minerals from the deepest layers of the soil. But even perennial crops do not live forever, and there appear to be problems associated with direct replanting of perennials on old stands: higher incidence of weed and pest infestation, and higher mortality of seedlings, even in cases where the chemical nutrient base has not been seriously depleted. The problem may be most acute for cocoa (RUF, 1987 and 1992).

Fallowing of crop land can also restore fertility in this zone, but there is a debate on the length of an "adequate" fallow time: does it require the twenty or so years that it takes to reestablish a secondary forest, or are seven or so years of natural regrowth, often characterized by the presence of a weed known as *Chromolaena odorata* that improves the PH level, adequate? It is with reference to the former view that forestry researchers have developed recommendations to "speed up" the fertility reestablishment phase by the planting of nitrogen-fixing trees. Results indicate that this could cut the waiting time down to ten years (CIRAD, 1992*b*). The advantages of such a solution obviously need to be weighed against the costs to farmers of engaging in a tree planting exercise. Concerning the exploitation of shorter fallows with *C. odorata* (5 to 7 years), the question is how to manage the weed at the level of the farms' different cropping systems (*C. ODORATA* NEWSLETTER, 1994).

What combinations of inorganic and organic materials will enable fertility restoration in this zone? With what types of crop associations? These are some of the challenges to the research system for the future of agriculture in this zone.

Pests and Diseases

Susceptibility to pest and disease attacks is the other main environmental factor that affects the geographical distribution of agricultural potentials and constraints in the Region. In livestock, there is a widespread problem of *trypanosomiases,* which limits the ability to raise cattle; this constraint is extremely limiting in the more humid zones. In the subhumid areas, there is some scope for raising cattle based on trypano-tolerant species (*N'dama, Baoule*), and it appears in some areas (*e.g.*, Nigeria) that the zone of high morbidity may be being pushed back as more and more bushland is put under cultivation.[10]

For crops, many of the phytosanitary problems of the Region have a multi-country range: *striga*, a parasitic weed particularly damaging to cereal

10. This observation, made by researchers at the Nigerian Animal Production Research Institute, seems confirmed by some recent literature (JABBAR, 1993 and 1994).

cultivation in the savanna zones; cocoa swollen shoot virus disease, which is a menace to this crop in Ghana, and to a lesser extent Togo and Nigeria; *phytophtora megakarya*, a fungus causing serious yield loss in cocoa in Cameroon, Nigeria and Togo, which is now appearing in Ghana; leaf diseases in rubber in the Central African countries; black sigatoka in banana and plantain cultivation, in Central Africa and spreading to West Africa, and so on. Such diseases, pests and weeds often spread from one country to another within the Region. The multi-country nature of plant protection problems suggests that these will frequently be issues on which collaboration among national research systems could be highly beneficial.

Demographic and Infrastructural Resources

Market Accessibility

Despite the many variations in climatic and soil quality factors throughout this Region, there are sufficient overall similarities in the basic traits to merit its consideration on the basis of the two broad agroecological zones, humid and subhumid. If one were instead to use demographic characteristics as a dividing line, it is unlikely that the same boundaries would be retained. One finds within this Region both the most and least densely populated areas of sub-Saharan Africa.[11] All along the coast of the Gulf of Guinea, and further to the north in Nigeria, are located some of the largest cities of the continent, centers of commerce and important sources of demand for food products coming from the hinterland. In the western part of the coastal zone (Côte d'Ivoire, Ghana, and especially Nigeria), the countryside is also relatively densely populated, at least by African standards. It is in reference to these areas, with ten hectares of agricultural land or less per farmer, that one often hears the reflection that "there is no more forest in the forest zone". By contrast, the countryside of the forest zone in the Central African countries (Zaire, Congo, Gabon, the Central African Republic) has in places such low population concentrations – around 5 persons per km^2 or less – that systems of hunting and gathering remain economically viable alternatives to agriculture (YUNG, 1989; TSHIBAKA, 1989). Although population densities do not fall to these extremes in the savanna zones of most countries in the Region, the absence of large population centers limits the viability of selling agricultural produce, since the distances to the coastal areas impose high unit transportation costs.

Some countries, most notably Nigeria and Côte d'Ivoire, have managed to diminish such locational handicaps through the improvement of transportation

11. Appendix Tables 1 and 2 provide estimates of population densities and urbanization rates.

and communications networks over the years. The handicaps have been reinforced in others, such as Zaire, Guinea, and until recently Ghana, where the infrastructure has seriously deteriorated through lack of investment and maintenance. Most countries in the Region, including those with comparatively good networks, continue to have areas of high production potential that are virtually cut off from the market because of their remoteness. Although the policy discussions on this question have tended to focus on the need for more rural (*i.e.*, feeder) roads (RIVERSON *et al.*, 1991; GAVIRIA *et al.*, 1989), the problem often relates to the lack of good trunk and secondary road connections as well.

The Scope for Intensive Land Use

It is important to bear in mind the contrasts in population densities when considering the challenges facing the Region's agriculture. Whereas soil fertility may be the greatest agroecological constraint, the relatively low population densities in most parts of the Region have reduced the extent to which it has become a limiting factor for the development of the sector. Overall, although the Region has been experiencing rapid population growth since the 1950s, land has been plentiful, and farmers have been able to open up new areas for cultivation when fertility declines. The question on the horizon concerns the limits to this practice as the population continues to expand: at some point, the agricultural land-to-labor ratios will have declined enough that farmers will need to take measures to maintain fertility on the existing farmlands.

It is a matter for debate as to where the technical limits to opening up new areas for cultivation are, depending on how much land one judges should be left in its natural state. Some argue that the limit has already been reached, or indeed overstepped, in much of this Region as throughout the continent, because of the lack of governmental and social controls on the occupation of new lands (CLEAVER and SCHREIBER, 1992). Such assessments are difficult to verify by comprehensive statistics, since the national-level data on land use and land available for agriculture are notoriously poor. For what they are worth, these numbers (presented in Appendix Tables 3 and 4) suggest that most countries in the Region still contain vast uncultivated areas that could be suitable for agriculture. As little as 1-3 percent of the land in Gabon, Zaire, Congo and the Central African Republic was devoted to crops in 1991, and 12-16 percent in Benin, Togo, Cameroon, Côte d'Ivoire, and Ghana, all countries with relatively developed agricultural sectors. By contrast, in Nigeria 36 percent of the area was estimated to be under crops.[12] In all countries

12. This figure is subject to downward revision in light of the 1991 census results, which placed the total population near 90 million instead of the over 120 million projected from earlier censuses.

except Gabon and Nigeria, comparisons of these data over the decade 1980-90 suggest that land use per rural inhabitant has been on the decline (Figure 1). There are two competing interpretations of these statistics: either that land pressure has forced rural dwellers to reduce their per capita holdings; or that there has been a natural, if mild, intensification process associated with the development of the sector over the period.

One conclusion does seem clear: the point when fertility maintenance measures become an absolute necessity will come sooner in those areas where population densities are highest, as in the delta area of eastern Nigeria and the coffee/cocoa areas of western Cameroon and central Côte d'Ivoire, than in the sparsely populated areas of Congo, the Zairian Basin and Gabon.[13]

If land has not yet been registered as an overriding constraint in most of this Region, the corollary is that labor shortages have posed a major obstacle within the farming systems in all but the most densely populated areas. The typical family farm faces sharp seasonal labor constraints associated with key points in the agricultural calendar: planting, weeding, and harvesting. This is augmented by the fact that health conditions are typically the worst during the prime agricultural months, when food reserves are lowest and climatic conditions most favorable for vectors of various diseases.

The relative abundance of land, combined with the fact that land holdings are distributed widely across the population, has meant that there do not exist large local pools of low-cost agricultural laborers. To supplement family labor with substantial quantities of hired help, it is generally necessary to import labor into the area, from other regions or neighboring countries, where economic opportunities are more limited, and where the peak agricultural season falls at a different time. Farmers are typically only interested in hiring help for commercial crops that produce monetary revenue. Whether or not this has been an attractive option has depended, of course, on the profitability of the crops in question. It has also depended on government policy with respect to the labor market: countries that have encouraged labor movements, like Côte d'Ivoire, and like Nigeria before the oil price decline in the early 1980s, stand in contrast to countries that have prevented this, like Cameroon.

The labor constraints are augmented by the lack of capital resources available to most small farmers. In general, as in most other parts of Africa, farmers have few assets other than their land. This sharply limits their willingness to take risks, such as specialization in commercial agriculture and reliance on local markets for the purchase of food staples. It also limits their ability to pay for farm equipment and inputs that could increase the productivity of labor.

One area in which solutions need to be sought is in the organization of rural capital markets, so that farmers can get production credit at reasonable rates.

13. See Van der Pol (1990) for a case of environmental degradation in a cotton-growing area in the subhumid zone.

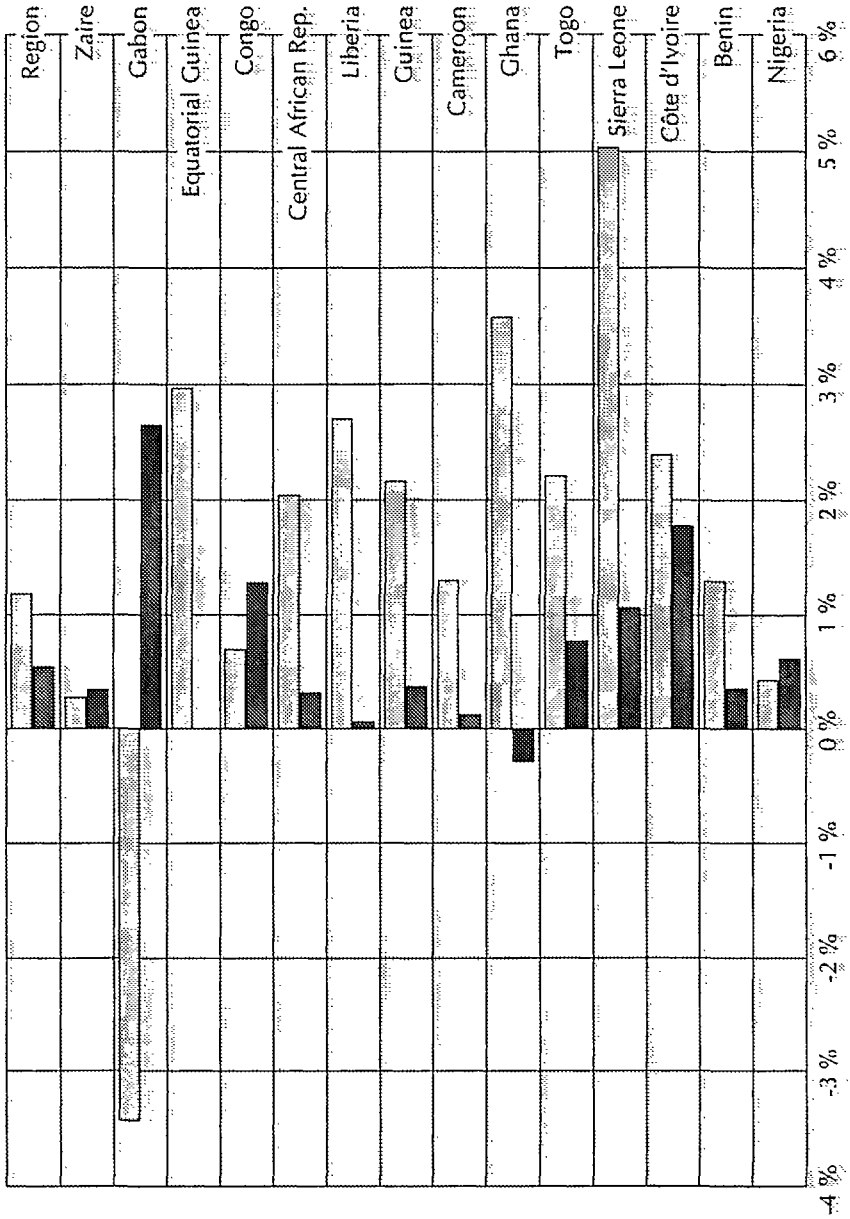


Figure 1. Evolution of cultivated area and rural population growth rates, 1980-1990.
rural population
cultivated area

To date, it has proven to be extremely difficult to find policy solutions to this problem. With the exception of the cotton projects in the franc zone countries, projects providing input credits have generally operated with very high costs, and have not been able to ensure sufficient repayment levels. As a result, the rural development banks have gone bankrupt almost everywhere, and agricultural credit has all but dried up. There remain formidable institutional challenges to the restructuring and building up of rural credit markets. Given the high costs of intermediation, unsubsidized agricultural credit typically is offered at real interest rates on the order of 20 percent per annum. At such rates, it is highly unlikely that farmers could find it profitable to borrow for most production-related activities.

Agricultural research is also directly concerned by the labor and capital constraints in smallholder agriculture. A greater array of solutions is needed to tackle problems of labor productivity, and in particular to relieve bottlenecks. Since access to credit is likely to remain limited, this implies the need for solutions that have low cash requirements.

The Dynamics of Agricultural Growth

A History of Successive Growth Dynamics

Over the past five decades, the Region has witnessed successive cycles of leadership in agricultural growth, until recently based essentially on booms in traditional export crops and on the exploitation of the tropical forest. Zaire, Nigeria, Ghana and Guinea all experienced rapid growth in the colonial period. As these countries began to experience problems in the decade after independence, the agricultural economies of several of the franc zone countries took off (especially Côte d'Ivoire, but also Cameroon, and a larger number of countries in cotton). Most recently, these latter countries have been experiencing difficulties – slow growth, stagnation, and even decline in output levels – while there has been a modest comeback in the industrial crop sectors of Ghana, Nigeria, and, from a small base, Guinea.

The net result of these shifting dynamics is an overall picture of industrial crop production in the Region that appears to have been fairly stable over the past twenty years. As one can see in Figure 2, the Food and Agriculture Organization (FAO) estimates of overall output of rubber, cocoa, and groundnuts have changed relatively little since 1970, cotton has grown substantially after an initial decline, and the only consistently upward trends have been witnessed in the produce of the two important palm trees, oil palm, and at a much smaller scale, coconut.[14] In almost every case, there has been

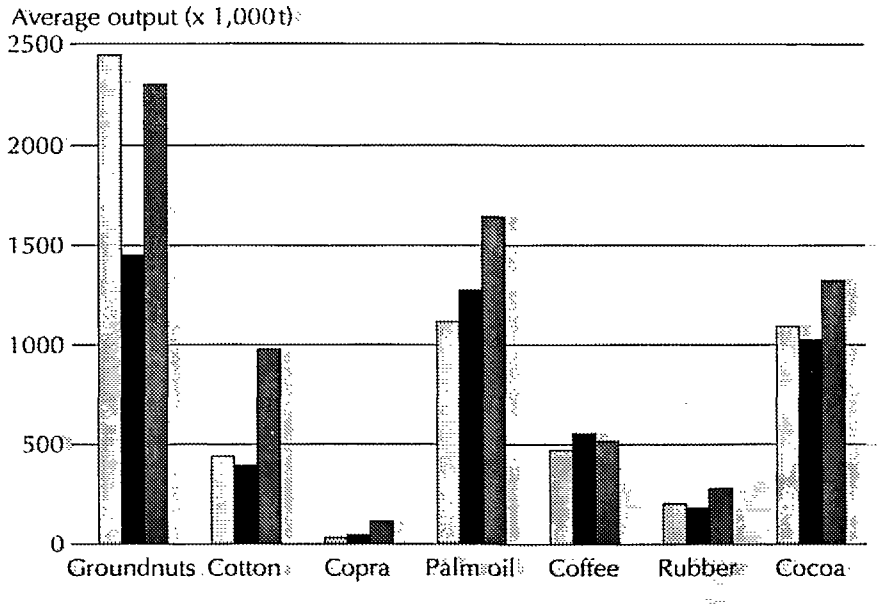


Figure 2. Evolution of industrial crop output.
1969-71 1979-81 1989-91

substantial displacement among countries in the overall totals (Appendix Table 6): Ghanaian and Nigerian cocoa have diminished while Ivorian cocoa has expanded dramatically, Liberian rubber has made way for that of Cameroon and Côte d'Ivoire, Ivorian palm oil has displaced that of Zaire. In cotton and groundnuts, Nigerian production took a major dip in the middle of this period, to be revived from the middle of the 1980s onward. In the meantime, Côte d'Ivoire, Benin, Togo, and Cameroon substantially increased their cotton output.

We highlight the distinction between the aggregate and the individual trends to challenge the conventional wisdom that loss of market shares for such products is a ubiquitous characteristic of African agricultural economies over this period. Industrial crop growth has been a major source of rural income

14. Since many of these crops are sold through formal channels, these output data are among the most reliable that exist concerning the agricultural sector. They are most questionable for groundnuts, and in some countries palm oil, both of which are characterized by a high degree of sale via "informal" channels for domestic uses, rather than for export or local industrial uses. For palm oil statistics, the Nigerian case is particularly difficult, owing to the vast areas of naturally-occurring palm, an unknown proportion of which is harvested. Some sources estimate that the oil boom generated a production decline much more pronounced than that indicated by the FAO data shown here (ISNAR, 1988; WORLD BANK, 1989*b*).

growth as well as an important contributor to the foreign exchange earnings of many countries in the Region. The oil crops are also an important component of the local food supply. If Nigerian exports of both palm oil and groundnuts have all but ceased, this is only partly linked to a decline in output; rapidly expanding local demand has simultaneously reoriented virtually all production to the domestic market.[15]

An assessment of the staple food crop situation in African countries is always fraught with difficulties, given the poor state of data collection for these items, large volumes of which are consumed by farmers or sold through informal channels. It nevertheless seems possible to make a rather positive assessment of the performance of the Region in this respect.[16] By the standards of the continent, the Region has always been relatively self-sufficient, thanks in part to the fairly stable growing conditions afforded by the rainfall regimes. Despite some growth in food imports for rice, and to a more limited extent wheat, meat and dairy products, the large towns of the coastal area provide an important source of demand for local foodstuffs. Dishes based on the root and tuber crops continue to dominate the diets in these areas, even though there is an increasing diversity in the foods urban people eat. For towns and cities in the savanna zone, as well as some of the coastal towns with dryer climates (Accra, and the south of Benin and Togo), the locally-grown coarse cereals (sorghum and maize) are popular. The only clear exceptions to the phenomenon of local supply are Gabon and Guinea, with towns highly dependent on imports for their staple foods.

Figures 3 and 4 provide FAO estimates of production of the major food crops of the Region between 1979-81 and 1989-91, on a per capita and per rural inhabitant basis, respectively. The data suggest that overall, per capita production has been rising somewhat over this period, and that there has been even stronger growth per farm dweller. The only exception is plantain, which registers a per capita decline, and sorghum, which remains at a constant level per capita. From the individual country data in Appendix Tables 8 and 9, one sees that these trends have not been uniform throughout the Region. The strongest performance is registered in Nigeria, for all the food crops. Although it is quite likely that these data overstate the actual performance,[17] it seems clear to many observers within the country that there has been a strong growth

15. Much of the market-oriented production of groundnuts in Nigeria, by far the largest producer in the Region, comes from the semi-arid zone. The decline of Nigerian exports is partly related to technical factors: the spread of the rosette virus, which took a toll on output, and the high incidence of aflatoxin, which limits access to the external market.

16. This section draws heavily from chapter 1 and the statistical appendix of BRICAS *et al.* (1992).

17. Production is not estimated independently of population for crops such as these, since a high proportion is assumed to be produced for subsistence. It is therefore likely that the production estimates will need to be revised downward in line with the downward revision of the census.

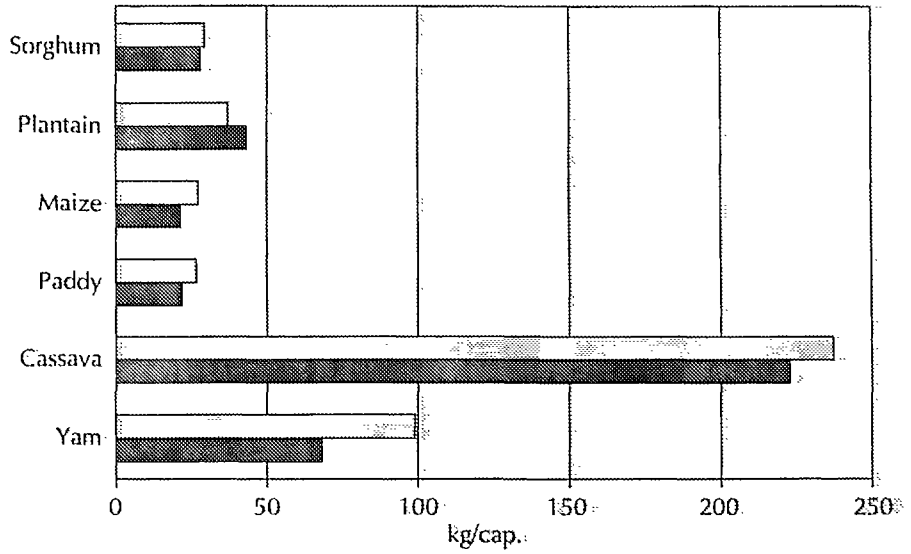


Figure 3. Food crop output per capita.
1979-81 1989-91

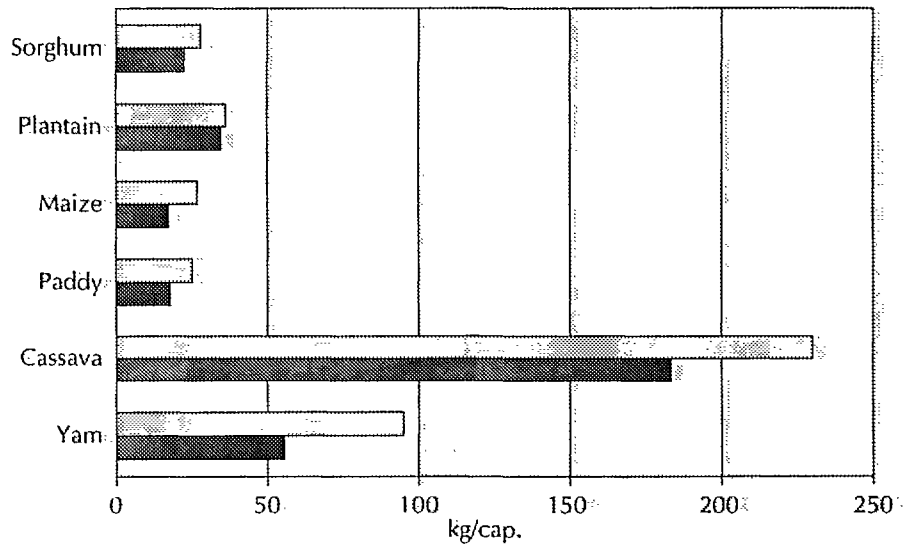


Figure 4. Food crop output per rural inhabitant.
1979-81 1989-91

dynamic in food production since the mid-1980s. At the other extreme, two countries register substantial declines in both cereals (predominantly rice) and the roots and tubers: Sierra Leone and Liberia. Recent political troubles are surely a factor in the latter country.

The majority of countries registered more moderate changes: among those with positive growth per capita in both the cereals and the root crops are Benin, Ghana, and Zaire. Overall per capita declines were registered in Cameroon and Guinea (on a per farm population basis, only in Guinea). To the extent that one can place confidence in these trends, they suggest that, on average, farmers in most countries in the Region are continuing to expand their output, in order not only to feed themselves, but to feed the growing urban populations.

Nevertheless, the overall per capita data suggest that the growth in many countries is not sufficient to keep up with urban population growth rates. If imports are not available to fill the gap – a problem in many countries because of the reduced incomes and foreign exchange constraints accompanying the economic crisis – per capita consumption will suffer. For what they are worth, FAO estimates of consumption profiles for 1987-89 showed only four countries (Côte d'Ivoire, Gabon, Cameroon and Liberia) with per capita calorie availability above 2400 calories per day, and three countries (Zaire, Sierra Leone, and the Central African Republic) with levels below 2100 calories per day (Appendix Table 10). These data suggest that the food situation remains fragile in the Region, despite the relatively favorable position of local production.

Conditions Favoring a Strong Growth Dynamic

Looking across the diversity of experiences in the Region over the past few decades, it seems possible to draw some general conclusions concerning the conditions favoring a strong growth dynamic in agriculture. A *sine qua non* has been favorable conditions of sale. Important have been both the level of producer prices and the ease of access to markets. To be convinced of the importance of the development and maintenance of transportation infrastructure, it suffices to contrast the experience of Côte d'Ivoire and Nigeria, countries having made substantial progress in this area, with Zaire, Guinea and the Central African Republic. For certain commodities requiring primary processing before sale (oil palm, rubber, cotton, coffee, rice, cassava), the development of processing capacity has been a precondition to growth in output.

The Special Constraints to a Growth Dynamic in Food Crops

For food crops, the expansion of production for the market has had to contend with two types of constraints related to favorable market access: the size of the urban markets (as measured both by the number of people and their ability to buy), and the heavy burden of transportation costs in moving foods from production areas to these markets. These constraints have limited the ability of food crops to replace the industrial crops as "cash crops." For although the town dwellers of the Region eat local foodstuffs, the urban markets are generally not large enough to accommodate rapid production increases. The experience of Ghana shows that the limits can be attained relatively quickly. In the early 1990s, a maize production boom associated with the Global 2000 project quickly flooded the market in Accra and other urban centers. The sale price dropped sharply, at which point farmers were unable to reimburse their input credit.

A few cities (Abidjan, Brazzaville, Douala) appear to have been able to support a strong growth in supply from the local agricultural base in recent years. But the Region's only truly vast market is Nigeria, whose urban population far surpasses that of the other countries (Appendix Table 5). The strong growth dynamic witnessed in Nigeria since the mid-1980s has been linked to satisfying this demand, which had come to rely heavily on imported foods in the decade of the oil boom. The Nigerian market is a potential gold mine for farmers in neighboring countries as well. In the early 1980s, before the restrictions on food imports were imposed by Nigerian authorities, many farmers in Benin, Togo, Niger and Cameroon specialized in production for the Nigerian market. Although this practice has not ceased, it appears to have diminished greatly once border restrictions were introduced. Nigeria's trade policies on foodstuffs are therefore critical for any trade initiatives designed to encourage greater regional integration.[18]

For some production areas, the market size constraint is compounded by the transport cost constraint. A good road network can help, but it does not work miracles. Transport costs still impose substantial obstacles to food crop marketing at long distance, and form an important barrier to hooking up the subhumid savanna zones with the urban markets in the coastal humid zone. Only in Nigeria has this link been well-established, under the combined conditions of good road networks and extremely low fuel costs.[19] In other

18. On the dynamics of regional trading patterns, predominantly an informal sector phenomenon, see EGG *et al.* (1993) and IGUÉ (1989).

19. In the spring of 1993, a liter of fuel in Nigeria cost approximately US$0.02, whereas in non-oil-producing countries such as Côte d'Ivoire and Ghana, who tax petroleum imports, the price could run up to a hundred times that value. Even after the recent increases in the Nigerian price, the gap remains large.

countries, the transport cost barrier has given a relative edge to farmers in the humid zone itself, permitting them to diversify their sources of cash income.[20] It has also meant that cotton is the mainstay of the cash income base in the savanna zones.

What Constitutes an Appropriate Policy Environment for Stimulating Agricultural Growth?

There is a tendency in current policy discussions to take a monolithic view of the appropriate policy package for achieving a favorable economic environment for agricultural growth.[21] In particular, the catchwords for the institutional forms being advocated throughout the Region are liberalization and privatization. To ensure that producers receive a favorable price, governments are also being discouraged from taxing output and encouraged to use the tool of devaluation actively. Although it is beyond the scope of this study to provide a detailed analysis of these policy issues, we believe it is important to emphasize that there has been no single formula for achieving favorable growth conditions in the past.

Diverse institutional forms, ranging from fully public to fully private operations, have at times been successful. On the whole, food marketing in this Region has been outside the sphere of direct government control, and producers have received the price the market would pay. In the industrial crops, there has been a greater tendency for intervention, with marketing and processing being at least overseen, if not directly managed, by the public sector, and with guaranteed producer prices. The transition to new institutional forms poses a number of challenges for agricultural growth.

As the experience of cocoa in the Côte d'Ivoire demonstrates, there is no iron-clad rule against the state taxing producers for a share of the world market price: cocoa production in that country increased from under 200,000 tons to over 700,000 tons between 1970 and 1990, all the while contributing to government revenues (Jarrige, 1994). Cocoa also provides the example of the depressing effect on output of excessive taxation: this is the case of Ghana over the 1970s and early 1980s, where output declined from over 400,000 tons to under 200,000 tons, in response to high direct taxes on cocoa and a heavy indirect tax because of the overvaluation of the Ghanaian exchange rate (Stryker, 1991).

The issues of direct and indirect taxation of export crops should be seen in the context of evolving world market prices. From 1986 to the end of 1993, low international prices for the majority of tropical agricultural products made it

20. For food crop dynamics in Côte d'Ivoire, see Chaléard (1988 *a*), Biarnes and Colin (1987), Colin (1990), Fusillier (1991); for maize in Cameroon, see Conte *et al.* (1993).

21. These are the positions promoted by the World Bank (1993 and 1994), among others.

difficult for producers to receive adequate remuneration. (See the price graphs in the statistical appendix.) In such a context, any taxation can be excessive, and the tendency was rather toward subsidization of the producer price in systems that ensure guaranteed prices. For governments whose budgets depend on trade taxes, the problem of direct taxation needs to be resolved in tandem with finding alternative sources of revenue. This continues to be a problem for Ghana, for whom cocoa has remained a mainstay of the revenue base.

Devaluation has been promoted in a context of low world prices because of its potential to permit producers to receive higher shares of the world market price. The mechanism is potentially straightforward: at a new exchange rate, the local value of the product goes up (for a given world price) and producers will receive a higher share of the total as long as other actors in the commodity system (the various intermediaries and the government) are not able to increase their own share. Since the mid-1980s, this issue has been at the center of policy debates, both because the extent of the real impact of a devaluation is not certain until after the measure is undertaken, and because different countries in the zone operate under different monetary regimes. The anglophone countries (Nigeria, Ghana, Sierra Leone, Liberia), the lusophone country (Sao Tome) and two of the francophone countries (Zaire, Guinea) have independent exchange rate regimes, while the countries of the CFA franc zone (in this Region, the majority of the francophone countries – Côte d'Ivoire, Cameroon, Gabon, Congo, Togo, Benin, the Central African Republic – as well as the hispanophone Equatorial Guinea) have until recently maintained a constant parity with the French franc since 1948.

Various countries in the former group lost control of their monetary policy over the late 1970s and early 1980s, with the result of high parallel market exchange rates. Some that have engaged in major devaluations (Ghana, Nigeria, Guinea) appear to have induced favorable effects on producer incentives. Many observers also considered the CFA franc to be overvalued, particularly in light of the fall in world prices of agricultural exports (Devarajan and de Melo, 1991; World Bank, 1994). One important difference between the situation in the franc zone economies and those aforementioned, however, is that the zone had experienced relatively low inflation rates, and maintained a convertible currency. The debate on the merits of devaluation for countries of this zone stemmed from the risks that instead of improving the real gains to producers, it would generate a rapid rise in inflation, posing difficulties for overall economic management, and that differential rates of inflation among members could threaten the viability of the zone itself, a source of macroeconomic stability (Guillaumont and Guillaumont, 1988; Freud, 1991).

The countries of the zone did undertake a major devaluation of 50 percent, doubling the parity with the French franc, in January 1994. The real effects of this measure are as yet uncertain. It was taken at a time when world prices began to improve, independently providing economic relief. Preliminary

evidence suggests that the degree of success in managing inflation has been highly variable among member countries.

Growth Dynamics and the Organization of Agricultural Production

In contrast to the savanna zone, where smallholder agriculture has always predominated, the humid forest zone has been characterized by a dichotomy in the organization of agriculture, with a strong role for large-scale plantations in industrial crop agriculture. During the colonial period, plantations were the basis of commercial agriculture in Zaire (oil palm, rubber, coffee, cocoa) and Sao Tome (cocoa). In other countries, plantation agriculture coexisted with a smallholder sector (coffee and cocoa in Côte d'Ivoire and Cameroon, oil palm and rubber in Nigeria). More rare were the cases, such as cocoa in Ghana and Nigeria, reserved more or less exclusively for smallholders. Since independence, there have been continued investments in plantation agriculture. This has especially been so in Côte d'Ivoire (oil palm, rubber, coconut palm, dessert banana and pineapple), but substantial investments have also beem made in Nigeria, Ghana, and Cameroon. The post-independence period has also been marked by a growing emphasis on the smallholder sector. Large-scale plantations in cocoa and coffee have practically disappeared, and smallholder development has been encouraged in the traditional plantation crops in some areas (rubber, oil palm, dessert banana and pineapple).

In contrast to smallholder growth in coffee and cocoa, which has been of a fairly spontaneous nature in response to favorable price incentives (at times with input and marketing support through area-based projects), the development of smallholder involvement in oil palm and rubber has been mainly through closely monitored outgrower schemes associated with the plantations (Colin and Losch, 1990). Cotton development in the francophone countries has similarly occurred under the guise of tightly-run projects, responsible for farmer recruitment, input and credit supply, and output marketing. We will henceforth refer to these projects as belonging to the "CFDT model" after the French-based textile development company, *Compagnie française pour le développement des fibres textiles*, which has been associated with them throughout this zone (Fok, 1993).

Food production in both zones has almost exclusively been the province of the smallholder sector. The exceptions are some investments in state farms, as in Nigeria, Ghana, Cameroon and Congo in the 1970s, and some isolated cases of large-scale private agriculture, mainly in Nigeria. As we shall see, projects have played an important role in some countries, notably Nigeria, in the development of the smallholder sector, but these situations could still be considered fairly spontaneous in the sense of low control of producer behavior

by the project authorities. The only parallel to the tightly-run schemes that one finds in the industrial crops is in large-scale irrigated rice in the Sahelian zones of Nigeria and Cameroon. In some periods, the CFDT projects have also provided some supervision of food crops produced by participants.

Given these evolutions, the current landscape contains four broad types of farm organization, the first of which is the large-scale plantations, important in oil palm (Côte d'Ivoire, Nigeria, Ghana), coconut (Côte d'Ivoire), rubber (Liberia, Côte d'Ivoire, Cameroon, Nigeria, Ghana) and fruits destined for export (bananas in Cameroon and Côte d'Ivoire, pineapple in Côte d'Ivoire). Smallholders operating in special schemes compose the second type of organization and are numerically most important in the CFDT cotton zone, but are also present in oil palm (Côte d'Ivoire, Nigeria, Ghana), rubber (Côte d'Ivoire, Nigeria, Liberia) and fruits for export (bananas and pineapple in Côte d'Ivoire). The third type are smallholders engaged in relatively "spontaneous" commercial agriculture. This includes all of the marketed food crops (staple foods and horticulture), as well as virtually the entire production of cocoa, coffee, natural oil palm (especially important in Nigeria, but present throughout the humid zone) and more limited quantities of fruits for export (pineapple in Côte d'Ivoire, Ghana, Guinea). The forth and last type of farm organization are smallholders engaged almost exclusively in subsistence agriculture. These smallholders are present throughout the Region, but especially concentrated in areas without viable market outlets (large parts of the remoter and sparsely populated areas of the Central African Republic, Zaire and Congo, as well as areas in the savanna zones of countries such as Cameroon and Côte d'Ivoire where cotton is not present).

These distinctions are important as we consider the role of agricultural research in the development of the Region's agriculture. Overall, the degrees of research's association with these four types of producers, and its ability to successfully translate its messages into action, have been closely correlated with the ordering of this list.

The Contribution of Research to Agricultural Development

The Institutional Context

The history of the Region's agricultural research has also been subject to successive dynamics. The earliest large programs were in the export crops, first launched in Zaire at the *Institut national pour l'étude agronomique au Congo* (INEAC)[22] in the inter-war period, from the 1940s in the anglophone countries as a group (Ghana taking the lead for cocoa, Nigeria for oil palm), and in the former French colonies. Independence led to a number of ruptures: the dissolution of INEAC (whose results on coffee, cocoa and oil palm were retained by transfers to the French system) and the breakup of the regional networks of the colonial period into national systems. Although a diversity of crop research programs exists in most countries, the major post-independence research programs are in Côte d'Ivoire (all perennials, cotton and fruits), to a lesser extent Cameroon (cocoa, coffee, rubber, cotton and fruits), Benin (oil palm) and Togo (cocoa) within the francophone zone; and in Nigeria (all perennials and fruits) and Ghana (cocoa) in the anglophone countries.

22. An extremely thorough history of the research strategies and results from this institute's work is DRACHOUSSOF *et al.* (1991). See also SCHLIPPÉ (1956) for the work done on smallholder farming systems.

Some research on staple foods was undertaken in the colonial period, notably by INEAC within the francophone zone (smallholder production systems, rural sociology, improvement of farming practices), and at regional centers within the anglophone zone (Sierra Leone for rice). But it is since independence that large programs in these areas have been built up. They function to a large extent in association with the two members of the Consultative Group for International Agricultural Research (CGIAR) having a regional mandate. The International Institute for Tropical Agriculture (IITA), established in the late 1960s and headquartered in Ibadan, Nigeria, covers maize, roots and tubers, legumes, and plantain. The West African Rice Development Authority (WARDA) became a member of the CGIAR in the late 1980s after a long period as a regional association, and recently moved its headquarters from Liberia to Bouaké in the savanna zone of Côte d'Ivoire.

Despite these advances, the scope of food crop research in the Region remains more limited than that of the industrial crops. Nigeria, in association with IITA, has the only major program for the roots and tubers, the main staples of the humid zone. Large programs in plantain, the other staple of the zone, were launched in the late 1980s at IITA. In Cameroon, research on plantain begun in the 1970s has been reinforced recently with the creation of the *Centre régional bananiers et plantains* (CRBP), a center intended to have a regional vocation. The International Network for the Improvement of Banana and Plantain (INIBAP) has been established to coordinate research on this crop worldwide. Maize and rice research programs exist in a number of countries; the Region has also been able to benefit from research in other parts of the world for these crops (CIMMYT, IRRI).[23]

Research on crop associations and natural resource management is in its infancy. The vast majority of crop research is concerned with monocultures, implying a radical switch from the typical practice of intercropping in peasant agriculture in the Region. The two main centers of research on crop associations and their applicability in management of natural resources are IITA and the Nigerian national research system.

Observers of the current problems in the national agricultural research systems (NARS) frequently note the problem of scientific isolation and lack of cross-country linkages. For obvious reasons, the absence of linkages among national systems is most marked across the language barrier, and any efforts to break down this wall will necessitate special measures with respect to language skill development.

But there are also problems of linkages among countries within the same language zone. Whatever the reasons behind the decomposition of the

23. *Centro Internacional de Mejoramiento de Maís y Trigo*, the maize and wheat institute headquartered in Mexico City, and the International Rice Research Institute, headquartered in Manila.

regional research networks of the colonial period into national systems, one negative consequence has been to isolate the individual national systems. The situation is most pronounced among anglophone countries. In the francophone case, and particularly for the export crops, there has been the possibility to maintain more linkages among the national systems. This has been due to the maintenance of a substantial development cooperation program in research at the regional level, with a large expatriate presence through the French overseas institutes, the *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD) and the *Institut français de recherche scientifique pour le développement en coopération* (ORSTOM).[24] The progressive withdrawal of these institutes poses questions for the continuity of such linkages across the countries in the francophone zone.

There is a need to find new ways for the NARS to hook up, through such mechanisms as networks. The principle of networks is not new, and a number of them already exist under different auspices. Indeed, some observers argue for the need to rationalize the network landscape, possibly cutting back to avoid duplication.[25] Without wishing to pronounce judgment on such an exercise, we would point out two areas where there seems to be too little, rather than too much, networking.

First, few networks effectively cross the language barrier. For instance, a number of crop-based networks exist in the francophone zone under the auspices of the *Conférence des responsables de la recherche agricole africaine* (CORAF), an organization linking the African NARS and the French agronomic research institutes. Since 1993, anglophone countries in the Region have been accorded the possibility to participate in CORAF, and individual countries are gradually beginning to join. On the other side, one must note that despite its efforts, IITA remains a predominantly anglophone organization, a factor that can limit the development of its collaborations with the non-English-speaking NARS. Regional networks coordinated by WARDA on various aspects of rice

24. CIRAD was created in 1985 with the fusion of the commodity-based institutes established in the colonial era, including: for cotton, *Institut de recherche sur le coton et les textiles exotiques* (IRCT); for coffee and cocoa, *Institut de recherche sur le café et le cacao* (IRCC); for oil crops, *Institut de recherche sur les huiles et les oléagineux* (IRHO); for natural rubber, *Institut de recherche sur le caoutchouc* (IRCA); for fruits and citrus, *Institut de recherche sur les fruits et les agrumes* (IRFA); for forestry, *Centre technique forestier tropical* (CTFT); for animal sciences, *Institut d'élevage et de médecine vétérinaire tropicale* (IEMVT), and several institutes of more recent origin: *Institut de recherche sur l'agronomie tropicale* (IRAT), created in 1960 and covering food crops; *Centre d'expérimentation et d'études du machinisme agricole tropical* (CEEMAT), covering agricultural machinery; and *Département systèmes agraires* (DSA), covering agricultural systems. ORSTOM covers a range of disciplines in addition to agricultural sciences, including geology and soil sciences, social sciences, and public health.

25. This is, for instance, the objective of a working group on networks organized under the auspices of SPAAR.

research may have the best track record in bridging the gap, perhaps as a result of the long bilingual history of this association.

Across the language barrier, the lack of contacts can be especially important in the cases where the research strength in the Region is highly localized. For instance, the French-speaking world is largely uninformed about the dynamics of cassava improvement occurring in Nigeria, whereas the English-speaking world is in a comparable situation regarding the development of the cotton-growing zone of the francophone countries. This leads to the risk either of duplication of efforts, or of failure to benefit from results that could be transferred from neighboring countries.

If the language barrier can result in a duplication of efforts among existing networks, the same cannot be said for the second area where networks are missing. In both the anglophone and the francophone worlds, existing networks focus almost entirely on food crop issues, leaving researchers in the industrial crop institutes relatively isolated. The one exception is the CORAF network for cotton.

From the scientific standpoint, it seems clear that the countries of the Region could gain from some type of collaboration on these crops – whether it involves as little as sharing information on common problems or as much as exchanging genetic material. Yet to the extent that some countries may view each other as potential or actual competitors in these commodities, collaboration may be a more sensitive issue than in the food crops largely destined for the domestic market. Such a view is unfortunate, since in most cases, the real threat of competition comes from other regions in the world: Southeast Asia for the perennial crops, Latin America for fruits.

For some crops, it might be possible to build on the informal networks that already exist. The most obvious case in point is for the perennial oil crops, where a regional producers' organization, the *Association pour le développement du palmier à l'huile* (ADPH) already exists and has expressed an interest in pursuing common research themes at the regional level (BUROTROP, 1991). In cocoa and rubber, the Region's NARS meet each other in the context of worldwide professional organizations, the International Cocoa Organization (ICCO) and the International Rubber Research and Development Board (IRRDB). For the time being, the interests of such organizations are too broad to be of specific help to the research needs of the Region, but it might be possible to explore some common research themes under a West African subgroup. Such a one already exists for rubber. For some other crops, there may be a need to start the regional exchange process from scratch.

Overview of Research Strategies and Results

To examine the role research has played in the development of the Region's agriculture, we need to answer a two-part question: what technical solutions has research been able to offer, and which of these results have been adopted? In this section, we explore the first part of this question, by providing a brief overview of the key research issues and the main achievements for the major crops and for systems research. A review of this length is unable to do justice to the full range of individual research themes that have been treated over the years; we refer readers seeking more scientific details to the various sources in the bibliography.[26]

Overall, it is fair to say that the dominant orientation of research in the Region has been the selection of high-yielding varieties that respond favorably to the application of chemical fertilizers (and to mechanization in the savanna zones) in monocropping situations. Chemical control continues to be the primary means promulgated for containing pests and disease of the industrial crops, but tolerance/resistance has also been an objective of a number of varietal improvement programs. For the food crops, the main strategy in this area has been varietal improvement. For both types of crops, other characteristics attractive to growers such as precocity (early-maturing varieties) have been pursued with success. While the research systems of the Region cannot rest on their laurels, there have been some impressive technical achievements for a number of the Region's crops.

If we hazard a rough hierarchization, it would appear that the following crop programs have registered the greatest degree of success in producing results: oil and coconut palm, cotton, rubber, maize, cassava and export-quality bananas and pineapple. The programs with some notable but more limited achievements are in cocoa, robusta coffee, rice, groundnuts and sorghum. The most limited progress has occurred in yams and plantain. Research on systems of production and natural resource management have yielded mixed results. The various vegetable crops (local and "European" species) have been the object of little or no research in this Region.

26. Those seeking slightly lengthier technical overviews of the state of crop research in the Region can consult the two summary documents prepared for the workshop launching the SPAAR regional initiative: for the food staples and legumes, IITA (1992), and for the various industrial/export crops, CIRAD (1992 *a*). Several additional synthesis documents covering research in this Region are CARR (1989), WORLD BANK (1987 *a*), and *MINISTERE DE LA COOPÉRATION ET DU DÉVELOPPEMENT* (1991 *a*).

Oil Palm

One species of oil palm is native to this Region (*Elaeis guineensis*) and there is a long tradition of harvesting natural palm trees, not only for the oil (palm oil and palm kernel oil), but also for wine. In the countryside, there are also a variety of uses for the fronds, as fencing and roofing materials, and for the by-products of oil processing. Shells are used as flooring material, and the ash is used in soap production. There is a tight time constraint for the processing of oil: once harvested, the quality of the oil in unprocessed fresh fruit bunches deteriorates quickly (rise in the free fatty acid content), leaving a window of two to three days for processing without high losses. Although fairly hardy, the local varieties of this plant, often referred to by the name *dura*, are not very productive, typically yielding well under 1 ton of oil per hectare.

Research efforts have focused principally on how to augment the productivity of both the plant and the processing stage within the framework of agro-industrial plantations producing for export or local industrial uses. These efforts began with the selection of superior strains of the local *dura* population, but already by the end of the 1930s it became evident that the best results could be obtained by crossing these varieties with another local strain, *pisifera*, resulting in the *tenera* hybrid (SURRE and ZILLER, 1963). Successive improvements in the hybrid population have resulted in a dramatically improved yield potential. Today, it is not unusual to obtain 3 to 4 tons of oil per hectare under plantation conditions. The improved varieties produce more bunches, whose seeds have a higher oil content than the *dura*. The improved varieties also have a better quality of oil, with a lower saturated fat content.

The combined effect of these improvements, together with technological progress in the plants themselves, has been relatively high extraction rates in the industrial-scale processing plants, which regularly achieve rates of 20-24 percent. This represents a substantial efficiency gain over the traditional methods of extraction for local use, most often done manually, but in some cases with small-scale partially mechanized units, which at best obtain 10-12 percent. Yet the comparison between artisanal and agro-industrial systems is not straightforward. The products are in fact quite different: although the industrial quality oils have far superior stability properties, they do less well on a "taste" scale than the artisanally-processed oil, preferred in local cooking. This issue is not important for palm oil products destined for export markets or industrial uses, but we will argue that it is important in considering the future of supply of the local market in food oil.

Other main advantages of the new varieties are earlier maturity, lower labor costs of harvesting and disease tolerance. The economic life of the new breeds has been lengthened thanks to slower trunk growth, which makes it possible to easily harvest the trees. There has been some success in breeding tolerance to the main disease affecting oil palm, *fusariosis*, but this work is incomplete.

There are questions concerning the degree to which the tolerance achieved in one site can be maintained at other production locations (CIRAD, 1990).

Coconut Palm

Coconut palm covers a far more limited area than oil palm, being essentially confined to coastal areas. Whereas oil palm products form a basis of the local diet throughout the humid zones of this Region, the main coconut food products, oil and milk, are not widely consumed, in contrast to some tropical areas where the plant is found, like Southeast Asia and northeastern Brazil. Processing of the coconut can be done over a more flexible time range than with oil palm fruits, but the task is exceptionally onerous if done manually, a factor that may have inhibited the spread of coconut harvesting in the Region. Like the oil palm, the coconut palm appears to do better under higher moisture levels than those that are present in this Region.

Research orientations have followed similar lines to those in oil palm, essentially by-passing the traditional sector by aiming at high productivity of oil production in agro-industrial plantations. The results have been similarly impressive (Green, 1991; De Taffin, 1993). Through a strategy of hybrid breeding, yields have been augmented substantially: hybrids can obtain roughly 2.7 tons per hectare of copra, versus roughly 1.5 tons per hectare with selected local varieties, themselves improved over traditional cultivars. Research to build in disease resistance (to MLO, *Phytophtora*, St. Paul's wilt) is underway, but has made only limited progress to date. Drought tolerance is another element of current breeding programs in which research has yet to make substantial headway. One might note that the world's largest collection of genetic materials of coconut palm resides in this Region, at the Marc Delorme station in Côte d'Ivoire.

Cotton

Cotton is a crop well-suited to the climatic conditions of the dryer parts of the subhumid zone, since its characteristic of multiple-flowering renders it relatively robust to gaps in rainfall during this period (Parry, 1982). This is a critical point for certain other crops, such as maize and rice, where crop losses can be high if the rains fail. To obtain high yields, the plant requires high nutrient levels. As is true for other annual crops, it is necessary to practice shifting cultivation of cotton when fertilizers are not used. Cotton is also subject to a number of pests and to diseases that are able to adapt rapidly to phytosanitary treatments. Under normal conditions of natural soil fertility, yields are in fact far more sensitive to the absence of phytosanitary treatments than to the absence of fertilizers.

Like oil palm research, cotton research in this zone has made advances along the entire commodity chain, combining objectives of yield increases (now 2 to 3 tons per hectare of seed cotton on station), fiber and seed quality improvement, and higher fiber extraction rates (moving from 35 to 40 percent since 1960). Although chemical plant protection remains an integral part of the "package," improved varieties are also less susceptible to a number of insects and diseases (jassides, bacteriosis).

In contrast to either oil or coconut palm, research strategies have been geared to serving the smallholder sector, through the various CFDT-model cotton projects. This orientation has been instrumental in the focus on improving cultivation techniques via animal traction for plowing, sowing, and weeding. Techniques for chemical phytosanitary treatments have also been developed for smallholder use: ultra low-volume sprayers, which are light to carry and substantially reduce the water requirements for the mixtures.

Two byproducts of cotton fiber that have their own market value are the meal and oil obtained from cotton seed. In regular cotton varieties, the presence of the gossypol gland renders the meal unsuitable for consumption either by humans or by monogastric animals such as poultry, unless it undergoes special treatment. A significant amount of effort has gone into breeding varieties without gossypol. "Glandless" cotton is now available in some countries, in particular Côte d'Ivoire.

Rubber

Efforts to promote the growth of rubber, a plant of Brazilian origins, began in the early part of this century, as part of a drive by the industrialists in Europe and the United States to ensure alternative sources of supply to those in Southeast Asia, which remains the world's major production zone (Sérier, 1993). The links with the Asian production source, also under colonial rule at the time, have meant that rubber research in this Region has benefited from advances in Asia. In relation to Asia, the western part of the Region does not suffer from any major natural disadvantages for rubber production, as long as specific production zones are clearly identified. In Central Africa, there is a persistent problem of leaf diseases that tax yields (Compagnon, 1986).

Here, as with the palm trees, the focus of research has been on improving productivity in plantation settings. Primary processing of the latex is almost without exception located on site at the plantations, but this is less a technical necessity than in the case of oil palm. For rubber processed into crumb rather than sheets (the two intermediate forms of rubber), it is possible to let the latex coagulate and postpone the industrial processing step.

Some major achievements have been made in yield potential: while yields of roughly 350 kg per hectare were considered more than satisfactory in the

1920s, clonal material now available in the Region permits 2 to 3.5 tons per hectare on station. Basic tapping techniques have also been improved, considerably lowering labor requirements. These techniques can be combined with methods of artificially stimulating latex production to radically diminish labor inputs, by reducing the number of times any individual tree needs tapping. Another privileged research theme has been the maintenance of quality consistency, which has been a problem for African producers. Recent changes in the strategies of some of the major industrial users of natural rubber appear to have reduced this constraint; they have apparently adjusted their processing needs to accommodate non-homogenous qualities.

Maize

Maize, of American origin, was introduced into the Region centuries ago and has become an important secondary staple in a number of farming systems. In the humid zones, "green" (undried) maize often serves as a relay crop during the hungry season, since it can be harvested relatively quickly after the onset of the rains. In some of the subhumid areas, it is becoming an increasingly important alternative to the traditional sorghum (Fusillier, 1994; Bosc and Hanak Freud, 1994; Silvestre, 1994). Manual processing of dried maize is onerous, but simple mechanical technologies (small mills) exist that easily handle the task at low cost. A greater natural constraint in the post-production stage may be post-harvest storage losses, estimated at over 10 percent of the harvest in Côte d'Ivoire and Cameroon in recent studies (Fusillier, 1991; Conte *et al.*, 1993).

Major efforts have been directed toward maize research in this Region. While the orientation has been toward smallholder growers, the focus has mainly been on cultivation in single-stand, a practice differing considerably from the norm in smallholder agriculture, where maize tends to be associated with a variety of other crops – particularly cassava, plantain, and different legumes. Drawing on new research as well as results obtained elsewhere, a wide range of varieties have been released, corresponding to different levels of intensification and to different maturities (Bosc *et al.*, 1990).

Cultivated under optimal conditions (monoculture, with application of chemical fertilizers and mechanized soil preparation), certain hybrids are able to obtain 5 to 10 tons per hectare, and a number of more "rustic" composite and selected local varieties from 3 to 4 tons per hectare. It should be noted nonetheless that this Region does not have the high performance record in maize of some areas of Eastern and Southern Africa (Kenya, Zimbabwe). Under farm conditions, even when farmed intensively, yields rarely achieve these levels in this Region, tending to peak at 2-3 tons. Average yields based on USDA (United States Department of Agriculture) data are estimated at under

1 ton per hectare here, and at 1.2 and 1.5 tons per hectare in Southern and Eastern Africa, respectively (GILBERT *et al.*, 1993).

Some of the new varieties exhibit tolerance to diseases such as the maize streak virus, downy mildew, and *helminthosporiosis*; this has been achieved by crossing local strains exhibiting natural resistance with higher yielding varieties. A major plant protection problem that has met with little success, despite considerable research attention, is *striga*, a virulent parasitic plant that is spreading rapidly throughout the Region, but especially in the areas where soils are heavily depleted. There are considerable debates on the appropriate strategies for attacking the *striga* problem, centering in particular on the possibilities to breed resistance into maize varieties (GILBERT *et al.*, 1993). This option, pursued by IITA, seems to have generated promising results at the experimental stage, which will need to be confirmed on a larger scale and by more diverse criteria (KIM, 1994). Given the association of this parasite with degraded ecological conditions, it may be promising to combine this with strategies that seek to improve the environment itself. One such option might be through encouraging maize-legume associations in susceptible areas, since *striga* appears to thrive most with monocropped maize, and since certain legumes, such as groundnuts, can block its cycle. *Striga* also affects sorghum in this Region.

Cassava

Cassava, also a plant of American origin, is grown widely in both the humid and subhumid zones and serves a variety of functions within the production systems, depending on the varietal characteristics (FRESCO, 1986; SILVESTRE and ARRANDAU, 1983). Shorter-cycle varieties (twelve months) are grown in a variety of associations on new fields, for both home use and marketing, whereas longer-cycle varieties (ready at eighteen months, but able to be kept in the ground for much longer) are often left as a last crop on fields that are entering the fallow stage. As long as cassava is left in the ground, it is subject to few storage problems. However, once harvested, it rots within a short space of two to three days unless processed. Processing before eating is a requirement for the cassava varieties of the "bitter" type, which contain potentially lethal amounts of cyanide. Some type of fermentation method is used to remove the poison, and the resulting produce is then processed into one of various forms (chips, paste, meal) before being prepared as a local dish (MUCHNIK and VINCK, 1984). "Sweet" varieties can, but do not need to, undergo the fermenting process. Most popular in the Central African countries are fermented paste-based dishes (*chickwangue, foufou*); in Nigeria, various dishes based on a dried, roasted couscous known as *gari*; and in Côte d'Ivoire, a couscous-type dish known as *attiéké*. The leaves of cassava are also highly appreciated as an ingredient in sauces and certain other dishes, such as *saka saka* in Congo.

Relatively neglected if one takes account of the importance of the crop in this Region, cassava research has nevertheless made some significant progress in both yield increases and disease control (IITA, 1990). Cassava is a plant which responds well to high input use, and yields of 40 tons per hectare under intensively farmed plantation conditions are not unreasonable in this zone. In contrast to the majority of crop research programs, however, cassava research has explicitly taken into account the likelihood that users would be operating under "sub-optimal" conditions, on poor soils, with little or no chemical input use. Several IITA varieties of the "bitter" cassava most commonly consumed in Nigeria and Central Africa generate roughly 75 percent higher yields of fresh cassava than unimproved varieties (an increase from approximately 11 to 19 tons per hectare on average under low input conditions), are earlier maturing, and exhibit increased tolerance to cassava mosaic disease and cassava bacterial blight. Cassava has also been the beneficiary of a major biological control program against the cassava mealy bug, which has succeeded in controlling this parasite over a vast area (NEUENSCHWANDER, 1993; NEUENSCHWANDER and HERREN, 1988; NORGAARD, 1988).

Less progress has been made so far in increasing the yield potential of the sweeter varieties more commonly consumed to the west of Nigeria. By the same token, little work has been done on the longer-maturing varieties and there is some debate as to whether this is a useful line of research: is it physiologically possible to develop varieties that do not become more fibrous with longer time spent in the ground?

Fruits

A large research effort has been devoted to the release of improved varieties of a range of fruit trees – mangoes, citrus, papaya, passion fruit – destined for local, and in some cases export, markets (CIRAD-IRFA, 1992). These varieties are particularly sought out for the establishment of new orchards, but can also be used to enrich home gardens. For the time being, however, the impact of research within the Region is undoubtedly most felt in the two commodity systems with well-established export channels, dessert bananas and pineapple.

DESSERT BANANAS

For dessert bananas (in particular, varieties of the Cavendish subgroup commonly found in European and U.S. supermarkets), research has produced a package of recommendations combining high-yielding varieties with fairly capital-intensive farm management techniques (high levels of chemical inputs, as well, in most cases, as irrigation and drainage) (CHAMPION, 1963; CIRAD-IRFA, 1990; CIRAD-FLHOR, 1993; LASSOUDIERE, 1978). The improved varieties are better adapted to the Region's agroclimatic conditions (GANRY, 1988-92), although natural conditions remain more favorable in some other tropical

areas. This is particularly the case in Latin America, where soils are more fertile and rainfall conditions more favorable, such that recourse to irrigation is rarely necessary. Using the combined package of results, plantation-scale producers are able to obtain yields of 30 tons per hectare, more than double the level obtained in the 1940s. Research has also been concerned with the downstream aspects of the commodity system. In particular, an important objective has been to improve the quality of bananas shipped by sea. This is done via refrigeration of immature bunches, which are artificially stimulated to ripeness with the aid of ethylene.

Disease and pest problems continue to pose substantial problems for banana production. At present, chemical treatments are the only means available in the fight against nematodes and weevils. Given the high costs which this imposes, integrated pest management is increasingly considered to be a high priority for research (CIRAD-FLHOR, 1992).

The black sigatoka fungus (*cercosporiose noire*) also necessitates permanent control measures (MOURICHON, 1988-92). The development of control strategies based on early warning systems has permitted a more rational use of fungicides, with only twelve to fourteen treatments annually (as against over twenty-five in Latin America). This represents not only a cost savings, but clear advantages from the environmental standpoint.

PINEAPPLE

Pineapple research has made similar progress in raising yield potential, and in achieving quality improvements for the export market (PY *et al.*, 1984; CIRAD-IRFA, 1991). Intensive production techniques well-adapted to the production of fresh fruit in agro-industrial plantations have been adopted by producers and have permitted the development of this subsector (GERDAT-IRFA, 1984). Certain pest and disease problems persist, affecting both yields and quality of output. Chemical techniques for controlling nematodes and symphiles remain costly, and solutions have yet to be identified to control the black spot fungus, which compromises fruit quality.

The reconversion of numerous smallholder growers toward the production of fresh fruit in Côte d'Ivoire, following the collapse of the local canning industry, has generated new problems, essentially downstream in nature. The current challenges for smallholders there and in the other countries concern the control of quality, which covers a range of aspects: maturity, color, calibration, appearance and taste (sugar content and level of acidity) (SODETEG, 1990; COLEACP, 1993). As is true for the plantation-scale growers, small-scale producers seeking to meet export market standards adopt intensive growing methods. In their case, technical support via producers' organizations appears to be the most successful means to assure the production of high quality fruits.

Cocoa

Cocoa growing in this Region began with the spread of the *amelonado* variety, first introduced in Sao Tome. Cocoa is a crop particularly well-adapted to smallholder conditions: it is at once easy to grow, with few maintenance requirements once a canopy cover is established, and can undergo the primary processing stage (hulling, fermenting and drying of the beans) on the farm, with few capital costs.

The yield improvement strategy fairly quickly began to focus on crossing *amelonado* with other varieties, all of American origin (BRANDEAU, 1969). A range of the resulting hybrid materials has been released since the 1950s; those now available in the principal producing countries of the Region obtain 2 to 3 tons per hectare on station, as opposed to under 400 kg per hectare obtained with unimproved material in the inter-war period. In practice, there are some questions concerning the reliability of the hybrid materials in relation to these results. Some observers (BLOOMFIELD and LASS, 1992) note the tendency of research to use superior trees to classify the whole hybrid population, which can, in the first instance, lead to an overestimation of average yield potential. However, follow-up testing on station is then done to verify the assessment of potential.

One clear advantage of the new varieties is that they mature earlier, bearing fruit after only four years, instead of seven with the *amelonados*. On the other hand, it appears that the hybrid materials may die out sooner than the traditional varieties, at least on station, but this finding is not necessarily confirmed under on-farm conditions. Observations by farmers and some research results do tend to indicate a diminished longevity of hybrid material.

As elsewhere in the world, cocoa production in this Region has always been confronted with pest control issues, which have been a primary focus of research since its inception. There have been few successes in genetic work in this area. Although the new materials may exhibit some tolerance to the cocoa swollen shoot virus disease, the mechanisms for resistance to this deadly disease have not yet been established, despite over forty years of research, and the long-standing recommendation remains to cut down infected trees. To cope with the two other main plant protection problems, capsids (a leaf-eating insect) and the several species of the *Phytophtora* fungus, the blanket solutions recommended are relatively high levels of chemical control, by the standards of the Region.

There are some debates concerning the appropriate farming practices for this plant (CIRAD-IRCC, 1991). In a wide range of farming situations, young cocoa plants appear to need shade, which is usually provided by associated crops, notably plantain, in addition to shade trees left in fields after land clearing. Once mature, cocoa can continue to be left under shade, or it can be grown in full sunlight. The debate centers on the advantages and disadvantages of this choice. Unshaded cocoa can produce more, at least over a certain period, and

suffers less from fungal diseases. Fertilizer use is considered an essential ingredient of such a practice. Shade is known to cut down on capsid attacks, and it may prolong the productive period of the tree. There is a presumption that shaded cocoa leads to less soil degradation and therefore to fewer problems of replanting when the trees grow old, but this remains a question to be addressed by research. As we will argue, this is one of the major issues for the long-term health of cocoa-growing in this Region.

Robusta Coffee

This plant is suitable in many of the same areas as cocoa but has two main disadvantages in relation to that crop: weeding and pruning remain important maintenance activities throughout the plant cycle, and harvest requirements can be onerous. Regardless of the quantity produced by the bush, the staggered maturity of the berries makes it necessary to pass through the same fields several times in the season in order to avoid high rates of black (reject quality) beans. The berries are usually dehulled after on-farm drying, and there are both artisanal (manual or small-scale motorized machines) and industrial-scale options for the dehulling.

Coffee research in this Region has made notable progress in varietal improvements, raising yields and introducing tolerance to some diseases (Coste and Cambrony, 1989). Varieties now available enable yields of 2 to 3 tons of green coffee per hectare on station, as opposed to only 250 kg per hectare in the inter-war period, and exhibit some tolerance to rust and to drought conditions. Although not a direct target of breeding programs, labor productivity is also improved by these yield increases, to the extent that it rises in tandem with increased yields. For the time being, recommendations specifically concerning the reduction of labor time appear limited to the identification of a pruning technique known as capping, which makes the berries more accessible by encouraging the coffee bushes to grow outward rather than upward (Viroux and Petithuguenin, 1993).

The debates concerning "with" or "without" shade for coffee are similar to those for cocoa, although evidence from some areas, such as Togo (Funel *et al.*, 1984; Antheaume and Pontié, 1990), suggests there may be fewer difficulties in replanting this crop on old stands.

Rice

Rice growing is traditional in the western part of the Region, which is considered the genetic home of one rice species (*Oryza glaberrima*). Thanks to the introduction of other varieties over the centuries, rice farmers in the Region have access to a wide genetic diversity, including the Asian *O. sativa* types. As

LEPLAIDEUR (1992) noted, a broad comparison of rice in this Region with rice growing in Asia permits one to identify two quite different strategies: whereas the management of the physical environment, and particularly of water, has been the primary characteristic of Asian rice systems, management of varietal diversity to fit different environmental requirements has been the dominant characteristic of their West African counterparts. West African rice systems can be differentiated by the water sources they draw on, generally with little or no measure of water control: valley bottom (fed by rains and accumulated runoff water), upland (rainfed) and the lower slopes between the two (fed mainly by rain, but also benefiting from groundwater interflow from upper slopes) (ANDRIESSE and FRESCO, 1991). The only main exception is the systems fed by the brackish waters of mangrove swamps, in which control of salinity is a necessity.

The predominant research and development effort for rice in this part of the world has concerned the large irrigated schemes in the Sahel, including those located in northern Nigeria and Cameroon. Of those efforts within the humid and subhumid areas, the concentration has been on the upland and mangrove systems. For the mangrove systems, a number of high-yielding varieties have been released, in some cases with particularly good post-harvest characteristics. Research to improve the productivity of upland rice systems has had successes in meeting the combined objectives of higher yields and tolerance to drought with early-maturing varieties (POISSON, 1989). Breeding work has achieved tolerance to blast rust, the major disease, but the variability of the forms of the pathogens gradually erodes the acquired tolerance. The outstanding constraint to yields in upland systems is weeds, which can cut yields in half, and for which there are no technical solutions apart from costly herbicides. This problem is a symptom of continuous cultivation; weeds are far less present when rice is introduced on newly-cleared lands.

The valley bottom and lower-slope areas have two advantages over the upland systems: less risk of hydric stress and lower weed infestation. Yet these systems have received relatively little attention by research, even though numerous development projects have been geared to the promotion of more intensive use of low-lying areas (SAVVIDES, 1981; OOSTERBAAN *et al.*, 1987; REBUFFEL, 1993). Apart from upstream research of a morpho-pedological nature (RAUNET, 1985), the main research effort for the valley bottoms has been varietal selection among varieties initially developed or selected in other contexts (Asia, Latin America) (CARSKY, 1992). Substantial effort has gone into introducing, sorting and diffusing varieties to national systems since the early 1970s. There has been surprisingly little research on the management of water in these and the lower-slope areas, which appears to have the potential to be far lower-cost than the large irrigated schemes (for Guinea, see BALDE *et al.*, 1993).

Sorghum and Millet

The sorghum and millet varieties indigenous to the savanna zones of the Region have several basic technical advantages in relation to maize. First, like cotton, they are relatively robust to rainfall failures. Second, they have good storage properties. Third, they require less labor for manual food preparation (husking and pounding) (BRICAS *et al.*, 1995), and may also require less cooking time (and hence less fuel) than maize. Finally, and not least, they are, by virtue of their traditional dominance of the cropping patterns, the preferred staples for preparation of local dishes.

In comparison, maize has two main characteristics in its favor. First, being of shorter cycle, it can be harvested earlier in the season, thereby filling the food gap during the traditional "hungry season." Second, it responds well to fertilizer, in sharp contrast to the local sorghum varieties, whose high photosensitivity leads only to greater stem and leaf growth. If maize has been gaining on the traditional coarse grains in cropping patterns, this would appear in no small way linked to the obstacles encountered by research in its search for higher-yielding sorghums that retain the organoleptic and storage qualities of the local varieties.

For millet, the main varietal improvement effort has been devoted to the short-cycle varieties most prevalent in the semi-arid zones of the Sahel (BOSC *et al.*, 1992-94). Relatively little work has been done on the long-cycle millet grown more commonly in the moist savanna, since research placed more hopes on the potential of sorghum for this zone. The initial improvement strategy was to work with East African varieties (*sorghum caudatum*) that respond better to fertilizer. Despite higher yield potential, these varieties encountered farmer resistance because of their color (reddish in contrast to local white), grain quality (mealiness, lending itself poorly to preparation of local dishes such as *tô*), and problems of moldiness during storage resulting from grain bunches insufficiently exposed to the air which, in addition to causing losses, leads to lower germination rates of grain stored for seed. Although some progress has been made in cross-breeding strategies – for instance, the color problem has been resolved – research continues to search for a successful combination of characteristics, using strategies that include molecular genetics.

Yam

Although concentrated in Nigeria, the largest producer and consumer of yams in the world, the yam-eating zone of this Region stretches from western Côte d'Ivoire to Cameroon. This is a plant characterized by a great degree of natural genetic diversity, adapted to a wide range of production conditions within the Region (DEGRAS, 1986). Yam varieties generally achieve high yields (10 to 20 tons per hectare) and many have excellent storage properties, in contrast to cassava. They generally have more stringent growing requirements than

cassava, as concerns both soil quality (high potassium levels are needed, favoring recently cleared lands) and cultivation techniques (high labor inputs in soil preparation work, to build mounds, and frequently the need to provide stalking material). Yam growing also has high costs in terms of planting material. Using traditional methods, up to one-third of the harvest must be retained for use as seed-yams.

Yams have been relatively neglected by agricultural research, and to date results that can raise productivity have been far more limited than for cassava, the other major root crop. In effect, there are a number of technical obstacles to breeding work (among which, "shy flowering," which slows down cross-fertilization work), and research has yet to develop improved varieties. The major technical achievement has been a more economic method of seed-yam multiplication, known as the "mini-sett" technique. Under this system, much smaller pieces of seed-yam (the "mini" setts) can be used as planting material, enabling substantial reductions in the amount of the crop that must be retained. Despite initial hopes, there seem to be doubts concerning the widespread receptivity of farmers to the technique in Nigeria: although mini-setts permit an equivalent yield for a smaller amount of planting material, the individual yams it produces are smaller, and less desirable (Onweme, 1990).

Another avenue of innovation has been through varietal screening and introduction from other producing areas in the world (the Americas as well as the Pacific Basin).

Plantain

Itself a major staple in the humid zone, plantain plays a key role in crop associations in the humid areas, both as a shade crop for young perennials and as a companion to various food crops, and in some cases adult perennials. Although plantain shares many characteristics with dessert bananas, the impressive set of research results for those species are not directly transferable. A major difference in research orientation is necessitated by the fact that smallholder producers of this crop, which is largely destined for subsistence purposes, will not be able to use the degree of chemical inputs that form part of the high-productivity banana packages (Tezenas du Montcel, 1985). Given the local range of the markets for plantain, there is also less need (if any) to refine the conditioning aspects for sale. By contrast, building in genetic resistance to pests is an important issue. The major focus of the breeding work so far has been precisely in this area, and there appear to be promising results in a variety exhibiting resistance to the black sigatoka fungus, now at the testing stage.

Vegetable Crops

Within the Region, there are two axes along which one can distinguish vegetable crop production: according to the supply zones – peri-urban versus counter-season systems located at some distance from the towns – and according to the type of species produced – local, mainly leafy, vegetables versus exotic or "European" types, especially tomatoes, onions and cabbage. The implied foreign character of the latter species should not mislead one to think they are minor among vegetables consumed in the local diets: tomatoes and onions are in fact deficit items in a number of countries in West and Central Africa, and represent a high foreign exchange cost for some countries, like Côte d'Ivoire.

In places where transport cost problems can be surmounted, the natural advantages of producing the European-type crops in certain dryer areas, where there are fewer pest problems, lead to a predominance of the savanna zone in the urban vegetable supply. A case in point is Nigeria, where observers estimate that 70 percent of the supply of these crops for the thriving trade in the large southern cities is produced in the valley bottoms (*fadama*) and irrigated areas in the dryer subhumid and semi-arid areas of the north. The leafy vegetables do well in the humid zone, thereby favoring local supply sources.

There is a strong dynamic in vegetable production of both local and European types, despite the lack of major technical inputs from local research.[27] For some of the European species (especially tomatoes and onions, but also okra) as well as local eggplant varieties, some results are available based on research in the dryer areas. But producers of these crops are also able to borrow heavily from European private sector research; seed purchase by mail is quite common. Use of inputs (pesticides and both organic and chemical fertilizers) are also common in these systems, strongly tied to the market.

The majority of the local vegetable types have not been the subject of research. There is the need for very basic inventory work on genetic resources, and basic identification work on potential applied research topics in this area.

Systems of Production, Natural Resource Management

Systems research aimed at understanding farmers' behavior has made important contributions in this Region, as elsewhere in Africa. Already before the 1960s, and before substantial funding began to be channeled into this area roughly fifteen years ago, researchers began to diagnose the reasons for

27. For case studies of Brazzaville, see LEPLAIDEUR (1991), LEPLAIDEUR and MOUSTIER (1991); of Lomé, SCHILTER (1991); of Kinshasa, RICHARD *et al.* (1985); of Bissau, DAVID and MOUSTIER (1993).

farmers' divergence from recommended practices (SCHLIPPÉ, 1956). Although the dialogue between systems research and thematic research has not always been easy, some of this diagnostic work has been able to feed into more upstream research, such as breeding objectives for early-maturing varieties and other "hardy" characteristics (for instance, see GILBERT *et al.*, 1993, on the influence of systems research on maize breeding in Nigeria).

While this type of systems work is based on diagnosis of actual farm situations, there is another whole field of systems research concerned with creating or designing new combinations of crops and farming methods. This field of research is especially important for soil fertility management, given the low chemical input use by poor smallholders, and the need to complement inorganic fertilizers with organic materials to maintain fertility, even in high-input situations. At present, the portfolio of research results concerning crop associations is very limited (ELEMO *et al.*, 1990). Probably the best-known type of system proposed by research, although not adopted by farmers, is the alley-cropping technique, designed to associate annual food crops with nitrogen-fixing trees and bushes. In savanna areas, some progress has been made in knowledge on the introduction of leguminous plants such as groundnuts into cereals cultivation, as well as on the associations of crops with animal raising.

The Record on Adoption

It is more difficult to answer the second part of the question concerning the impact of research. In effect, there has been relatively little work done to examine the adoption of results, and the research system itself does not dispose of mechanisms that enable it to appreciate the extent to which its results are put to use. Drawing on those studies that do exist, often associated with development projects, it is nevertheless possible to make some overall assessments. One cannot avoid the conclusion that the record on adoption has been far more mixed than the record on research results examined *a priori*.

Adoption of "Packages"

These results are typically proposed to farmers as "technology packages" – new varieties to be used following improved practices (typically including chemical fertilizers and pesticides), in single-stand, following recommendations on spacing and a crop calendar. Yet the only systematic cases of across-the-board adoption of packages are found in the large-scale plantations. In smallholder agriculture, the cases of intensification based on a package are few. They are limited mainly to two types of cases: projects for outgrowers of large plantations and major crop development programs. The

outgrower projects concern rubber and oil palm in Côte d'Ivoire, Ghana and Nigeria. However, smallholders rarely attain the yield levels of the plantations under these schemes. Rubber in Côte d'Ivoire seems to be the exception (HIRSCH, 1990*b*). The development programs concern cotton in many of the French-speaking countries following the CFDT model, food crops in some of these same projects, and cassava and maize in the Nigerian Agricultural Development Projects.

Through the cotton projects, average yields in a number of countries (Cameroon, Côte d'Ivoire, Benin, Togo, as well as Mali and Burkina Faso in similar agroecological areas) have more than doubled, to 1000 or more kg per hectare of seed cotton. There has been widespread adoption of animal traction (BIGOT and RAYMOND, 1991). Although soil fertility declines lead to the need for periodic fallowing, the production systems have become more sedentarized, in stark contrast to the low-input, itinerant cotton growing practiced in the 1960s. There is an unusually good set of information on adoption in these projects, thanks to their monitoring units and to frequent evaluation missions.[28]

Especially over the past decade, the cotton projects have been successful in encouraging the intensive cultivation of improved maize and sorghum varieties as rotation crops. These crops also benefit from the animal traction techniques (FUSILLIER, 1994).

Information collected by the Collaborative Study on Cassava in Africa (COSCA) (see the reports by NWEKE and his collaborators) shows that in Nigeria, by the early 1990s, 90 percent of sample villages surveyed in the cassava growing areas had some farmers growing the improved varieties; adoption occurred on a large scale (more than half the farmers) in 60 percent of the villages. Although one of the breeding objectives was to produce a high-yield response with limited chemical inputs, farmers closely linked to the market also use fertilizers.

Information collected by IITA and for a study of maize impact sponsored by USAID (United States Agency for International Development) (BRADER, 1991; SMITH *et al.*, 1994; GILBERT *et al.*, 1993) shows a widespread introduction of improved maize into the northern guinea savanna of Nigeria. Whereas no farmers in the survey were using improved varieties in 1970, by 1989 all farmers reported adoption, mainly of the early-maturing open-pollinated varieties, which are tolerant to drought conditions. These same varieties have also been very popular in the more humid zones, where they have permitted

28. For synthesis reviews at the level of the zone, see *Ministère de la coopération* (1991*b*), CAMPAGNE and RAYMOND (1994), and BOSC and HANAK FREUD (1994). For case studies, see: for Togo, FUNEL *et al.* (1983), FAURE (1990) and COUSINIÉ (1993); for Benin, RAYMOND (1994); for Mali, FOK (1993); for Burkina Faso, FAURE (1994); for Côte d'Ivoire, PELTRE-WURTZ and STECK (1991) and LE ROY (1993); for Cameroon, RAYMOND *et al.* (1994); and for the Central African Republic, BOUTILLIER and CONESA (1984) and YUNG (1989).

double cropping, and where they are appreciated because of resistance to lowland rust and blight. In the savanna areas, the spread of maize has been accompanied by the spread of animal traction. Fertilizer use on maize is widespread in the savanna areas, whereas it is less important in the humid zone areas.

Improved Varieties

In smallholder agriculture, there are many more cases of very partial adoption of technical recommendations. The category of research results most interesting to farmers appears to be the improved genetic material. This should not be surprising, if one bears in mind the history of spontaneous experimentation with crops in this Region. With the exception of sorghum, yam and oil palm, all the major crops in the Region have been introduced over the last few centuries, and farmers have constantly been on the look-out for varieties with interesting properties, which they have exchanged among themselves.

There is evidence of adoption of composite maize, improved rice varieties, cocoa and coffee hybrids, and yams (a Puerto Rican variety, *florido,* brought to Côte d'Ivoire by the research system).[29] In general, such adoption occurs under extensive farming practices, whereby far lower yields are obtained than under the "package": 250-450 kg per hectare for coffee and cocoa are typical levels in this Region, as against the 2-3 tons per hectare on station. The adoption rates of pure hybrids for cocoa and clones for coffee are not overwhelmingly high (estimated at roughly 10 percent in Côte d'Ivoire), but there is also a large population of hybrid descendants, which farmers appear to have preferred to the traditional varieties in many cases.

Improved oil palm varieties appear to be in high demand by small farmers outside of the special outgrower schemes, but their diffusion has largely been limited to the project areas. Rubber varieties also appear to have qualities that would be attractive to small farmers outside of schemes, but again their diffusion has been limited so far to the projects.

Fertilizers

When used by smallholders, fertilizers are almost universally limited to annual crops. Farmers recognize the yield-augmenting effect of fertilizer on annuals, and apply it when it is available and affordable. Apart from cotton, which is the object of special supply channels, the main recipients appear to be maize and the garden vegetables. The effect of fertilizers on perennials is either too

29. For maize, see FUSILLIER (1994); for mangrove rice, see ADESINA and ZINNAH (1991 and 1993); for *florido* yam, see CHALÉARD (1988 *b*) and DOUMBIA (1990).

long-term or not apparent. Even in closely monitored projects, such as the oil palm outgrower schemes, farmers divert fertilizers intended for the perennials to food crops.[30] The single major exception is coffee in the Moungo Valley of western Cameroon, where farmers spontaneously developed an intensive cultivation system including chemical fertilizer use, bringing yields from an average under extensive conditions of 300-400 kg to 900 kg per hectare (LOSCH *et al.*, 1991).

The reluctance of smallholders to apply fertilizer to perennials rejoins a debate concerning the reliability of the research recommendations on this theme. There appear to be unresolved issues concerning the types and levels of nutrient additions needed to achieve high performance with the improved varieties of these plants under smallholder conditions.

Pest control

The only case where there is extensive chemical pest control undertaken by farmer initiative is cotton in the CFDT zone. In cocoa, farmers have practiced spraying against capsids and *phytophtora* on a much less intensive scale than that recommended by research, except in certain zones where the spraying has been done by extension services (Ghana and the central-south of Cameroon in some years). Treatments against scolytes in the intensive coffee system in the Moungo area have, until recently, also been the responsibility of the plant protection service. Apart from cowpeas and certain vegetables, there is little evidence of adoption of chemical pest control techniques for food crops, except on occasion for storage (maize, groundnuts). Chemical treatments of seeds, to protect them from attacks after planting, is also a popular, low-cost practice for groundnuts and for the coarse grains.

Specific Farming Practices

Evidence of adoption of specific farming practices recommended by research is extremely scant. When they are not obliged to do so by special project authorities, farmers pass to monocropped systems only under special circumstances: for food crops when purely destined for the market and farmed intensively (some maize and cassava in Nigeria), and for certain perennials (coffee, cocoa, but not oil palm) once sufficient growth has occurred to block light for food crops.

Farmers are often not convinced of recommendations on spacing. Most commonly spacing exceeds research recommendations, although the reverse can also occur, such as for cocoa in Ghana, where farmers plant in densities

30. The experience of the Ghana Oil Palm Development Corporation (GOPDC) is a case in point.

five to six times those recommended, to compensate for anticipated losses among seedlings and to cut down on weeding (WORLD BANK, 1987*b*).

Weeding recommendations rarely attain the levels recommended by research. Farmers recognize the importance of weeding for yield levels, but they are limited by labor constraints. This is one of the key attractions of crop associations, which tend to cut down on weeds.

For some crops, the same holds true for harvesting and post-harvest handling. For instance, coffee farmers typically pass through a grove two or three times during a season, but harvest each bush just once (strip picking), despite the much higher loss rates. Although labor constraints make it unlikely that farmers would reach recommended levels under any circumstances, the practice of purchasing coffee without quality grades has probably aggravated this practice in countries like Côte d'Ivoire.

Recommendations of research on replanting techniques for coffee and cocoa, demonstrated to be technically efficient on research plots, have generally not been adopted by farmers, who prefer to let the trees live long past their prime, harvesting a fraction of the peak yields (ANTHEAUME and PONTIÉ, 1990; PETITHUGUENIN, 1993*b*).

Conditions Favoring the Adoption of Improved Technology by Smallholders

There is little mystery in the adoption of research results by plantation agriculture; these systems have not been subject to the same degree of capital constraints for machinery, inputs and labor. Moreover, they have typically operated under very close links with the research establishment, often receiving management advice from research institutes. It should be noted that high technical efficiency is not necessarily synonymous with economic efficiency in this production mode, however. Often those plantations that operate at high technical efficiency (not uniformly the case, depending on the management quality and the agroecological appropriateness of the location) tend to have problems of high production costs in relation to producers in other parts of the world.[31]

For the future of agriculture in the Region, the more perplexing issue is to identify the conditions favoring adoption in peasant agriculture, and to see to what extent those conditions are reproducible elsewhere. We begin by recalling the general set of constraints to technology adoption in smallholder

31. For oil palm, see HIRSCH and BENAMOU (1989); for rubber, HIRSCH (1990*a*); for dessert bananas, FABRE (1995).

agriculture in comparison with plantation agriculture. Smallholder farmers face conditions – shortages of manpower and capital, aversion to risk, combined in many cases with a lack of land pressure – that make the adoption of complete technical packages less attractive, if not impossible. Yet the experience of intensification in cotton, maize and cassava shows that these constraints are not insurmountable.

A precondition for successful smallholder intensification is attractive and secure market access. This precondition appears even stronger than for growth of output without intensification, since intensification requires greater risk-taking in cash outlays. The marketing channels need not be official; in the CFDT cotton network they are, whereas in food crop marketing in Nigeria and in urban vegetable marketing more generally, they are not. But they do need to be reliable. In this respect, it is interesting to note NINNIN's (1994) finding, on the basis of FAO data, of a close correlation between intensification of agriculture and a synthetic indicator of market development within this Region.

For food crops, urban demand may be too limited to constitute a reliable market for intensive production. Intensive maize production in the cotton schemes in Mali dropped off noticeably once guaranteed official purchasing was stopped; in effect, the urban demand for the product was limited (FUSILLIER, 1994; BOUGHTON and HENRY DE FRAHAN, 1994). The problems encountered with intensive maize production in Ghana under the Global 2000 scheme reflect a similar phenomenon.

Secure market access may require access to processing facilities. This is clear in the case of cotton, for which industrial processing facilities have been constructed in tandem with the expansion of output. As the COSCA study has shown, availability in a village of small-scale mechanized facilities for processing *gari* – an intermediate form of cassava that has a long shelf-life and is in high demand by urban consumers – has been a key factor in the expansion of intensive cassava production with the improved varieties in Nigeria.

Intensification also requires favorable conditions "upstream". The cases of successful intensification have in common chemical input availability at affordable terms (input credit and/or subsidies in the cotton schemes, in the Nigerian maize and cassava cases, and in coffee in Moungo) and public investments in the diffusion of improved planting material.

This same set of preconditions, both upstream and downstream, are found in the extreme in the case of outgrowers associated with plantations.

The cases where there has been widespread adoption are marked by a close link between the research system and the producers, parallel to the conditions of research linkages with the large-scale plantations. Cotton research in the CFDT zone has been highly integrated into the development programs,

providing new material and updating recommendations for extension services at frequent intervals. The cassava success story in Nigeria results from close interaction between international and national research and the various development projects responsible for the diffusion of genetic material and the provision of extension advice, including extensive conduct of on-farm demonstrations. The same could also be said for maize in Nigeria, though with less pressing technical constraints to getting the genetic material out to farmers, since multiplication rates for maize are more rapid.

Too often, research has failed to make the transition from identifying a technical optimum to calculating the profitability of the packages being recommended. In cases where intensification has failed to take hold, despite the presence of a support infrastructure upstream and favorable marketing conditions (*e.g.*, cocoa throughout the Region and coffee outside the Moungo Valley area), one must ask why the failure has occurred. Experience does show that there can be wide divergences between the priorities of farmers concerning the factors of production to be managed most carefully and the priorities, whether implicit or explicit, embodied in research recommendations. But in some cases, the reason for non-adoption may simply lie in the lack of profitability of the package being recommended. Are fertilizer applications profitable on perennials? What are the cost:benefit ratios for treatments with pesticides and fungicides?

Key Economic and Technical Challenges for Agriculture

To identify Regional research priorities, it is necessary to take into account not only the past record of successes and failures in the development and diffusion of innovations, but also the key challenges of an economic and technical nature that will face the Region in the years ahead. We identify two issues of short- to medium-term urgency, and a third of medium- to longer-term concern.

Competitiveness of Export and Food Crops

Especially in their export markets, producers here face major challenges from competing sources of supply and a situation of fluctuating world market prices which, despite a recent improvement, seem to follow an underlying trend of long-term decline. This tendency threatens the viability of these activities as sources of income and foreign exchange. Food crops similarly face strong competition from low-cost international sources of rice, and to a more limited extent wheat, meat and dairy products.[32] After eight years of decline, world market prices for virtually every major agricultural export had, by early 1993, attained their lowest real levels in the post-war period. (See the price graphs in

the statistical appendix.) Ironically, the exception was tropical timber, which countries are being asked to avoid exploiting for environmental reasons, although they appear competitive in this sector internationally (CARRET and CLÉMENT, 1993). With the recent turnaround, the question becomes one of gauging the length of time during which price levels will afford the Region some breathing space before another decline. Price projections appear to be extremely unreliable guides for this purpose, especially in the short to medium term.

To meet international competition, efforts will need to be undertaken at the stages of production, processing, and the organization of the commodity systems in order to lower costs and/or raise quality. In many cases, this exercise will need to begin by conducting in-depth analyses of the domestic cost structure to identify weak points within the subsectors.

The Changing Institutional Context within the Agricultural Sector

In the context of structural adjustment reforms underway in the Region since the mid- and especially the late 1980s, the agricultural sector has been undergoing major institutional changes, characterized in most cases by a retreat of the parastatal input supply and marketing organizations, by the disappearance of agricultural credit, and by a withdrawal of subsidies on chemical inputs. Oftentimes these parastatal organizations had high fixed costs, and had difficulty reducing their operating margins. Nevertheless, the result of their withdrawal has been, at least temporarily, an institutional void, as private sector operators have been unable or unwilling to replace all of their functions (UPTON, 1992). In many cases, the responsibilities for various activities (input supply, marketing, extension) are falling on relatively unorganized farmers' groups, which have little experience in dealing with these problems and no financial cushion to withstand the management risks they impose.[33]

The institutional void is most marked in the areas of credit and input supply. Under unsubsidized conditions, demand for inputs has dropped dramatically. For instance, in Ghana authorities reported a drop in demand to one-third its

32. One objective of the devaluation of the CFA franc was to give a boost to the competitive position of domestic food sectors vis-à-vis imports. Simulations (such as FAO, 1994) suggest this will have occurred for rice, but it is too early to know whether the assumptions will be borne out in practice. One must bear in mind that countries with flexible exchange rates, such as Guinea and Ghana, have had difficulty defending their domestic food sectors from imports.

33. For the cotton zone in Mali, see BERTHOMÉ and MERCOIRET (1993); for coffee in Côte d'Ivoire and Cameroon, see LOSCH (1994 *a* and *b*).

previous level. Few private sector operators are willing to bear the risk of dealing in this area. The only exception to the general drop in the use of inputs seems to be in Nigeria, which has maintained its subsidy program.

The combined result of these institutional changes, the fall in world market output prices and the removal of subsidies has been to jeopardize the conditions for agricultural intensification. Intensive coffee growing in Cameroon has been abandoned, leading to a halving of output since 1990 (LOSCH *et al.*, 1992). There has been a 20 percent decline in cotton yields in the CFDT zone, despite the fact that the governments have maintained subsidies on the output price since the last big decline in the world price in 1991 (BOSC and HANAK FREUD, 1994).

The contours of a new institutional landscape are as yet uncertain. Under a policy of market pricing of inputs and outputs, there is little that governments can do to shield producers from the sometimes rapid shifts in profitability of input use. If governments are no longer to assure markets for output, however, one response that can help insulate producers from excessive risk would be to search for technologies that are more robust in a less-certain institutional environment.

This is an issue that particularly concerns the choice of processing technologies, themselves critical to the nature of the marketing system. Within the Region, the investment choices have typically favored large-scale industrial techniques, rather than artisanal methods (coffee, rice, oil palm, cassava, yam).[34] This presents a marked contrast with the developments in the agricultural sectors of Southeast Asia and Latin America (MUCHNIK, 1993), which have left much more room for artisanal techniques. The principle of seeking more robust techniques under institutional uncertainty implies moving toward processing systems that permit multiple locations for processing (closer to the various production sites), are less dependent on high imported content for their operations, and are therefore smaller-scale than the installations often chosen in the past.

Moving toward such systems will often be needed from the competitiveness perspective as well, whether for cost cutting or for raising quality. Artisanal units, although achieving lower technical efficiency (as measured by extraction rates or by the stability of the product), can often be run at substantially lower operating costs under local management conditions. As BRICAS and his colleagues have argued (1992), consumers frequently exhibit a quality preference for artisanally-processed food products. This appears to be true not only for palm oil, but also for cassava, yam, and even cereals to the extent that this ensures greater freshness. In many cases, there may be room for increasing the technical efficiency of artisanal processing methods, which in general have

34. For a synthesis review, see BRICAS *et al.* (1992). For case studies on cassava and yams, see TARI and TOUYA (1983) and OLORUNDA (1990).

received little attention from the research system. Such research hardly needs to start from scratch. A first step should be to see what techniques can be borrowed, perhaps with modifications, from Latin America and Asia. There may also be scope for simple modifications of existing techniques employed in the Region and for diffusion of techniques among the various subregions of Africa itself (NWEKE, 1994*a*; ALEXANDRE *et al.*, 1994).

Technical Solutions to Impending Situations of Rural Land Pressure

Soil fertility is a major agroecological challenge in the Region, and in areas of high population density, farmers will need alternatives to their earlier practices of planting on virgin land when existing soils are exhausted. Although the urgency is for the medium to long term, research on these issues is still at a very early stage. In the humid zone, it is clear that solutions will need to be found in some forms of agroforestry, that is, of associating tree crops with annual agriculture.

Challenges on a Crop-by-Crop Basis

In light of these three challenges, here are some of the issues at stake for the development of the Region's major crops:

Oil Palm

Oil palm is one of the crops in which the Region has clearly lost a natural advantage: over the past twenty years, Southeast Asian countries have been able to capitalize on their yield advantage and have rapidly displaced West Africa as the major world market supplier (HIRSCH and BENAMOU, 1989). These developments are largely responsible for the fall in the world market price, which should be considered a structural feature of this market rather than a temporary phenomenon. To be sure, the fluctuations in the price of palm oil depend, as well, on the market conditions for other internationally tradeable edible oils, for which palm oil is a partial substitute. The recent upturn in prices reflects, in particular, the worldwide shortage of soybean oil, due primarily to production shortfalls in the American Midwest.

Although such conditions may make it profitable to export palm oil from time to time, the future of this crop in the Region will depend, on the whole, on its

ability to make a successful transition to supplying the domestic market at a price competitive with imports. Such a task will be easier for countries whose production is already primarily consumed locally than for Côte d'Ivoire, a substantial part of whose production is geared for the export market. The issue should not just be one of relying on high import barriers to keep out the lower-priced products, a policy that is costly to poor consumers. This is nevertheless a key element of the Nigerian strategy for protecting its oil crop sectors.

Rather, it will be important to reexamine the strategies for development between the plantation sector and the smallholder sector that has largely been left outside of the scope of past development efforts. According to available studies, the plantation sector operates with higher technical efficiency, but higher imported content and fixed costs as well (World Bank, 1989*b* and 1991). By the same token, the outgrowers associated with plantations have high unit costs. On the demand side, consumers seem to prefer the taste of artisanally-processed palm oil, although the lack of stability and the still rudimentary character of processing techniques (low extraction rates) limit the potential to satisfy the growing urban demand for edible oils.

It therefore appears imperative to develop more reliable information concerning the substitutability of the two types of palm oil product, along with perspectives for improving the corresponding subsectors. *A priori*, there would appear to be substantial scope for low-cost supply of the local market using improved planting material under smallholder conditions, provided small-scale mechanized processing units were available. Research at the Nigerian Oil Palm Research Institute (NIFOR) has yielded some interesting applications for improving the productivity of the artisanal units, although the cost of the proposed equipment remains high (ISNAR, 1988). Researchers and those in the industry are currently undertaking an inventory of available techniques to help define the needs for further research in this area (BUROTROP, 1994).

Robusta Coffee

Robusta coffee, produced by many countries in the Region, is confronted with very wide swings in world prices. Producing countries faced a generalized crisis beginning in 1986, under which none appeared able to cover all costs. Moreover, the position of robusta had deteriorated in relation to arabica varieties, whose price advantage widened during the crisis (Daviron and Fousse, 1993). African producers were in an even more unfavorable position than their Southeast Asian competitors because of much higher intermediation costs, including transportation, processing and marketing (Freud and Hanak Freud, 1994). During the crisis years, they were also less successful in reducing these costs. Since mid-1993, there has been a spectacular boom in the world price, which appears to be a short- to medium-term adjustment to the overly depressed price. In the medium to long term, when prices are likely

to decline (although perhaps not as far as their 1992-93 level), the future of coffee in the Region will depend on the degree to which countries have been able to reduce their intermediation costs and raise farm-level productivity.

Cotton

Cotton similarly has passed through an acute crisis on world markets. For this crop, the world's major producers are heavily subsidized when world prices are low: during the crisis, U.S. growers received 50 percent over the world price; Uzbekistan has been selling at a large discount over actual production costs in order to earn scarce foreign exchange (J.M. CONSULTANTS, 1995). In contrast to the situation in coffee, cotton producers in this Region have undertaken deliberate and successful cost-cutting measures, particularly at the intermediation stage, and to a lesser extent at the production stage, since the mid-1980s. In most cases, there is little additional room for maneuver, and the financial equilibrium of cotton subsectors will depend on the maintenance of the mild improvement in the international price since late 1993.

Perhaps more than others, cotton-based systems also highlight the technical challenge of soil fertility maintenance in the savanna zones. Thanks to the relatively high doses of chemical fertilizers applied by farmers in the cotton projects, these systems have been among the first to move toward a certain degree of sedentarization. Finding economically and socially viable methods of land use management that can enable farmers to furnish the soils with sufficient quantities of organic matter is a challenge for the sustainability of these systems (BOSC and HANAK FREUD, 1994).

Cocoa

For cocoa, this Region is the world's largest producing area, and in contrast to oil palm, it appears to be well-placed in terms of costs of production and quality in relation to other major production zones (BLOOMFIELD, 1994; JOUVE and DE MILLY, 1990). Two big uncertainties will determine its ability to maintain this position in the future. In the medium term, the issue is the extent to which the spread of the virulent fungus species, *phytophtora megakarya,* can be contained, and the degree to which it can be controlled in infested areas at reasonable cost. This fungus, widely present in Cameroon, Nigeria and Togo but with recent sightings in Ghana, extracts yield-loss rates of 80 to 90 percent if left untreated. Under Cameroonian conditions, the multiple treatments needed are only cost-effective on relatively high-yielding plots (PETITHUGUENIN, 1993*a*).

The longer-term issue concerns the conditions for replanting as the existing cocoa farms age; the dynamics of growth in this crop have been based on

planting on virgin forest, a source of fertile land that is rapidly running out, and there appear to be constraints to replanting on old stands – at the least higher investment costs, at the worst substantially lower yield conditions (PETITHUGUENIN, 1993 *b*). Research is needed to clarify the extent to which technical constraints are the main barrier, as distinct from socioeconomic factors such as the age of planters, many of whose children, schooled on cocoa proceeds, are unwilling to take over the farms, often under terms of succession (inheritance, indivisibility, etc.) that are less than attractive (RUF, 1992).

Rubber

Rubber production in the Region also does not appear to suffer from natural disadvantages in relation to Southeast Asia, although there are higher management costs under local conditions (HIRSCH, 1990 *a*). The Region is a marginal supplier (6 percent of world supply), a factor that leads to some marketing handicaps. New market opportunities seem to be opening up for the wood from the rubber tree, which is beginning to be used in mass-produced furniture.

This crop has some favorable properties with respect to soil fertility, which suggest that it might be usefully explored as a diversification crop in smallholder (not outgrower) agroforestry systems. Such a development would presuppose the existence of industrial capacity to process crumb and a purchasing network for rubber balls, with primary processing done by farmers. Under such a system, there is no need for smallholders to be located right near the factory as is the case in the plantation-outgrower schemes. Such a decentralized system already exists in Nigeria in the Benin City area.

Coconut Palm

Since coconut palm faces even more acute international competition from Asian producers than does oil palm, its potential as an export crop appears extremely weak. Unlike oil palm, whose products are in high demand locally, there seem to be few reasons to expect a rapid growth in this crop in local diets. However, from the perspective of crop associations, the coconut palm has interesting properties that may merit exploring. Coconut is, for example, a beneficial shade crop for cocoa in Malaysia. Its successful integration into agroforestry systems in this Region would depend not only on biological factors, but also on the ability of the products of this plant to find a niche in local consumption habits.

Cassava

Cassava is already a staple food in much of the humid zone and has been spreading to the Nigerian savanna in the form of *gari* (NWEKE, OGWU and DIXON, 1992). The key issues for the further expansion of this crop on a commercial basis concern the ability to spread the conditions for the Nigerian success to other countries. One part of the equation concerns the improved varieties: will farmers and consumers accept the bitter Nigerian varieties, or will it be necessary to make further advances in the "sweet" cassavas for adoption in countries where these are preferred? A second part concerns the availability of mechanical processing to increase storage capability, reduce transport costs and enhance the convenience for consumers, taking into account the diversity of possible types of preparations. In the Nigerian south, processed products such as *gari* have been estimated to have high income elasticity even among wealthier urban dwellers (NWEKE, OKORJI, NJOKU and KING, 1992).

Yam

For yam, the questions on the horizon concern its ability to defend its position as a basic food item in the western part of the Region, given its relatively high production costs for equivalent caloric value as compared with other staples. In its favor is the fact that it has some margin in consumer preferences. Certain of the most popular white varieties are considered "preferred staples," for which consumers are willing to pay a higher price than for substitutes like cassava and coarse grains. However, if means are not found to lower production costs, yam risks to maintain its preferred position by becoming a luxury item, purchased for special rather than everyday occasions. In Nigeria, relative price movements between yam and some of the other staples are suggestive of this phenomenon (WORLD BANK, 1989*a*). At the same time, the market pull of yam has been pushing commercial production further and further north into the subhumid zone (CARR, 1989; DUMONT *et al.*, 1994; CHALÉARD, 1988*b*).

Maize

Maize is often considered to have great potential as an answer to the Region's food needs, in large part because of high technical potential with available improved varieties. Yet an important constraint to its expansion as a commercial crop will be market size. There appear to be important differences within the Region concerning the acceptability of maize as a staple food in areas with large population concentrations (BOSC and HANAK FREUD, 1994).

The traditional maize eating areas of the coast are those in the non-forest zone: Benin, Togo and the Accra region of Ghana. Maize has also shown its ability to spread as a staple food throughout the savanna areas of Nigeria where diets were traditionally based on sorghum and millet.

Maize has had much more limited success so far in breaking into the cities in traditional rice, root and tuber eating areas (Abidjan, the cities of the Nigerian south, and most of the other coastal cities in the humid zone). In these areas, the consumption of maize is mainly limited to agro-industrial uses – a small market for animal feed and in some cases for breweries – and to green maize when in season (FUSILLIER, 1991). An exception seems to be Cameroon, where there is a stronger maize eating tradition in the more humid areas thanks to its longstanding insertion in the intensive agricultural systems in the Moungo area (CONTE *et al.*, 1993). In general, the humid zone consumers will need to be convinced to switch over to maize, and that will only happen if the relative price drops considerably. This means that maize will need to become more productive (lower cost) than it currently is in relation to the other staples, both at the level of on-farm costs and processing.[35]

Rice

Rice faces serious problems of competition from lower-priced imports, despite its longstanding role in the farming systems in the western areas (BENZ and MENDEZ DEL VILLAR, 1994; CHATAIGNER, 1992; PEARSON *et al.*, 1981). Many of the traditional rice growing areas are subsistence-based, whereas the towns are mainly supplied by imports. It seems unlikely that the upland rice systems can compete with imports, given their low technical performance, due essentially to the lack of weed control. For alternative systems in valley bottoms and lower slopes, the gaps in the knowledge base are still too large to determine whether output can be expanded to serve the market at low cost. In addition, in some cases, Côte d'Ivoire in particular, the organization of processing in large-scale industrial complexes has dramatically increased costs over what they would be with artisanal hulling machines (LOUIS BERGER INTL., 1990; FREUD *et al.*, 1991).

Plantain

Plantain, a staple in the humid zone, also suffers from a lack of knowledge about production systems. In addition, the demand aspects of this crop, including the marketing flows, are poorly understood at the level of the

35. A similar problem of cost competitiveness is posed for urban consumers in Mali, where the choices are rice and the traditional coarse grains (sorghum and millet). See BOUGHTON *et al.* (1994).

Region, despite some recent research in this area in Cameroon (TEMPLE, 1994) and Côte d'Ivoire (N'GUESSAN *et al.*, 1993). It would be beneficial if a Region-wide study on demand and supply issues were undertaken, along the lines of the COSCA study for cassava. Although one must treat the aggregate statistics with caution, it is interesting to note the apparent correlation between the relative lack of research results on this crop and the fact that plantain is the only crop that registers a per capita decline over the past decade on the regional level.

Fruits

Commercial fruit crops such as banana, pineapple and mango are often signaled as a potential channel for export diversification, since their external market conditions appear less unfavorable. Within the Region, the only large-scale producers of these crops for export are Côte d'Ivoire (all three fruits) and Cameroon (banana); other countries (Ghana, Guinea) promoting this strategy have smaller sectors (under 10,000 tons), currently limited to air transport.

Although there is doubtless potential in this direction, it is important to note the considerable challenges for successfully commercializing these highly perishable products – especially when passing to large-scale production that can be handled by boat and sold at lower cost. Nor can all countries expand to fit the same niche. For instance, the market for air-shipped pineapples in Europe is a narrow "luxury" market; bananas fetch a high price only in the context of current protection accorded by the European Union (FABRE, 1995), a situation that continues to be contested by competing producers in the Latin American "dollar zone" (BORRELL and YANG, 1992). It is therefore unlikely that such diversification crops can be seen as a major replacement for export earnings from some of the more traditional primary commodity exports, even if their contribution to the economy of the producing zones themselves is significant.

The Specific Challenges for Agricultural Research

Looking ahead, we identify four specific challenges for agricultural research, of which three are thematic and the fourth organizational:

The Profitability of Technical Messages

This approach needs to be integrated systematically into the applied research process. To start with, there needs to be an effort to understand the cost:benefit relationship of existing research recommendations for elements of the "package," particularly for fertilizer and pesticide use. This can help to guide research in the next stage of finding ways to cut down on the purchased input and labor costs of the recommendations. Progress in this area has already been made in the CFDT cotton zone, and has begun in coffee for both treatments and harvesting techniques. It is in this spirit that research has noted the need to find ways to halve the nitrogen fertilizer needs of maize (IITA, 1992). This needs to become a generalized approach.

A medium- to long-term goal of such a focus is to be able to provide more nuanced recommendations to farmers, depending on the specific conditions at hand: effects of annual rainfall variation on planting and fertilizer recommen-

dations, variations within a country of the needed number of phytosanitary treatments, and so on (REBUFFEL *et al.*, 1994; MANYONG and CARSKY, 1994). This approach will imply a revolution in the type of messages given by extension services, which currently tend to be geographically uniform and insensitive to changing profitability conditions. The difficulties experienced by cotton extension in Côte d'Ivoire with "decision matrices" (CRÉTENET, 1987) are instructive in this respect (P. BISSON, pers. comm.)

Although cotton research is unusual for its relatively high degree of specificity of the recommendations by production region, recommendations within an area were standardized for all producers. In an effort to cut down on input waste, the extension services attempted to provide their agents with a means for tailoring input use recommendations to the requirements of individual farmers within an area, according to their time of planting, since late planting reduces the effectiveness of the "optimal" doses of fertilizers based on timely planting schedules. The extension agents were provided with "decision matrices" to help them calculate the individual fertilizer needs. In the event, there proved to be strong farmer resistance to this innovation, and it had to be abandoned. Responsibility lies at least partly with a problem of communication: the matrix was widely interpreted as a tool to sanction farmers who planted late. This highlights the need for developing unambiguous messages, and for a close working relationship and understanding among research, extension, and the farming community.

The Constraints in Peasant Farming Systems

To more effectively serve its smallholder clients, research needs to continue its move away from a "productivist" approach concerned with raising yields under high input conditions, to an approach concerned with raising yields under constraints likely to be faced by farmers. Through interdisciplinary work, including breeding, agronomy and plant protection, there is a need to tackle objectives of:

Phytosanitary Protection

Cost constraints to the use of chemical agents, combined with the environmental risks they impose, have led to a new approach to the problem of pest and disease control via integrated management (KISS and MEERMAN, 1991; NEUENSCHWANDER, 1993). Alternative strategies, including genetic improvement, classical biological control and limited chemical control as a function of threshold populations, need to be explored, as does the more systematic use of local resources for phytopharmacology. For example, extracts from the bark of the neem tree are used as insecticide.

Improvement of Plant "Rusticity"

Other plant characteristics that increase the "rusticity" of the crop under smallholder conditions include drought tolerance and lower sensitivity to following a strict schedule for various agricultural tasks (planting, weeding, harvesting), and will in many cases be an important objective of breeding programs.

Reduction of Labor Requirements and Investment Costs

Some successful examples of plant characteristics and farming techniques that reduce labor requirements and/or investment costs are early-maturing cassava, cocoa, and oil palm varieties; slower-growing oil palm trunks that cut down on harvesting costs; improved rubber tapping techniques; and the introduction of animal traction in the savanna zones through the cotton projects. By contrast, there has been too little work on reducing labor inputs into coffee harvesting. This may be as simple as introducing less onerous gathering techniques. For instance, belted harvesting baskets that can be worn at waist level are widely used in Latin America but have not been introduced to this Region, where farmers continue to bend to the ground to fill their baskets. Solutions that cut down on weeding needs are required for many crops. It may not be a coincidence that some of the crops that have done best in this Region are those that are able to fight against weeds naturally with their canopy cover (mature cocoa, rubber and oil palm, cassava).

To determine the most important objectives in each crop, there will be a need to combine analysis of the important constraints to be tackled and the scientific possibilities to do so. In many cases tradeoffs will exist between the choice to focus on characteristics for market-oriented or subsistence-oriented farmers. Given the strong links between innovation and the market, and the high diversity of the needs in subsistence-oriented systems ("population-driven" systems, in SMITH and WEBER's [1994] terminology), there is probably more to be gained by focusing efforts on the characteristics enhancing conditions of crops destined for the market.

The Sustainability of the Agricultural Systems

The search for modes of intensification that are not highly capital-intensive, and thus affordable by the Region's farmers, is mainly a challenge for agronomic research involving new types of crop associations and, where possible, the association of livestock with crop systems.

The Humid Zone

In the humid zone, there is a clear need to develop recommendations on viable ways to restore fertility through organic-inorganic fertilizer combinations, most particularly through crop associations incorporating perennials, given the crucial role of trees in preventing soil erosion and nutrient depletion in this Region (NAIR, 1990). At present, the state of knowledge on fertility issues is both incomplete and disparate.

An important first step in pushing forward the frontiers of knowledge on fertility issues could be to pull together the research results touching various aspects of the problem into a "state of the art" review, as has been done for the savanna zones (PIÉRI, 1992). Such a study could help identify the data gaps that need to be filled in order to provide farmers with pertinent advice. Two lines of past research would warrant particular attention in such a review.

The first is agronomic work on fertilization of perennial crops. In some cases (oil palm, rubber – CIRAD, 1990 and 1991), opinions on the effects of fertilization diverge. In others (coffee, cocoa), farmers' practices contradict the recommendations of research. Such an exercise could draw on long-term data from research stations and large-scale plantations to identify the technical issues at stake and compare this information with that arising from monitoring and evaluation work on the reasons underlying smallholder practices.

The second area is the role of intercropping on soil fertility maintenance. To date, the major system promoted for associations of annuals and perennials, alley cropping, has hardly been adopted after a decade of on-farm testing. This may be because farmers in the Region are not yet under sufficient land pressure, given the high labor costs of the alley farming system. But perhaps successful adoption will require the consideration of associations with a wider range of trees, which themselves have an economic value (CGIAR-TAC, 1990).

The preoccupation with introducing leguminous trees into the system may have precluded the consideration of integrating some perennials with economic value (rubber, oil palm, and various local trees with medicinal and food values). Although non-leguminous, these other trees can have value in certain aspects of soil fertility retention, at the least in preventing leaching. Although this area has not received adequate attention, there have been some studies of intercropping of food and perennial crops at the beginning of the growth cycle (*e.g.*, LEDUC, 1984; ONWUBUYA *et al.*, 1989); of introducing oil palms into alley cropping systems (IITA in association with NIFOR); and of intercropping oil palm or coconut and cocoa (NIFOR and the Cocoa Research Institute of Nigeria [CRIN, 1989]; the Cocoa Research Institute of Ghana).

Further experimental work on crop associations incorporating economically interesting perennials is an imperative for the Region; a synthesis of existing findings can provide a useful starting point. One obstacle to research in this area has been institutional: the separation of perennial crop research from the

research on food crop systems, and frequently the separation among researchers working on various perennial crops and forest trees.

Given the long time lags that will be involved in generating results by traditional experimentation methods for these long-lived crops, it might be fruitful to explore more unconventional "on-farm" experimentation in this area, compiling performance data from actual associations being practiced. There is a need to gather information on both the biological and economic compatibility of the various possible associations. By biological compatibility, we mean the complementarities, synergies, or competition among root systems vis-à-vis nutritional resources and among vegetative cover systems vis-à-vis sunlight. Economic compatibility concerns the timing of periods of production and the calendar of labor requirements, the investment needs and length of time before entering into production phase, as well as the articulation between life cycles of the perennial crops and those of the planters, given the tenure problems linked to inheritance.

The Subhumid Zone

In the subhumid zone, although the diagnosis of the problem seems clear, there are challenges to finding solutions that will increase the attractiveness of fertility restoring practices. Concerning the introduction of organic fertilizers, research is needed to expand the range of options available: how to increase the biomass recycled by animals; what legume crops to introduce. The rich assortment of plants available in the subhumid zones and the economic value of certain local tree species suggest that not all the possibilities have been adequately explored. The same applies to non-tree legumes, which are more likely to be introduced into crop cycles if they have their own economic value. This line of research may imply some basic genetic work on the individual legumes, such as groundnuts and cowpeas, for which little recent research has been done concerning these agroecological zones (Gillier and Silvestre, 1969; CORAF, 1990; Cattan and Schilling, 1992).

Technologies of the future should also attempt to better exploit our understanding of the role of fallow in fertility restoration, to see to what extent it can be mimicked by agricultural activities (Garin, 1993). The issue here is to encourage the two dynamic thrusts of the "live phase" of the soil, rooting and biological activity. The development of the root system and the global root mass should be favored in order to ensure uninterrupted biological activity related to humification and mineralization. This means that research orientations should give greater attention to this biological dimension: varietal selection that improves the root mass, intercropping trees and crops that have complementary root systems, and so on.

Devising systems solutions is more complex than agronomic work in monocrop situations and will need to involve substantial on-farm research to unders-

tand the functioning of the associations and develop appropriate messages. Such on-farm research should receive a high priority.

For the Region as a whole, it appears that the questions relating to soil fertility maintenance and restoration cannot be viewed in isolation of land tenure conditions of production. Since trees and perennial crops tend to demarcate a certain right of tenure, this limits the possibility of tree planting for those who do not have clearly recognized rights to the land. Soil fertility improvements under precarious tenure arrangements can, moreover, lead rapidly to revisions of rental terms, or even access to the land in question. This implies that research needs to take into account the tenure dimension and, from an operational standpoint, to reason at the level of larger land areas under the jurisdiction of communities (*terroirs*). Such an approach poses a definite methodological challenge, given the diversity of situations encountered in the field.[36]

Closer Linkages Between Research and Smallholders

Close research-farmer linkages have been a natural part of the development process in plantation agriculture, where the producers have been in a position to articulate their concerns and needs: producer-clients have been able to "place orders" to the research system for answers to specific problems. The challenge ahead for research seeking solutions for peasant agriculture is to find ways to integrate these farmers into the research process. Until now, this has been possible through contacts with farmers' associations where they exist, through joint work with extension services, and through on-farm trials that enable research to better take into account the real conditions of production. To become full partners in the process, farmers' groups will need appropriate support (MERCOIRET, 1994). For producers, this implies increased access to training and to information. For research, it implies the willingness to establish new partnerships and to envisage new institutional mechanisms.

36. For a discussion of approaches to resource management at the level of *terroirs*, drawing on Sahelian examples, see MERCOIRET (1994) and MERCOIRET *et al.* (1994).

Complementary Actions to Support Technical Progress in Agriculture

In the current climate of privatization and the retreat of the state from many of its service roles in the agricultural sector, there are nevertheless some areas where public support is likely to remain a prerequisite for agricultural innovation.

Support for the Diffusion of Genetic Material

Special conditions in the supply of improved genetic material (hybridization, cloning, slow multiplication processes for some crops) suggest that there is a public sector role to be played in getting genetic material out to small farmers. In some cases, improved material already exists, but its use is limited by supply constraints (oil palm, cocoa, rubber, cassava outside of Nigeria). The Nigerian cassava example shows the importance of public support to diffusion in such cases. Private sector suppliers are unlikely to step in on the scale warranted, given the risks involved (fragility of seedlings, uncertain demand under commercial conditions). This is less of a problem in the cereals, which are predominantly open-pollinated varieties, and which have more rapid multiplication rates.

Support for the Diffusion of Artisanal Processing Technologies

Actions appear warranted in two respects: on the one hand, the identification of techniques from elsewhere (Asia, Latin America and other subregions of Africa) that can be used, or adapted in some cases by research; and on the other hand, the establishment of distribution networks for machines that are suitable. Although there may be scope for improvements, processing technology for cassava, oil palm, rice, coffee already exists. The establishment of distribution networks may require subsidized credit and support to organizations that can provide processing services on a rental basis in order to make the initial investments possible.

Review of Tax and Subsidy Policies

Beyond this minimum, the experience of successful innovation also suggests grounds to reexamine the policies of taxing petroleum products and of eliminating all subsidies on inputs. Although fuel taxes are an important source of revenue in non-producing countries, the constraints to agricultural development posed by high transport costs in this zone, particularly between the savanna and the southern consumption centers, suggest that alternative tax bases, such as value-added taxes, may be needed. The Nigerian example of integrated agricultural trade, under conditions of low fuel prices, highlights the interest in posing this question.

Input subsidy elimination should be reconsidered, even if one agrees that input subsidies are a poor means of lowering the costs of production. Given the role of subsidy in the reduction of risk, subsidies on inputs (fertilizer in particular) can encourage farmers to innovate, and to sedentarize their production systems. Here the Asian experience, where input subsidies continue to be the rule, should not be forgotten, nor should the fact that the only "green revolution" occurring in the Region in food crops is in Nigeria, where the subsidies have continued. It is also the case that in Africa, the "market" price of inputs is extremely high, with landed costs often at double the world market price, even before adding upland transport costs (Rizets, 1994). Governments may not have the resources under the current crisis conditions. But this may be an area meriting support by donors as a development tool.

References

Syntheses on research and technology transfer

BOSC PM, CALKINS P, YUNG JM. 1990. Développement et recherche dans les pays sahéliens et soudaniens d'Afrique. Montpellier, France: CIRAD, 310 pages.

BOSC PM, DOLLÉ V, GARIN P, YUNG JM. 1992-94. Le développement agricole au Sahel. Vol. I, Milieux et défis; Vol. II, Recherches et techniques; Vol. III, Terrains et innovations; Vol. IV Défis, recherches et innovations; Vol. V, Bibliographie. Montpellier, France: CIRAD-SAR, Collection documents systèmes agraires, no. 17.

BOSC PM, HANAK FREUD E. 1994. Agricultural innovation in the cotton zone of francophone West and Central Africa: Progress achieved and challenges ahead. Paper presented at IITA/FAO workshop on sustainable cropping systems for the moist lowland savanna zones of sub-Saharan Africa, Cotonou, Benin, 19-23 September 1994. Forthcoming as working paper, Unité de recherche en prospective et politiques agricoles, Paris, France: CIRAD, 33 pages.

BRADER L. 1991. IITA: recent achievements and future outlook. Text of presentation at International Centers Week, Washington D.C., October 1991. Ibadan, Nigeria: IITA, 27 pages.

BRICAS N, BRIDIER B, FUSILLIER JL, SAUTIER D, THUILLIER C. 1992. La valorisation des produits vivriers dans les pays d'Afrique humide et sub-humide. Situation et perspectives pour la recherche. Paper presented at the regional workshop on revitalizing African agricultural research, SPAAR and the Conference of Ministers of Agriculture of West and Central Africa, Abuja, Nigeria, 5-9 October 1992. Washington D.C., USA: SPAAR, 39 pages + appendixes.

CARR SJ. 1989. Technology for small scale farmers in sub-Saharan Africa. Experience with food crop production in five major ecological zones. Technical paper no. 109. Washington D.C., USA, World Bank, 106 pages.

CGIAR-TAC. 1990. Report of the third external programme review of the International Institute of Tropical Agriculture. October 1990. Washington D.C., USA: TAC, 85 pages + appendixes.

CIRAD. 1992*a*. Technical notes: citrus, pineapple, bananas and plantains, cocoa, coffee, coconut palm, cotton rubber, oil palm. Paper presented at the regional workshop on revitalizing African agricultural research, SPAAR and the Conference of Ministers of Agriculture of West and Central Africa, Abuja, Nigeria, 5-9 October 1992. Washington D.C., USA: SPAAR.

CONFERENCE OF MINISTERS OF AGRICULTURE OF WEST AND CENTRAL AFRICA (CMAWCA), SPAAR. 1994. Coalition for change: a framework for action for improving technology development and transfer in the humid and sub-humid zones of West and Central Africa. Fourth draft, September 1994. Washington D.C., USA: SPAAR.

D'AQUINO P, LHOSTE P, LE MASSON A. 1994. Systèmes de production mixtes, agriculture pluviale et élevage en zones humide et subhumide d'Afrique. Draft working paper, July 1994. Montpellier, France: CIRAD-EMVT, 108 pages.

DRACHOUSSOF V, FOCAN A, HECQ J. 1991. Le développement rural en Afrique centrale. 1908-1960/62. Synthèse et réflexions, Brussels, Belgium: Fondation Roi Baudoin, 2 vol., 1 023 pages.

ELEMO KA, KUMAR V, OLUKOSI JO, OGUNGBILE AO. 1990. Review of research work on mixed cropping in the Nigerian savanna. Samaru miscellaneous paper no. 127. Nigeria: IAR, Samaru, Ahmadu Bello University, 130 pages.

IITA (International Institute for Tropical Agriculture). 1992. Food crop improvement and resource research: major achievements and challenges for the future. Paper presented at the regional workshop on revitalizing African agricultural research, SPAAR and the Conference of Ministers of Agriculture of West and Central Africa, Abuja, Nigeria, 5-9 October 1992. Washington D.C., USA: SPAAR,18 pages.

JABBAR M. 1993. Evolving crop-livestock farming systems in the humid zone of West Africa: Potential and research needs. Outlook on Agriculture, 22 (1):13-22.

JABBAR M. 1994. Energy needs, opportunities and potentials of mixed farming in the moist savanna. Paper presented at the IITA/FAO workshop on sustainable cropping systems for the moist lowland savanna zones of sub-Saharan Africa, Cotonou, Benin, 19-23 September 1994. Ibadan, Nigeria: IITA.

KISS A, MEERMAN F. 1991. Integrated pest management and African agriculture. Technical paper no. 142, Africa Region Technical Department. Washington D.C., USA: World Bank, 122 pages.

LHOSTE P, DOLLÉ V, ROUSSEAU J, SOLTNER D. 1993. Zootechnie des régions chaudes: les systèmes d'élevage. Paris, France: Ministère de la coopération, collection manuels et précis d'élevage, 288 pages.

MINISTERE DE LA COOPÉRATION ET DU DÉVELOPPEMENT. 1991*a*. Mémento de l'agronome. 4th edition. Paris, France: Ministère de la coopération, 1635 pages.

MUCHNIK J (coordinator). 1993. Alimentation, techniques et innovations dans les régions tropicales. Paris, France: L'Harmattan, 556 pages.

PIÉRI C. 1992. Fertility of Soils: A future for farming in the West African savannah. Berlin, Germany: Springer Verlag, 346 pages.

REBUFFEL P, BIGOT Y, BISSON P. 1994. Constraints on the testing and adoption of technology. Several methods for taking into account the agricultural diversity used in moist savanna zones in francophone Africa. The institutional consequences. Paper presented at the IITA/FAO workshop on sustainable cropping systems for the moist lowland savanna zones of sub-Saharan Africa, Cotonou, Benin, 19-23 September 1994. Ibadan, Nigeria: IITA, 19 pages.

SMITH J, WEBER GK. 1994. Strategic research in heterogeneous mandate areas: an example from the West African savanna. *In* Agricultural Technology Policy Issues for the International Community, Anderson JR (ed.), London, UK: CAB International.

SPURLING A, PEE TY, MKAMANGA G, NKWANYANA C. 1992. Agricultural research in Southern Africa. A framework for action. Discussion paper no. 194, Africa Technical Department Series. Washington D.C., USA: World Bank, 61 pages.

WEIJENBERG J, DIONÉ J, FUCHS-CARSCH M, LEFORT J. 1993. Revitalizing agricultural research in the Sahel: a proposed framework for action. Discussion paper no. 211, Africa Technical Department Series. Washington D.C., USA: World Bank, 89 pages.

WORLD BANK. 1987*a*. West African Agricultural Research Review. West African Projects Department, 1985-86. Washington D.C., USA: World Bank, 420 pages.

The physical environment and resource management

BERGER M, BELEM PC, DAKOUO D, HIEN V. 1987. Le maintien de la fertilité des sols dans l'ouest du Burkina Faso et la nécessité de l'association agriculture élevage. Coton et fibres tropicales, 42(3): 201-210.

BERGER M. 1991. La gestion des résidus organiques à la ferme. *In* Savanes d'Afrique, terres fertiles ? Actes des rencontres internationales, Montpellier, 10-14 December 1990. Paris, France: Ministère de la coopération et du développement, CIRAD, pages 293-315.

CARRET JC, CLÉMENT J (coordinators). 1993. La compétitivité des bois d'oeuvre africains. Paris, France: Ministère de la coopération, collection rapport d'étude, 298 pages.

CÉSAR J, COULIBALY Z. 1991. Le rôle des jachères et des cultures fourragères dans le maintien de la fertilité des terres. *In* Savanes d'Afrique, terres fertiles ? Actes des rencontres internationales, Montpellier, 10-14 December 1990. Paris, France: Ministère de la coopération et du développement, CIRAD, pages 271-287.

CHROMOLAENA ODORATA NEWSLETTER. 1994. Summary of proceedings of the Third International Workshop on Biological Control and Management of *Chromolaena Odorata*, Abidjan, Côte d'Ivoire, 15-19 November 1993.

CIRAD. 1992*b*. Revue externe du Centre technique forestier tropical. Paris, France: CIRAD.

CLEAVER K, SCHREIBER G. 1992. The population, agriculture and environment nexus in sub-Saharan Africa. Agriculture and Rural Development Series no. 1, Africa Region Technical Department. Washington D.C., USA: World Bank, 206 pages.

ESPACE (Evaluation et suivi de la production agricole en fonction du climat et de l'environnement). 1987. Annual report. Montpellier, France: CIRAD-IRAT, 458 pages.

ESPACE (Evaluation et suivi de la production agricole en fonction du climat et de l'environnement). 1988. Annual report. Montpellier, France: CIRAD-IRAT.

FOREST F, REYNIERS FN, LIDON B. 1991. Prendre en compte le risque agroclimatique et le coût de l'intensification pour analyser la faisablité de l'innovation. *In* Savanes d'Afrique, terres fertiles? Actes des rencontres internationales, Montpellier, 10-14 December 1990. Paris, France: Ministère de la coopération et du développement, CIRAD, pages 531-541.

GARIN P. 1993. Rôle des jachères dans les systèmes de culture tropicaux pour maintenir la capacité de production des sols et fournir des éléments nutritifs pour les cultures en rotation. Bibliographic note. Document CIRAD-SAR no. 97/93. Montpellier, France, CIRAD-SAR, 45 pages.

GIGOU J. 1987. L'adaptation des cultures dans le centre de la Côte d'Ivoire. L'agronomie tropicale, 42 (1):1-12.

HIEN V, BELEM PC, BERGER M, RICHARD L. 1984. Aspect général de l'évolution de la fertilité des sols burkinabé en culture continue. Notes et documents burkinabé, 15 (4):18-24.

LABROUSSE R. 1993. Typologie des problèmes spécifiques à la zone inter-tropicale humide (écologie et systèmes agraires). Réseau recherche-développement. Groupe de travail "avenir de la zone inter-tropicale humide". Paris, France: Caisse française de développement, 74 pages.

LAL R, OKIGBO B. 1990. Assessment of soil degradation in the southern states of Nigeria. Environment working paper no. 39, September 1990. Washington D.C., USA: World Bank, 58 pages.

LANDAIS E, LHOSTE P, GUÉRIN H. 1991. Systèmes d'élevage et transferts de fertilité. *In* Savanes d'Afrique, terres fertiles ? Actes des rencontres internationales, Montpellier, 10-14 December 1990. Paris, France: Ministère de la coopération et du développement, CIRAD, pages 219-270.

LEDUC B. 1984. Liaison recherche-développement, recherche de systèmes stables de cultures vivrières en zone forestière. Premier bilan 1971-1982. Bouaké, Côte d'Ivoire: IDESSA, 164 pages.

MERCOIRET MR, DEMANTE MJ, GILLET T, LASICA Y, MERCOIRET J. 1994. Développement rural participatif, durabilité et environnement. Rome, Italy: FAO.

NAIR PKR. 1990. Prospects for agroforestry in the tropics. Technical paper no. 131. Washington D.C., USA: World Bank, 90 pages.

REYNIERS FN, FOREST F. 1989. Améliorer l'alimentation hydrique et son efficience en agriculture pluviale en Afrique au sud du Sahara. *In* Agriculture irriguée en Afrique, vol. I. Wageningen, The Netherlands: CTA, pages 107-139.

RUF F, BEAUSEJOUR OK, KONAN KONAN G, KONAN N'GUESSAN F. 1992. Après la forêt, quelle stabilisation de l'agriculture de plantation. Le cas du département d'Abengourou, Côte d'Ivoire. Report no. 04/92. Montpellier, France: CIRAD-SAR, 21 pages.

SAUTTER G. 1958. De l'Atlantique au fleuve Congo. Paris, France: Mouton.

VAN DER POL F. 1990. L'épuisement des terres, une source de revenus pour les paysans du Mali-sud. *In* Savanes d'Afrique, terres fertiles? Actes des rencontres internationales, Montpellier, 10-14 December 1990. Paris, France: Ministère de la coopération et du développement, CIRAD, pages 403-418.

The socioeconomic and institutional environment

BERNSTEN RH, STAATZ JM. 1993. The role of subsector analysis in setting research priorities. Staff paper no. 92-104. East Lansing, USA: Michigan State University, Department of Agricultural Economics, 13 pages.

BERTHOMÉ J, MERCOIRET MR. 1993. L'aventure ambiguë (désengagement de l'Etat, organisation des producteurs, professionnalisation de l'agriculture). Courrier de la planète, courrier Afrique, 18: 5-6.

BRIDIER M, MICHAILOF S. 1980. Guide pratique d'analyse de projets. Paris, France: Economica, 264 pages.

CHERVEL M, LE GALL M. 1989. Manuel d'évaluation économique des projets: la méthode des effets. Paris, France: Ministère de la coopération et du développement, collection méthodologie, 2nd edition, 202 pages.

COLIN JP, LOSCH B. 1990. "Touche pas à mon planteur". Réflexions sur les "encadrements" paysans à partir de quelques exemples ivoiriens. Politique africaine (40):83-99.

DEVARAJAN S, DE MELO J. 1991. Membership in the CFA Zone: Odyssean journey or Trojan horse? *In* Economic Reform in Sub-Saharan Africa. A World Bank Symposium, Chibber A, Fischer S (eds.), Washington D.C., USA: World Bank, pages 25-33.

DURUFLÉ G, FABRE P, YUNG JM. 1988. Manuel d'évaluation des effets sociaux et économiques des projets de développement. Paris, France: Ministère de la coopération et du développement, collection méthodologie de la planification, no. 22, 201 pages.

EGG J, AFFONDA AS, ENGOLA OYEP J, HARRE D, IGUÉ JO, SOULE BG. 1993. L'intégration par les marchés dans le sous-espace Est: l'impact du Nigéria sur ses voisins immédiats. Paris, France, Club du Sahel (OECD), IRAM, INRA, UNB, 150 pages.

FAO (Food and Agriculture Organization of the United Nations). Various years. Production yearbook. Rome, Italy: FAO.

FAO. 1994. Etude de la dévaluation du FCFA sur la compétitivité des productions rizicoles dans les pays de l'UEMOA. Report no. 107/94 BOAD WAF 2. Rome, Italy: FAO, 48 pages + appendixes.

FREUD C. 1988. Quelle coopération ? Un bilan de l'aide au développement. Paris, France: Karthala, 268 pages.

FREUD C. 1991. La zone franc est-elle le bouc émissaire de l'échec du développement? Cahier d'études africaines, 31 (1-2) no. 121-22:159-74.

GAVIRA J, BINDLISH V, LELE U. 1989. The rural road question and Nigeria's agricultural development. MADIA discussion paper no. 10, Washington D.C., USA: World Bank, 35 pages.

GUILLAUMONT P, GUILLAUMONT S (eds). 1988. Stratégies de développement comparées: zone franc et hors zone franc. Paris, France: Economica, 766 pages.

IGUÉ JO. 1989. Les périphéries nationales: support des échanges régionaux. Paper presented at the Lomé seminar on regional cereal species in West Africa, 6-11 November 1988, 15 pages.

KALASA B. 1993. Description du peuplement en Afrique de l'Ouest. Commentaire de la base de données. Available in English as working paper no. 1, West Africa Long Term Prospective Study. African Development Bank, Club du Sahel, CILLS. Paris, France: Club du Sahel (OECD), 124 pages + appendixes.

LOSCH B. 1994*a*. "Cameroun" and "Côte d'Ivoire" *In* Cafés: études de cas sur la compétitivité des principaux pays producteurs. Paris, France: Ministère de la coopération.

LOSCH B. 1994*b*. Les agro-exportateurs face à la dévaluation. Politique africaine (54):88-103.

MERCOIRET MR (ed.). 1994. L'appui aux producteurs ruraux: guide à l'usage des agents de développement et des responsables de groupements. Paris, France: Ministère de la coopération, Karthala, 464 pages.

NINNIN B. 1994. Géographie économique du milieu ouest-africain ; marchés, peuplement, agriculture, routes ; éléments de modélisation. Available in English as working paper no. 4, West Africa Long Term Prospective Study, African Development Bank, Club du Sahel, CILLS. Paris, France: Club du Sahel (OECD), 107 pages + appendixes.

RIVERSON J, GAVIRA J, THRISCUTT S. 1991. Rural roads in Sub-Saharan Africa. Lessons from World Bank experience. World Bank technical paper no. 141, Africa Technical Department. Washington D.C., USA: World Bank, 48 pages.

RIZETS C. 1994. Le poids du transport dans la compétitivité de l'agriculture africaine. *In* Economie des politiques agricoles dans les pays en développement, Tome 1: les conditions internationales, Griffon M. (ed.), Paris, France: Revue française d'économie, pages 179-206.

SCHAFFER J. 1973. On the concept of subsector studies. American Journal of Agricultural Economics, 55:333-335.

STRYKER D. 1991. Ghana. *In* The Political Economy of Agricultural Pricing Policy, Krueger A, Schiff M, Valdes A (eds.). Baltimore, USA: Johns Hopkins Press for the World Bank.

UPTON M. 1992. Privatization of agricultural input delivery systems. 29e séminaire de l'association européenne des économistes agricoles (AEEA), "Les politiques alimentaires et agricoles sous ajustement structurel", Hohenheim, Germany, 21-25 September 1992. Hohenheim, Germany: University of Hohenheim.

WORLD BANK. 1989*a*. Nigeria. Strategy for agricultural growth. Report no. 7988-UNI, West Africa Department, Agriculture Operations Division. Washington D.C., USA: World Bank, 141 pages.

WORLD BANK. 1989*c*. L'Afrique sub-saharienne: de la crise à une croissance durable. Etude de prospective à long terme. Washington D.C., USA: World Bank, 346 pages.

WORLD BANK. 1991. Ghana. Medium-term agricultural development strategy. An agenda for sustained growth and development. Report No. 8914-GH, West Africa Department, Agriculture Operations Division. Washington D.C., USA: World Bank.

WORLD BANK. 1992. Market outlook for major primary commodities. Vol II: Agricultural products, fertilizers and tropical timber. Report no. 814/92, International Trade Division, International Economics Department. Washington D.C., USA: World Bank, 287 pages.

WORLD BANK. 1993. A strategy to develop agriculture in sub-Saharan Africa and a focus for the World Bank. Africa Region Technical Department, Agriculture and Rural Development Series no. 2. Washington D.C., USA: World Bank, 133 pages.

WORLD BANK. 1994. Adjustment in Africa. Reforms, results, and the road ahead. Oxford, UK: Oxford University Press, 284 pages.

Case studies of farming systems

BIARNES A, COLIN JP. 1987. Production vivrière et accès à la terre dans un village de basse Côte d'Ivoire. Cahiers des sciences humaines, 23 (3-4): 455-470.

CHALÉARD JL. 1988*a*. La place des cultures vivrières dans les systèmes de culture en agriculture de plantation: le cas du département d'Agboville (Côte d'Ivoire). Cahiers des sciences humaines, 24 (1):35-49.

COLIN JP. 1990. La dynamique des systèmes productifs agricoles en basse Côte d'Ivoire. *In* Dynamique des systèmes agraires, la dimension économique. Paris, France: ORSTOM, collection colloques et séminaires, pp 165-190.

FREUD C, AMSELLE JL, BULTEAU P, HANAK E, TOURE A. 1991. Evaluation du programme soja. CIRAD, Ministère de l'agriculture, République de la Côte d'Ivoire. Montpellier, France: CIRAD, 236 pages.

MANYONG MV, CARSKY RJ. 1994. From characterization to technology testing: a case study of the northern guinea savanna of Nigeria. Paper presented at the IITA/FAO workshop on sustainable cropping systems for the moist lowland savanna zones of sub-Saharan Africa, Cotonou, Benin, 19-23 September 1994. Ibadan, Nigeria: IITA.

SCHLIPPÉ P DE. 1956. Shifting cultivation in Africa, the Zande system of agriculture. London, UK: Routlegde and Kegan Paul, 303 pages.

TSHIBAKA BT 1989. Food production in a land-surplus, labor-scarce economy: the Zairian basin. Research report no. 74, June 1989. Washington D.C., USA: IFPRI, 70 pages.

Groundnuts

CATTAN P, SCHILLING R. 1992. Facteurs techniques d'amélioration de la productivité arachidière en Afrique de l'Ouest. Arachide infos, la lettre du réseau arachide de la CORAF, no. 4, December.

CORAF. 1990. Les acquis de la recherche arachidière et la coordination des programmes en zone à deux saisons des pluies. CORAF réseau arachide, DGRST Congo, Brazzaville, 12-16 December 1989. Dakar, Sénégal: CORAF, 85 pages.

GILLIER P, SILVESTRE P. 1969. L'arachide. Paris, France: Maisonneuve et Larose. Collection techniques agricoles et production tropicales, no. 15, 292 pages.

Plantain

N'GUESSAN A, OSSENI B, YAO N, SERY Z, GNONHOURI P. 1993. Le bananier plantain dans les systèmes agroforestiers du sud de la Côte d'Ivoire. Abidjan, Côte d'Ivoire: IDEFOR/DFA, IDESSA.

TEZENAS DU MONTCEL H. 1985. Le bananier plantain. Paris, France: Maisonneuve et Larose, 143 pages.

TEMPLE L. 1994. La dynamique d'approvisionnement en bananes plantain. Essai d'une démarche pour une recherche en économie du changement technique. Paper presented to the working group "Avenir des zones tropicales humides", Réseau recherche-développement, 27 September 1994. Paris, France: CFD, 15 pages.

Coffee and cocoa

ANTHEAUME B, PONTIÉ G. 1990. Les planteurs-rénovateurs de cacao du Litimé (centre-ouest du Togo). L'innovation technique à marche forcée. Cahiers des sciences humaines, 26 (4):623-654.

BLOOMFIELD EM. 1994. Cocoa: costs of production in various producing countries. Cocoa Growers Bulletin, (47):9-19.

BLOOMFIELD EM, LASS RA. 1992. Impact of structural adjustment and adoption of technology on competitiveness of major cocoa producing countries. Paris, France: OECD, 90 pages.

BRANDEAU J. 1969. Le cacaoyer. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 17, 304 pages.

CIRAD-IRCC, 1991. L'agronomie du cacaoyer à l'IRCC. Montpellier, France: IRCC-CIRAD, 44 pages.

CRIN (Cocoa Research Institute of Nigeria). 1989. Progress in tree crop research. Ibadan, Nigeria: Cocoa Research Institute of Nigeria, 2nd edition, 224 pages.

COSTE P, CAMBRONY A. 1989. Caféiers et cafés. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 40, 373 pages.

DAVIRON B, FOUSSE W. 1993. La compétitivité des cafés africains. Paris, France: Ministère de la coopération, collection rapport d'étude, 252 pages.

FREUD C, HANAK FREUD E. 1994. Les cafés robusta africains peuvent-ils encore être compétitifs? Cahiers d'études africaines, 136, vol. XXXIV (4):597-611.

FUNEL JM, PONTIÉ G, RAYMOND C, RUF T. 1984. Evaluation *a posteriori* de la rénovation de la caféière et de la cacaoyère du Togo. Paris, France: Ministère de la coopération et du développement, série évaluations de projets, 360 pages.

JARRIGE F. 1994. La dynamique d'offre de cacao entre marché, conditions naturelles et institutions. Interprétation à partir d'une comparaison Côte d'Ivoire - Malaisie. Ph.D. diss., faculté de science économique et de gestion, université de Bourgogne, Dijon, France, 345 pages + appendixes.

JOUVE P, DE MILLY H (coordinators). 1990. Compétitivité du cacao africain. Analyse du marché mondial et des principaux producteurs. Paris, France: Ministère de la coopération et du développement, collection rapport d'étude, 279 pages.

LOSCH B, FUSILLIER JL, DUPRAZ P. 1991. Stratégies des producteurs en zone caféière et cacaoyère du Cameroun. Quelles adaptations à la crise? Montpellier, France, CIRAD-SAR, collection documents systèmes agraires, no. 12, 252 pages.

LOSCH B, DAVIRON B, FREUD C, GERGELY N. 1992. Relance régionalisée de la production paysanne de café et de cacao au Cameroun. République du Cameroun, Ministère de l'agriculture. Montpellier, France: CIRAD, 119 pages.

PETITHUGUENIN P. 1993*a*. Bilan diagnostic de la recherche agronomique café/cacao. Quels acquis pour le développement dans le contexte actuel? Relance régionalisée de la production paysanne de café et de cacao au Cameroun. Montpellier, France: CIRAD-CP, 46 pages.

PETITHUGUENIN P. 1993*b*. Reproducibility of cocoa cropping systems: the Ivorian and Togolese experience. Paper presented at the International Conference on the Cocoa Economy, Bali, Indonesia, 19-22 October 1993. Montpellier, France: CIRAD-CP.

RUF F. 1987. Eléments pour une théorie sur l'agriculture des régions tropicales humides. I. De la forêt, rente différentielle, au cacaoyer, capital travail. L'Agronomie tropicale, 42-3:218-232.

RUF F. 1992. Les crises cacaoyères, la malédiction des âges d'or. Cahiers d'études africaines, 31 (121-122):83-134.

VIROUX R, PETITHUGUENIN P. 1993. L'écimage du caféier robusta: un mode de conduite économiquement avantageux. Café cacao thé, XXXVII (1):21-34.

WORLD BANK. 1987*b*. Ghana. Cocoa rehabilitation project. Staff appraisal report. Report no. 6816-GH, Africa Country Department IV, Agriculture Operations Division, 19 October 1987. Washington D.C., USA: World Bank, 116 pages.

Cotton

BIGOT Y, RAYMOND G. 1991. Traction animale et motorisation en zone cotonnière d'Afrique de l'Ouest. Burkina Faso, Côte d'Ivoire, Mali. Montpellier, France: CIRAD-SAR, collection documents systèmes agraires, no. 14, 95 pages.

BOUTILLIER JL, CONESA AP. 1984. Evaluation de la recherche sur le coton en RCA. Paris, France: Ministère des relations extérieures, de la coopération et du développement, série évaluations, 74 pages.

CAMPAGNE P, RAYMOND G. 1994. Le coton en Afrique de l'Ouest: une modernisation réussie? *In* Economie des politiques agricoles dans les pays en développement, tome III: les fondements microéconomiques, Benoit-Cattin M. (ed.), Paris, France: Revue française d'économie, pages 11-60.

COUSINIÉ P. 1993. Dynamique des systèmes de production en zone cotonnière au Togo. Working paper no. 9, November. Montpellier, France: CIRAD, Unité de recherche économie des filières, 114 pages.

CRÉTENET M. 1987. Aide à la décision pour la fertilisation du cotonnier en Côte d'Ivoire. Coton et fibres tropicales, 42 (4): 245-254.

FAURE G. 1990. Pression foncière, monétarisation et individualisation des systèmes de production en zone cotonnière au Togo. CIRAD-IRCT, Ph.D. diss. at ENSA, Montpellier, France, May 1990, 480 pages.

FAURE G. 1994. Les exploitations en motorisation intermédiaire au Burkina Faso. Working paper no. 1-94. Montpellier, France: CIRAD-CA, 21 pages.

FOK M. 1993. Le développement du coton au Mali par analyse des contradictions. Les acteurs et les crises de 1895 à 1993. Working paper no. 8, November. Montpellier, France: CIRAD, Unité de recherche économie des filières, 249 pages.

FUNEL JM, RAYMOND C, SCHULMANN JP, SCHWARTZ A. 1983. Evaluation économique de l'activité coton au Togo. Paris, France: Ministère des relations extérieures, de la coopération et du développement, série évaluations.

JM CONSULTANTS. 1995. Etude sur la compétitivité des producteurs de coton fibre hors zone franc. Study conducted for the Ministère de la coopération, the Caisse française de développement, and the Compagnie française pour le développement des fibres textiles, final report, January. Paris, France: JM Consultants, 43 pages.

LE ROY X. 1993. Innovation et culture cotonnière. L'exemple de la Côte d'Ivoire septentrionale. *In* Innovation et sociétés. Actes du XIVe séminaire d'économie rurale, Montpellier, France, 13-16 September 1993. Montpellier, France: CIRAD-MES, vol II, pages 327-335.

MINISTERE DE LA COOPÉRATION ET DU DÉVELOPPEMENT. 1991 *b*. Le coton en Afrique de l'ouest et du centre. Situation et perspectives. Paris, France: Documentation française, série études et documents, 353 pages.

PARRY G. 1982. Le cotonnier et ses produits. Paris, France: Maisonneuve et Larose, Collection techniques agricoles et productions tropicales, no. 30, 502 pages.

PELTRE-WURTZ J, STECK B. 1991. Les charrues de la Bagoué. Gestion paysanne d'une opération cotonnière en Côte d'Ivoire. Paris, France: ORSTOM, collection "A travers champs", 303 pages.

RAYMOND G. 1994. La production cotonnière en Afrique de l'Ouest: le cas du Bénin. *In* Economie des politiques agricoles dans les pays en développement, Tome III: les fondements microéconomiques, Benoit-Cattin M (ed.), Paris, France: Revue française d'économie, pages 201-230.

RAYMOND G, DEVAUTOUR H, KAMDEM R, YUNG JM, IYEBI MANDJEK O, KOULANDI J, MERCOIRET MR, NGNIADO B. 1994. Stratégies paysannes en zone cotonnière au Cameroun. CIRAD/Ministère de l'agriculture, République du Cameroun, draft. Montpellier, France: CIRAD.

YUNG JM. 1989. Aperçus sur les comportements des producteurs de coton en RCA. Paris, France: SEDES, 159 pages.

Fruits

BORRELL B, YANG M. 1992. EC bananarama 1992. The Developing Economies, XXX (3):259-283.

CHAMPION J. 1963. Le bananier. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 1, 263 pages.

CIRAD-FLHOR. 1993. Numéro spécial Bananes. Fruits, vol. 48 (1-2).

CIRAD-IRFA. 1990. Numéro spécial Bananes. Fruits, vol. 45.

CIRAD-IRFA. 1991. Numéro spécial Ananas. Fruits, vol. 46.

CIRAD-IRFA. 1992. Numéro spécial Agrumes. Fruits, vol. 47:97-274.

COLEACP (Comité de liaison Europe Afrique Caraïbes Pacifique), 1993. Symposium régional sur la qualité, la compétitivité, la promotion de l'ananas ouest et centre africain, 2-4 June 1993. Actes et recommandations. 2 tomes. Rungis, France: COLEACP.

FABRE P (project leader). 1995. Evaluation de la compétivitité de la production de bananes des pays ACP. CIRAD and Natural Resources Institute (NRI). Montpellier, France: CIRAD.

GANRY J. 1988-1992. Amélioration génétique des bananiers cultivés pour les consommations locales et pour l'exportation. Rapport final CCE/STD-TS.2.A.0094. Sous-programme: Agriculture tropicale et sub-tropicale. Brussels, Belgium: Commission of the European Community.

GANRY J. (ed) 1993. Breeding banana and plantain for resistance to diseases and pests. International syposium on genetic improvement of bananas for resistance to diseases and pests, Montpellier, 7-9 September 1992. Montpellier, France: CIRAD-FLHOR, 405 pages.

GERDAT-IRFA, 1984. La culture de l'ananas d'exportation en Côte d'Ivoire. Manuel du planteur. Abidjan, Côte d'Ivoire: Nouvelles Editions Africaines, 117 pages.

LASSOUDIERE A. 1978. Le bananier et sa culture en Côte d'Ivoire. Vol. 1 and 2. Abidjan, Côte d'Ivoire: GERDAT-IRFA, 351 pages.

MOURICHON X. 1988-1992. Elaboration de stratégies de lutte efficace contre la cercosporiose noire, maladie très menaçante pour les bananiers et les productions vivrières de plantains. CEE/STD-TS.21.0095 M. Sous-programme: Agriculture tropicale et sub-tropicale. Brussels, Belgium: Commission of the European Community.

PY C, LACOEUILHE J, TEISSON C. 1984. L'ananas: sa culture, ses produits. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 33, 562 pages.

SODETEG. 1990. Etude du marché et de la commercialisation de l'ananas de Côte d'Ivoire. Abidjan, Côte d'Ivoire: Ministère de l'agriculture / Direction et contrôle des grands travaux.

Rubber

CIRAD. 1991. Rapport de la première revue externe de l'Institut de recherches sur le caoutchouc, IRCA. Montpellier, France: CIRAD, 152 pages.

COMPAGNON P. 1986. Le caoutchouc naturel. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 35, 595 pages.

HIRSCH R. 1990*a*. Etude comparative des coûts de production de caoutchouc dans les grandes plantations en Afrique et en Asie. Paris, France: Caisse centrale de coopération économique, Département des politiques et des études, 3 tomes.

HIRSCH R. 1990*b*. Evaluation rétrospective du premier projet de développement de l'hévéaculture villageoise dans le sud-est ivoirien (PVSE1). Paris, France: Caisse centrale de coopération économique, 61 pages + appendixes.

SÉRIER JB. 1993. Histoire du caoutchouc. Paris, France: Editions Desjonquières, 273 pages.

Yam

CHALÉARD JL. 1988*b*. Croissance urbaine et dynamisme rural: l'igname des Lobi (Côte d'Ivoire). *In* Dynamique des systèmes agraires, la dimension économique. Paris, France: ORSTOM, collection colloques et séminaires, pages 129-147.

DEGRAS L. 1986. L'igname: plante à tubercule tropicale. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 36, 408 pages.

DOUMBIA S. 1990. L'adaptation des producteurs aux exigences de la demande commerciale: le cas de l'igname en Côte d'Ivoire. *In* Economie des filières en régions chaudes. Actes du Xe séminaire d'économie et de sociologie, 11-15 September 1989. Montpellier, France: CIRAD, pages 241-251.

DUMONT R, HAMON P, SEIGNOBOS C. 1994. Les ignames au Cameroun. Montpellier, France: CIRAD, collection Repères, 79 pages.

OLORUNDA AO. 1990. Etude de cas: l'industrie de transformation de l'igname au Nigéria. *In* Racines, tubercules et légumineuses. Potentiels et limites pour résoudre les problèmes alimentaires en Afrique. Agro Action Allemande, Fondation allemande pour le développement international (DES), Centre de développement pour l'alimentation et l'agriculture. Feldafing, Germany: DES, pages 126-141.

ONWEME IC. 1990. Etude de cas: une analyse critique de la technique du mini-bouturage de l'igname et de son adoption par les agriculteurs au Nigéria. *In* Racines, tubercules et légumineuses. Potentiels et limites pour résoudre les problèmes alimentaires en Afrique. Agro Action Allemande, Fondation allemande pour le développement international (DES), Centre de développement pour l'alimentation et l'agriculture. Feldafing, Germany: DES, pages 116-126.

Maize

ALEXANDRE C, MUCHNIK J, NAGO M, AYENAN B. 1994. Innovations agro-alimentaires et savoir-faire locaux. Montpellier, France: CIRAD-SAR.

BOUGHTON D, HENRY DE FRAHAN B. 1994. Agricultural research assessment: the case of maize technology adoption in southern Mali. International development working paper no. 41. East Lansing, USA: Michigan State University.

BOUGHTON D, STAATZ JM, SHAFFER JD. 1994. From pilot study to commodity subsector economics program: institutionalizing market-oriented approach to agricultural research in Mali. Paper presented at USAID seminar on strengthening linkages between demand and supply of agricultural technology in Africa, 21 June 1994. Washington D.C., USA: USAID.

BRICAS N, BRIDIER B, DEVAUTOUR H, MESTRES C. 1995. La valorisation du maïs à l'échelon villageois. *In* Production et valorisation du maïs à l'échelon villageois en Afrique de l'Ouest. Actes du séminaire Maïs prospère, CIRAD, FSA-UNB, 25-28 January 1994, Cotonou, Benin. Montpellier, France: CIRAD, collection colloques, 306 pages.

CONTE S, FUSILLIER JL, ILOGA L, NKOUENKEU T, VOUFO P. 1993. Analyse économique de la filière maïs au Cameroun. Yaoundé, Cameroun: Ministère de l'agriculture, Direction des enquêtes agro-économiques et de la planification agricole, 150 pages.

FUSILLIER JL. 1991. La filière maïs en Côte d'Ivoire. Un exemple d'adaptation spontanée des appareils de production et de commercialisation à l'extension du marché intérieur. Ph.D. diss. at Université Montpellier I. Montpellier, France: CIRAD.

FUSILLIER JL. 1994. La diffusion de la culture du maïs en Afrique de l'Ouest. Working paper no. 16. Montpellier, France: CIRAD, Unité de recherche économie des filières, 39 pages.

GILBERT E, PHILIPS LC, ROBERTS W, SARCH MT, SMALE M, STROUD A, HUNTING E. 1993. Maize research impact in Africa. The obscured revolution. Washington D.C., USA: USAID, 184 pages.

KIM, SK. 1994. Genetics of maize tolerance of *Striga hermonthica*. Crop Science, 34 (4):900-907.

SILVESTRE A. 1994. La diffusion du maïs au Nord-Cameroun : dynamique de l'innovation et culture technique locale. Ph.D. diss. at Ecole des hautes études en sciences sociales (EHESS), Paris, France, 448 pages.

SMITH JW, BARAU AD, GOLDMAN A, MARECK, JH. 1994. The role of technology in agricultural intensification: the evolution of maize production in the northern guinea savanna of Nigeria. Economic Development and Cultural Change, pages 537-54.

Cassava

FRESCO L. 1986. Cassava in shifting cultivation. A systems approach to agricultural technology development in Africa. Amsterdam, The Netherlands: Royal Tropical Institute, 48 pages.

IITA (International Institute for Tropical Agriculture). 1990. Le manioc en Afrique. Un manuel de référence. Ibadan, Nigeria: IITA, 190 pages.

MUCHNIK J, VINCK D. 1984. La transformation du manioc. Technologies autochtones. Paris, France: PUF, ACCT, collection techniques vivantes, 172 pages.

NEUENSCHWANDER P. 1993. Human interactions in classical biological control of cassava and mango mealybugs on subsistence farms in Tropical Africa. *In* Crop Protection Strategies for Subsistence Farmers, Altieri MA (ed.). Boulder, Colorado, USA: Westview Press, pages 143-77.

NEUENSCHWANDER P, HERREN H. 1988. Biological control of the cassava mealybug, *Phenacoccus manihoti*, by the exotic parasitoid *Epidinocarsis lopezi* in Africa. Philosophical Transactions of the Royal Society of London, B, 318:319-333.

NORGAARD RB. 1988. The biological control of cassava mealybug in Africa. American Journal of Agricultural Economics, 70 (2):366-71.

NWEKE FI. 1988. COSCA project description. COSCA, Collaborative Study of Cassava in Africa. Working paper no. 1, Ibadan, Nigeria: IITA, 31 pages.

NWEKE FI. 1992. Commercialization of cassava production: potential for production growth in Africa. COSCA, Collaborative Study of Cassava in Africa, working paper no. 14, first draft, December. Ibadan, Nigeria: IITA, 19 pages.

NWEKE FI. 1994*a*. Processing potential for cassava production growth in Africa. COSCA, Collaborative Study of Cassava in Africa, working paper no. 11. Ibadan, Nigeria: IITA, 47 pages.

NWEKE FI. 1994*b*. Cassava distribution in Africa. COSCA, Collaborative Study of Cassava in Africa, working paper no. 12. Ibadan, Nigeria: IITA, 38 pages.

NWEKE FI, DIXON AGO, ASIEDU R, FOLAYAN SA. 1994. Cassava varietal needs of farmers and potential for production and growth in Africa. COSCA, Collaborative Study of Cassava in Africa, working paper no. 10. Ibadan, Nigeria: IITA, 239 pages.

NWEKE FI, OGWU BO, DIXON AGO. 1992. The spread and performance of improved cassava varieties in Nigeria: an assessment of adoption. COSCA, Collaborative Study of Cassava in Africa, working paper no. 15, first draft, December. Ibadan, Nigeria: IITA.

NWEKE FI, OKORJI EC, NJOKU JE, KING DJ. 1992. Elasticities of demand for major food items in a root and tuber based food system. Emphasis on yam and cassava in southeastern Nigeria. Resource and crop management research monograph no. 11. Ibadan, Nigeria: IITA, 21 pages.

NWEKE FI, POLSON R, STRAUSS J. 1992. Cassava production trends in Africa. COSCA, Collaborative Study of Cassava in Africa, working paper no. 13, first draft, December. Ibadan, Nigeria: IITA, 27 pages.

SILVESTRE P, ARRANDEAU M. 1983. Le manioc. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 32, 262 pages.

TARI M, TOUYA JC. 1983. Le complexe industriel de Mantsoumba et la filière manioc au Congo. Paris, France: Ministère de la coopération et du développement, série évaluations, 104 pages + appendixes.

Vegetable crops

DAVID O, MOUSTIER P. 1993. Systèmes maraîchers approvisionnant Bissau. Résultats des enquêtes (December 15 1992 to July 15 1993). Working paper no. 7, October. Montpellier, France: CIRAD, Unité de recherche économie des filières, 101 pages.

LEPLAIDEUR A (project leader). 1991. Filières maraîchères à Brazzaville. Premiers éléments. Research project CIRAD-IRAT/AGRICONGO, with the participation of DGRST Congo. Montpellier, France: CIRAD, AGRICONGO, 231 pages.

LEPLAIDEUR A, MOUSTIER P. 1991. Dynamiques du vivrier à Brazzaville. Les mythes de l'anarchie et de l'inefficace. Cahiers des sciences humaines, 27 (1-2):147-57.

RICHARD J, AGEL C, PEREZ DE ARCE D. 1985. Projet maraîchage et pisciculture à Kinshasa. Paris, France: Ministère de la coopération et du développement, série évaluations, 2 vol., 205 pages.

SCHILTER C. 1991. L'agriculture urbaine à Lomé. Paris, France: IUED-Khartala, 334 pages.

Oil and coconut palm

BUROTROP (Bureau for the Development of Research on Tropical Perennial Oil Crops). 1991. Les contraintes de développement du palmier à huile en Afrique: intérêt et rôle d'un réseau de recherche et développement. Report presented at the June 10-15 seminar in Abidjan organized by the African Association for the Development of Palm Oil and BUROTROP. Paris, France: BUROTROP, 68 pages.

BUROTROP. 1994. Séminaire sur les petites et moyennes technologies de transformation du palmier à huile et du cocotier. Accra, Ghana, 6-9 December 1993. Paris, France: BUROTROP, 40 pages.

CIRAD. 1990. Rapport de la première revue externe de l'Institut de recherches pour les huiles et oléagineux, IRHO, département du CIRAD. Paris, France: CIRAD, 135 pages + appendixes.

DE TAFFIN G. 1993. Le cocotier. Paris, France: Maisonneuve et Larose, collection techniciens d' agriculture tropicale, no. 25, 186 pages.

GREEN AH (ed.). 1991. Coconut production. Present status and priorities for research. Technical paper no. 136. Washington D.C., USA: World Bank, 150 pages.

HIRSCH R, BENAMOU JF. 1989. Etude comparative des conditions techniques et économiques de production de l'huile de palme en Afrique et en Asie. Paris, France: Caisse centrale de coopération économique, 69 pages + appendixes.

ISNAR (International Service for National Agricultural Research). 1988. Review of the Nigerian Institute for Oil Palm Research (NIFOR). Report to the Ministry of Science and Technology of the Federal Republic of Nigeria. The Hague, The Netherlands: ISNAR, 168 pages.

ONWUBUYA II, ENEH FK, OFOH MC, IRUSOTA AO, ODIGIE EE. 1989. Development of mixed oil palm and food crops farming systems research in Nigeria: a response to population pressure and smallholder agriculture. Paper presented at the International Conference on Palms and Palm Products, Benin City, Nigeria, 21-25 November 1989. Benin city, Nigeria: NIFOR, 33 pages.

SURRE C, ZILLER R. 1963. Le palmier à huile. Paris, France: Maisonneuve et Larose, collection techniques agricoles et productions tropicales, no. 2, 243 pages.

WORLD BANK. 1989*b*. Nigeria tree crop project. Staff appraisal report no. 7429-UNI, Western Africa Department, Agriculture Operations Division, 28 February 1989. Washington D.C., USA: World Bank, 101 pages + appendixes.

Rice

ADESINA AA, ZINNAH MM. 1991. Adoption and economic impact of improved mangrove swamp rice varieties in West Africa. WARDA annual report. Bouaké, Côte d'Ivoire: WARDA, pages 23-29.

ADESINA AA, ZINNAH MM. 1993. Technology characteristics, farmers' perceptions and adoption decisions: a Tobit model application in Sierra Leone. Agricultural Economics, 9:297-311.

ANDRIESSE W, FRESCO LO. 1991. A characterization of rice growing environments in West Africa. Agriculture, Ecosystems and Environment, 33:377-395.

BALDE A, LEPLAIDEUR A, PUJO L, TOUNKARA O. 1993. Les filières du riz en Guinée forestière. Résultats intermédiaires. Working paper no. 13. Montpellier, France: CIRAD, Unité de recherche économie des filières, 61 pages.

BENZ H, MENDEZ DEL VILLAR P. 1994. Le marché international du riz: facteurs d'instabilité et politiques des exportateurs. *In* Economie des politiques agricoles dans les pays en développement. Tome 1: les conditions internationales, Griffon M (ed.), Paris, France: Revue française d'économie, pages 209-235.

CARSKY RJ. 1992. Rice-based production in inland valleys of West Africa: research review and recommendations. Resource and crop management research monograph no. 8. Ibadan, Nigeria: IITA, 31 pages.

CHATAIGNER J. 1992. La dynamique de la production rizicole en Côte d'Ivoire. Montpellier, France: Ministère de la coopération, INRA, 75 pages + appendixes.

LEPLAIDEUR A. 1992. Aménagement des bas-fonds en Guinée. Laboratoire économie, CIRAD-CA, no. 35. Montpellier, France: CIRAD-CA, 45 pages.

LOUIS BERGER INTERNATIONAL. 1990. Etude de la filière riz, rapport final. Abidjan, Côte d'Ivoire, Direction et contrôle des grands travaux, 270 pages.

OOSTERBAAN RJ, GUNNEWEG HAMI, HUIZING A. 1987. Water control for rice cultivation in small valleys in West Africa. *In* ILRI, annual report 1986. Wageningen, The Netherlands: ILRI, pages 30-49.

PEARSON SR, STRYKER JD, HUMPHREYS CP. 1981. Rice in West Africa. Policy and economics. Stanford, USA: Stanford University Press, 482 pages.

POISSON C. 1989. Amélioration variétale du riz en Afrique de l'Ouest. Paper presented at the Revue annuelle de la riziculture, WARDA, Bouaké, Côte d'Ivoire, 24-26 April. Bouaké, Côte d'Ivoire: WARDA, 19 pages.

RAUNET M. 1985. Bas-fonds et riziculture en Afrique. Approche structurale comparative. L'agronomie tropicale, 40 (3):181-201.

REBUFFEL P. 1993. La mise en valeur des bas-fonds du nord Ghana. Synthèse 1991-92, Crop Research Institute/CIRAD project. Montpellier, France: CIRAD, 49 pages.

SAVVIDES L. 1981. Guidelines to improving valley swamps *(fadamas)*. Ibadan, Nigeria: APMEPU, Bida Agricultural Development Project.

Statistical Appendix

Table 1. Population and area data for the Region, 1990.

Country	Total population (1 000 inhabitants)	Total area (1 000 ha)	Population density (inhabitants/km²)	Urbanization rate
Benin	4 776	11 062	43	0.38
Cameroon	12 239	46 540	26	0.41
Central African Republic	3 127	62 298	5	0.43
Congo	2 346	34 150	7	0.63
Côte d'Ivoire	12 462	31 800	39	0.49
Equatorial Guinea	360	2 805	13	
Gabon	1 211	25 767	5	0.69
Ghana	15 524	23 002	67	0.32
Guinea	5 934	24 586	24	0.28
Liberia	2 659	9 675	27	0.22
Nigeria	90 000	91 077	98	0.56
Sierra Leone	4 260	7 162	60	0.30
Togo	3 643	5 439	67	0.29
Zaïre	36 728	226 760	16	0.50

Sources: FAO Production Yearbooks; KALASA (1993).

Table 2. Population and area data, by density groupings.

	Population		Area	
	1 000 inhabitants	%	1 000 inhabitants	%
Countries with high population density (≥ 100 inhab./km²): Nigeria	90 000	46	91 077	15
Countries with intermediate-high population density (between 40 and 70 inhab./km²): Benin, Côte d'Ivoire, Togo, Sierra Leone, Ghana	40 665	21	78 465	13
Countries with low-intermediate population density (between 20 and 30 inhab./km²): Cameroon, Guinea, Liberia	20 832	11	80 711	13.5
Countries with low population density (below 20 inhab./km²): Zaïre, Congo, Equatorial Guinea, Central African Rep.	43 772	22	351 780	58.5
Total	195 269	100	602 033	100

Source: Table 1.

Table 3. Land use estimates in the Region.

Country	Total area (x 1 000 ha)	Annual crops ha (x 1 000)	%	Perennial crops ha (x 1 000)	%	Pasture and prairie ha (x 1 000)	%	Forests ha (x 1 000)	%	Others ha (x 1 000)	%
Benin	11 062	1 410	13	450	4	442	4	3 470	31	5 290	48
Cameroon	46 540	5 940	13	1 068	3	8 300	18	24 540	53	6 692	13
Central African Rep.	62 298	1 920	3	86	0	3 000	5	35 800	58	21 492	34
Congo	34 150	144	1	24	0	10 000	29	21 160	62	2 822	8
Côte d'Ivoire	31 800	2 430	8	1 260	4	13 000	41	7 380	23	7 730	24
Equatorial Guinea	2 805	130	5	100	4	104	4	1 295	46	1 176	42
Gabon	25 767	295	1	162	1	4 700	18	20 000	77	610	2
Ghana	23 002	1 140	5	1 580	7	5 000	22	8 070	35	7 212	31
Guinea	24 586	610	2	118	1	6 150	25	14 580	59	3 128	13
Liberia	9 675	128	1	245	3	5 700	59	1 740	18	1 862	19
Nigeria	91 077	29 765	33	2 535	3	40 000	44	11 900	13	6 877	7
Sierra Leone	7 162	500	7	150	2	2 204	30	2 060	29	2 248	31
Togo	5 439	600	11	69	1	1 790	33	1 600	29	1 380	25
Zaïre	226 760	7 250	3	610	0	15 000	7	174 310	77	29 590	13

Sources: FAO Production Yearbooks; KALASA (1993) for Nigeria.

Table 4. Evolution of land area under cultivation.

Country	Area 1980 (x 1 000 ha)			Area 1990 (x 1 000 ha)			Annual growth rate (%)		
	Annual crops	Perennial crops	All crops	Annual crops	Perennial crops	All crops	Annual crops	Perennial crops	All crops
Benin	1 350	446	1 795	1 410	460	1 860	0.44	0.11	0.36
Cameroon	5 910	1 020	6 930	5 940	1 068	7 008	0.05	0.46	0.11
Central African Rep.	1 870	75	1 945	1 920	86	2 006	0.26	1.38	0.31
Congo	134	14	148	144	24	168	0.72	5.54	1.28
Côte d'Ivoire	1 955	1 140	3 095	2 430	1 260	3 690	2.20	1.01	1.77
Equatorial Guinea	130	100	230	130	100	230	0.00	0.00	0.00
Gabon	290	62	352	295	162	457	0.17	10.08	2.64
Ghana	1 090	1 710	2 800	1 140	1 580	2 720	0.45	- 0.79	- 0.29
Guinea	590	112	702	610	118	728	0.33	0.52	0.36
Liberia	126	245	371	128	245	373	0.16	0.00	0.05
Nigeria	27 850	2 535	30 385	29 765	2 535	32 300	0.67	0.00	0.61
Sierra Leone	450	135	585	500	150	650	1.06	1.06	1.06
Togo	555	65	620	600	69	669	0.78	0.60	0.76
Zaïre	7 050	550	7 600	7 250	610	7 860	0.28	1.04	0.34
Total	49 350	8 208	57 558	52 262	8 457	60 719	0.57	0.30	0.54

Source: FAO Production Yearbooks.

Table 5. Evolution of urban and rural population.

Country	Population (x 1 000 inhab.)		Urbanization rate		Urban population (x 1 000 inhab.)		Rural population (x 1 000 inhab.)		Rate of population increase		
	1980	1990	1980	1990	1980	1990	1980	1990	Rural	Urban	Total
Benin	3 459	4 630	0.27	0.38	934	1 759	2 525	2 871	1.29	6.54	2.96
Cameroon	8 653	11 833	0.29	0.41	2 509	4 852	6 144	6 981	1.29	6.81	3.18
Central African Rep.	2 320	3 039	0.39	0.43	905	1 307	1 415	1 732	2.04	3.74	2.74
Congo	1 669	2 271	0.53	0.63	885	1 431	784	840	0.69	4.93	3.13
Côte d'Ivoire	8 194	11 997	0.41	0.49	3 360	5 879	4 834	6 118	2.38	5.75	3.89
Equatorial Guinea	217	352	0.54	0.62	117	218	100	134	2.97	6.42	4.96
Gabon	806	1 172	0.36	0.69	290	809	516	363	3.44	10.79	3.81
Ghana	10 736	15 028	0.30	0.29	3 221	4 358	7 515	10 670	3.57	3.07	3.42
Guinea	4 461	5 755	0.25	0.28	1 115	1 611	3 346	4 144	2.16	3.75	2.58
Liberia	1 876	2 575	0.18	0.22	338	567	1 538	2 009	2.70	5.31	3.22
Nigeria	70 390	88 500	0.47	0.56	33 083	49 560	37 307	38 940	0.43	4.12	2.32
Sierra Leone	2 271	4 151	0.24	0.32	546	1 328	1 726	2 823	5.04	9.92	6.22
Togo	2 615	3 531	0.24	0.30	628	1 059	1 987	2 472	2.20	5.37	3.05
Zaïre	26 225	35 568	0.34	0.50	8 917	17 784	17 309	17 784	0.27	7.15	3.09
Region	143 892	190 402	0.40	0.49	66 846	92 522	87 046	97 880	1.18	4.99	2.84

Source: FAO Production Yearbooks; Nigeria data and urbanization rates from KALASA (1993).

Table 6a. Evolution of the production of industrial crops in the Region.

Country	Unshelled groundnuts	Seed cotton	Copra	Palm oil	Coffee	Rubber	Cocoa
	Annual average 1969-71 (x 1 000 tons)						
Benin	46	36	3	28	2	0	0
Cameroon	206	67	1	67	90	13	127
Central African Rep.	68	52	0	2	10	1	0
Congo	17	0	0	14	1	1	1
Côte d'Ivoire	42	36	6	46	243	11	195
Equatorial Guinea	-	-	-	4	7	0	28
Gabon	3	0	0	2	1	0	5
Ghana	88	0	10	19	6	7	430
Guinea	75	0	2	44	12	0	2
Liberia	2	0	0	15	5	78	2
Nigeria	1 602	186	9	587	4	63	261
Sierra Leone	20	0	0	46	8	0	5
Togo	20	7	3	16	11	0	27
Zaïre	265	63	0	233	71	43	6
Total	2 455	447	34	1 123	471	216	1 090

Source: FAO Production Yearbooks.

Table 6b. Evolution of the production of industrial crops in the Region.

	Annual average 1979-81 (x 1 000 tons)						
Country	Unshelled groundnuts	Seed cotton	Copra	Palm oil	Coffee	Rubber	Cocoa
Benin	60	19	3	30	0	0	0
Cameroon	187	81	1	77	108	17	120
Central African Rep.	123	28	0	2	17	1	0
Congo	14	0	0	15	3	2	2
Côte d'Ivoire	73	131	23	158	298	21	427
Equatorial Guinea	0	0	0	5	6	0	8
Gabon	7	0	0	2	1	0	4
Ghana	125	7	7	21	2	10	268
Guinea	83	0	2	41	14	0	4
Liberia	3	0	0	26	10	81	5
Nigeria	466	92	10	667	4	49	169
Sierra Leone	12	0	0	47	11	0	9
Togo	25	19	2	20	8	0	14
Zaïre	334	23	0	168	90	21	5
Total	1 512	400	48	1 277	572	202	1 035

Source: FAO Production Yearbooks.

Table 6c. Evolution of the production of industrial crops in the Region.

Country	Unshelled groundnuts	Seed cotton	Copra	Palm oil	Coffee	Rubber	Cocoa
	Annual average 1989-91 (x 1 000 tons)						
Benin	72	139	3	40	1	0	0
Cameroon	103	107	1	105	82	38	107
Central African Rep.	105	30	0	2	18	1	0
Congo	26	0	0	17	1	2	1
Côte d'Ivoire	133	285	81	197	254	72	728
Equatorial Guinea	0	0	0	5	7	0	7
Gabon	15	0	0	5	2	0	2
Ghana	198	14	9	83	1	4	297
Guinea	50	3	2	49	13	0	2
Liberia	3	0	0	32	3	52	3
Nigeria	1134	246	13	859	1	102	142
Sierra Leone	20	0	0	56	26	0	24
Togo	29	86	2	14	11	0	8
Zaïre	28	77	0	180	110	15	5
Total	1 916	986	111	1 644	530	284	1 326

Source: FAO Production Yearbooks.

Table 7a. Food crop production estimates.

	Annual average 1979-81 (x 1 000 tons)								
Country	Maize	Sorghum	Paddy	All cereals	Cassava	Yam	Cocoyam	All roots and tubers	Plantain
Benin	289	59	10	366	631	687	3	1 363	0
Cameroon	418	301	48	866	977	203	0	1 683	1 022
Central African Rep.	40	39	13	103	920	153	32	1 106	61
Congo	12	0	3	15	631	12	0	678	51
Côte d'Ivoire	352	24	438	856	1 067	2 079	254	3 414	1 013
Equatorial Guinea	0	0	0	0	32	0	0	53	0
Gabon	10	0	1	11	242	80	49	372	165
Ghana	380	140	89	726	1 894	614	674	3 183	793
Guinea	87	25	438	678	480	64	30	644	340
Liberia	0	0	254	254	300	15	15	346	31
Nigeria	599	3 284	1 027	7 480	11 500	5 187	1 967	18 926	1 128
Sierra Leone	13	11	504	542	94	0	20	126	22
Togo	150	87	15	301	404	498	18	922	0
Zaïre	604	32	236	900	12 942	222	31	13 595	1 555
Total	2 954	4 002	3 076	13 098	32 114	9 814	3 093	46 391	6 181

Source: FAO Production Yearbooks . "All cereals" includes millets.

Table 7b. Food crop production estimates.

	Annual average 1989-91 (x 1 000 tons)								
Country	Maize	Sorghum	Paddy	All cereals	Cassava	Yam	Cocoyam	All roots and tubers	Plantain
Benin	228	104	9	550	941	1 061	2	2 035	0
Cameroon	400	364	74	903	1189	69	0	1 893	848
Central African Rep.	87	39	15	152	519	195	38	753	67
Congo	25	0	1	26	750	12	0	811	75
Côte d'Ivoire	491	26	671	1 244	1 200	2 562	288	4 298	1 114
Equatorial Guinea	0	0	0	0	45	0	0	77	0
Gabon	20	0	1	21	237	107	63	409	236
Ghana	745	197	102	1 166	3 215	886	1058	5 159	1 004
Guinea	96	34	15	812	419	102	63	691	396
Liberia	0	0	163	163	317	16	16	367	33
Nigeria	1 955	4 605	2 996	14 365	18 156	13 078	1300	32 835	1 424
Sierra Leone	12	21	469	526	110	0	28	152	28
Togo	269	125	29	499	501	410	13	930	0
Zaïre	874	49	350	1 311	17 742	282	40	18 528	1 807
Total	5 201	5 564	4 896	21 738	45 341	18 780	29 10	68 938	7 032

Source: FAO Production Yearbooks . "All cereals" includes millets.

Table 8a. Food production estimates per capita.

	Annual average 1979-81 (kg/cap.)								
Country	Maize	Sorghum	Paddy	All cereals	Cassava	Yam	Cocoyam	All roots and tubers	Plantain
Benin	84	17	3	106	182	199	1	394	0
Cameroon	48	35	6	100	113	23	0	192	118
Central African Rep.	17	17	6	44	397	66	14	477	26
Congo	7	0	2	9	378	7	0	406	31
Côte d'Ivoire	43	3	53	104	130	254	31	417	124
Equatorial Guinea	0	0	0	0	147	0	0	244	0
Gabon	12	0	1	14	300	99	61	462	205
Ghana	35	13	8	68	176	57	63	296	74
Guinea	20	6	98	152	108	14	7	144	76
Liberia	0	0	135	135	160	8	8	184	17
Nigeria	9	47	15	106	163	74	28	269	16
Sierra Leone	6	5	222	239	41	0	9	55	10
Togo	57	33	6	115	154	190	7	353	0
Zaïre	23	1	9	34	493	8	1	518	59
Total	21	28	21	91	223	66	21	322	43

Source: Table 5 and 7. "All cereals" includes millets.

Table 8b. Food production estimates per capita.

Country	Maize	Sorghum	Paddy	All cereals	Cassava	Yam	Cocoyam	All roots and tubers	Plantain
	Annual average 1989-91 (kg/cap.)								
Benin	49	22	3	119	203	229	1	440	0
Cameroon	34	31	6	76	100	6	0	160	72
Central African Rep.	29	13	5	50	171	64	13	248	22
Congo	11	0	0	11	330	5	0	357	33
Côte d'Ivoire	41	2	56	104	100	214	24	358	93
Equatorial Guinea	0	0	0	0	128	0	0	218	0
Gabon	17	0	1	18	203	91	54	349	201
Ghana	50	13	7	78	214	59	70	343	67
Guinea	17	6	3	141	73	18	11	120	69
Liberia	0	0	63	63	123	6	6	142	13
Nigeria	22	52	15	162	205	148	15	371	16
Sierra Leone	3	5	113	127	27	0	7	37	7
Togo	76	36	8	141	142	116	4	263	0
Zaïre	25	1	10	37	499	8	1	521	51
Total	27	29	26	114	238	99	11	362	37

Source: Table 5 and 7. "All cereals" includes millets.

Table 9a. Food production estimates per rural inhabitant.

	Annual average 1979-81 (kg/rural inhabitant)								
Country	Maize	Sorghum	Paddy	All cereals	Cassava	Yam	Cocoyam	All roots and tubers	Plantain
Benin	114	23	4	145	250	272	1	540	0
Cameroon	68	49	8	141	159	33	0	271	166
Central African Rep.	28	28	9	73	650	108	23	782	43
Congo	15	0	4	19	804	15	0	864	65
Côte d'Ivoire	73	5	91	177	221	430	53	706	210
Equatorial Guinea	0	0	0	0	321	0	0	531	0
Gabon	19	0	2	21	469	155	95	721	320
Ghana	51	19	12	97	292	82	90	424	106
Guinea	26	7	131	203	143	19	9	192	102
Liberia	0	0	165	165	195	10	10	225	20
Nigeria	16	88	28	201	308	139	53	507	30
Sierra Leone	8	6	292	314	54	0	12	73	13
Togo	75	44	8	151	203	251	9	464	0
Zaire	35	2	14	52	748	13	2	785	90
Total	34	46	35	219	369	113	36	533	71

Source: Table 5 and 7. "All cereals" includes millets.

Table 9b. Food production estimates per rural inhabitant.

Country	Maize	Sorghum	Paddy	All cereals	Cassava	Yam	Cocoyam	All roots and tubers	Plantain
	Annual average 1989-91 (kg/rural inhabitant)								
Benin	79	36	3	192	328	370	1	709	0
Cameroon	57	62	11	129	170	10	0	271	122
Central African Rep.	50	23	9	88	299	113	22	435	39
Congo	30	0	1	31	892	14	0	966	89
Côte d'Ivoire	80	4	110	203	196	419	47	702	182
Equatorial Guinea	0	0	0	0	336	0	0	573	0
Gabon	55	0	3	58	653	294	174	1 127	650
Ghana	70	18	10	109	301	83	99	484	94
Guinea	23	8	4	196	101	25	15	167	96
Liberia	0	0	81	81	158	8	8	183	16
Nigeria	50	118	77	369	466	336	33	843	37
Sierra Leone	4	7	166	186	39	0	10	54	10
Togo	109	50	12	202	203	166	5	376	0
Zaïre	49	3	20	74	998	16	2	1 042	102
Total	53	57	50	222	463	192	30	704	72

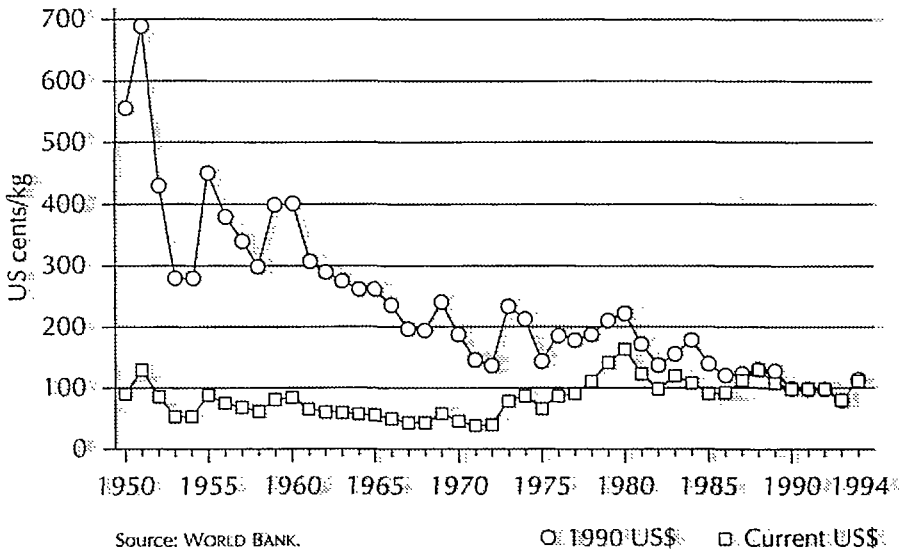
Source: Table 5 and 7. "All cereals" includes millets.

Table 10. Estimated per capita caloric availability per day.

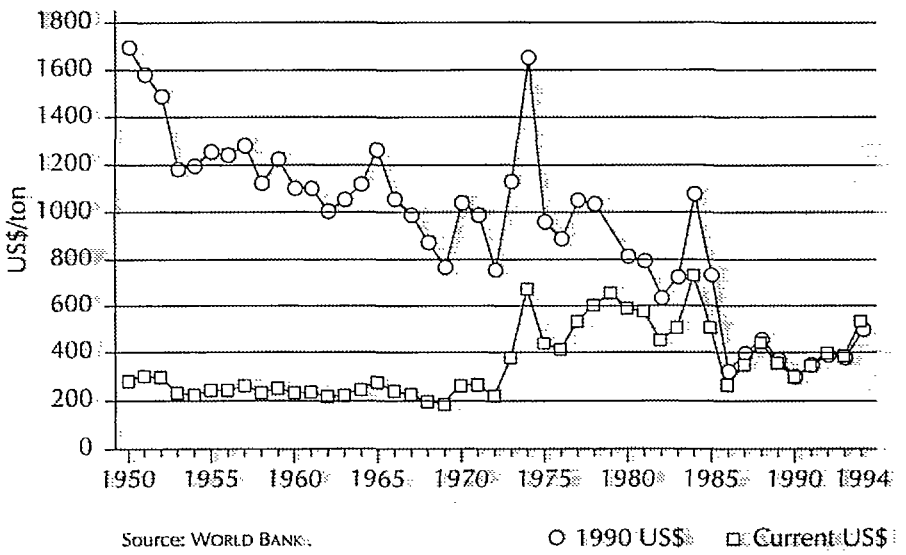
	1972-74	1975-77	1978-80	1981-83	1984-86	1987-89
Bénin	2 084	2 089	2 195	2 134	2 268	2 274
Cameroon	2 239	2 422	2 395	2 249	2 270	2 417
Central African Rep.	2 278	2 196	2 091	2 036	1 932	2 008
Congo	2 254	2 149	2 209	2 268	2 332	2 306
Côte d'Ivoire	2 331	2 320	2 549	2 668	2 654	2 597
Gabon	1 889	2 345	2 378	2 413	2 510	2 473
Ghana	2 195	2 112	1 984	1 848	2 122	2 245
Guinea	1 940	2 250	2 255	2 244	2 273	2 204
Liberia	2 236	2 312	2 397	2 373	2 384	2 404
Nigeria	2 084	2 171	2 287	2 252	2 235	2 318
Sierra Leone	1 931	2 010	2 080	2 012	1 864	1 841
Togo	2 103	2 037	2 185	2 145	2 127	2 134
Zaïre	2 288	2 240	2 118	2 124	2 146	2 084

Source: FAO Food Balance Sheets.

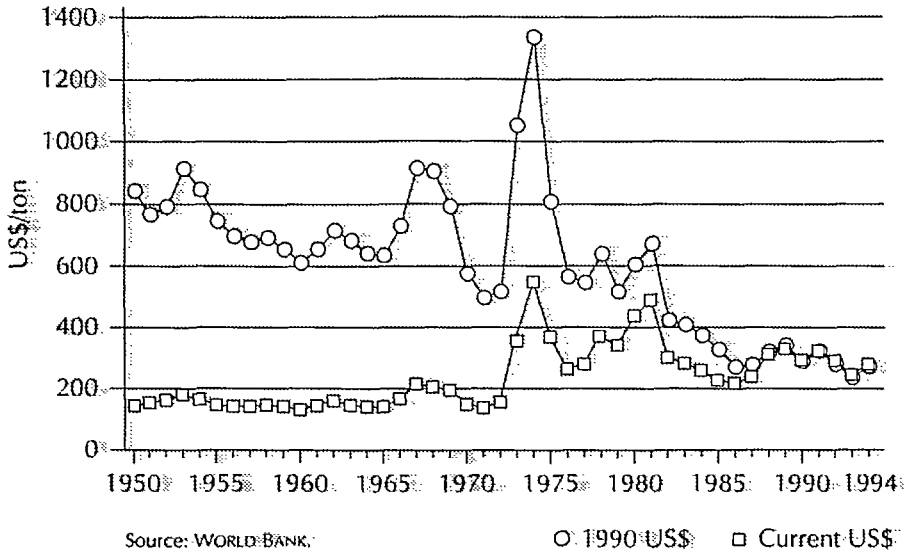
Commodity Price Histories



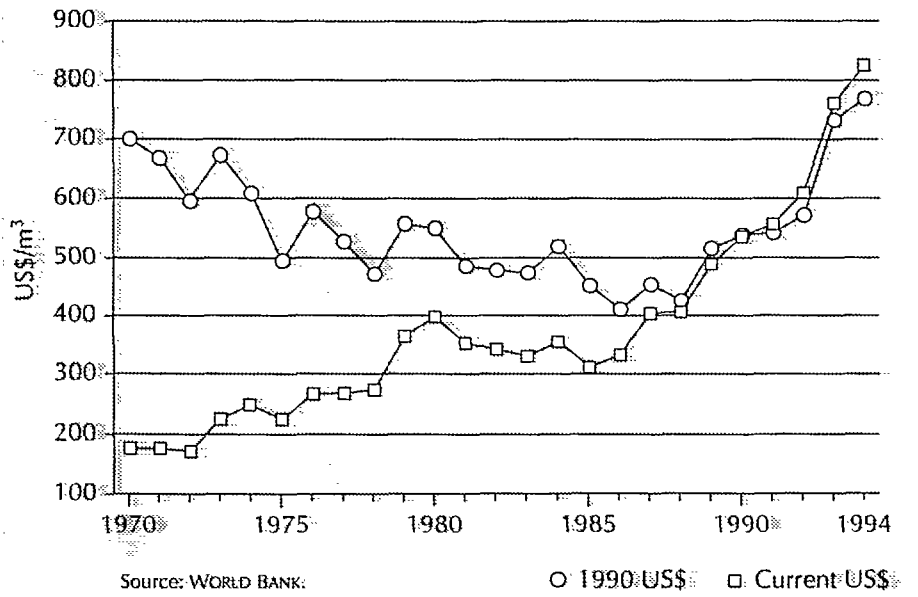
Graph 1. World natural rubber prices since 1950 (Malaysian, f.o.b. Kuala Lumpur).



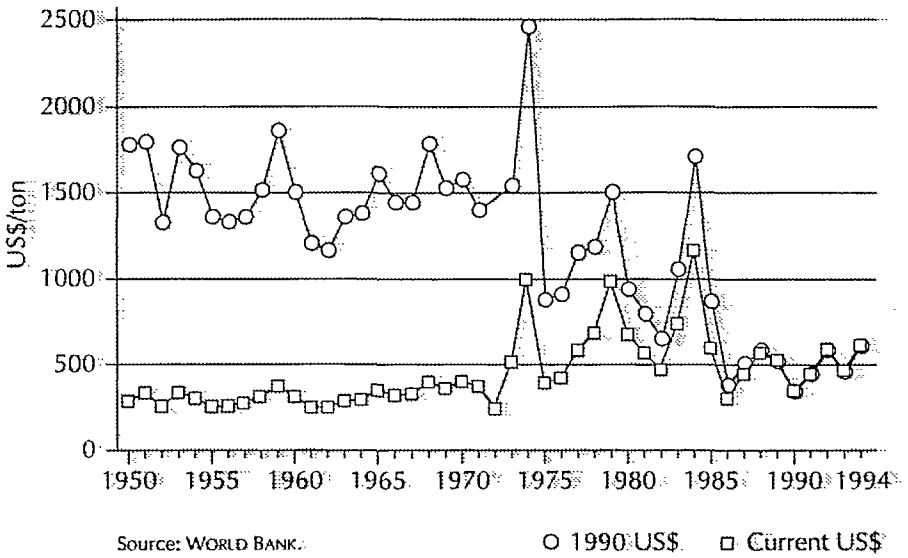
Graph 2. World palm oil prices since 1950 (Malaysian, c.i.f. N-W Europe).



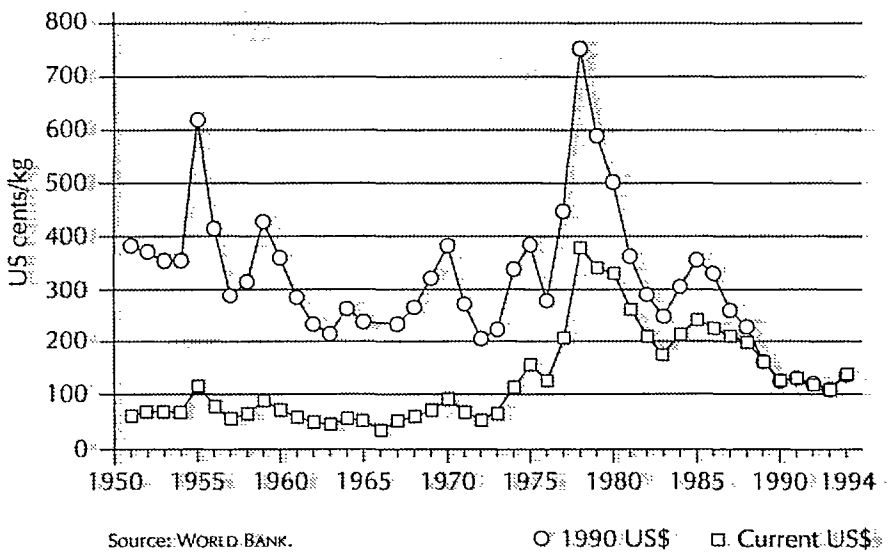
Graph 3. World rice prices since 1950 (Thai 5% broken, f.o.b. Bangkok).



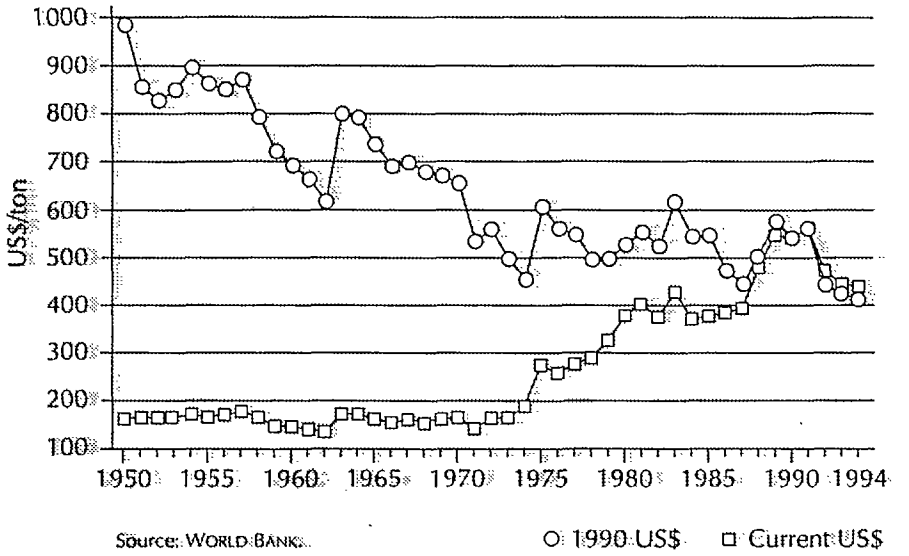
Graph 4. Tropical sawnwood prices since 1970.



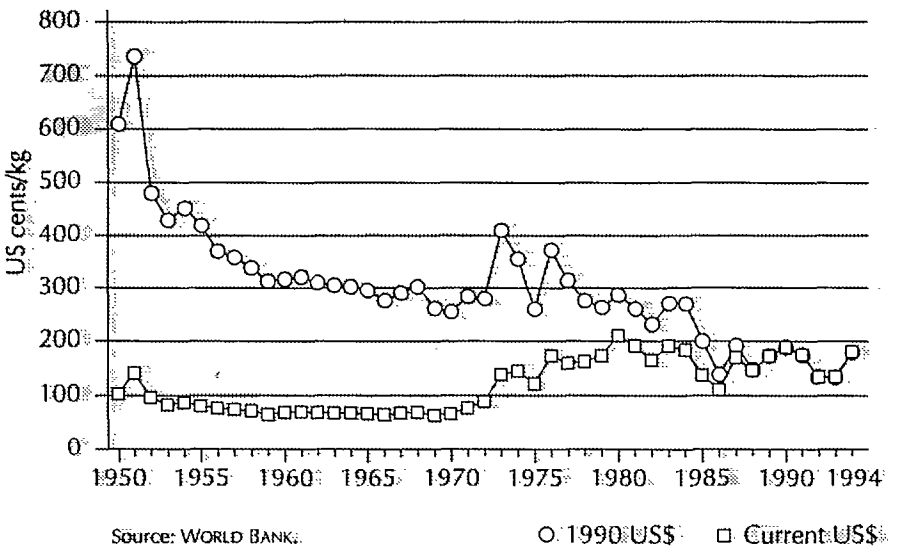
Graph 5. World coconut oil prices since 1950 (South East Asian, c.i.f. Rotterdam).



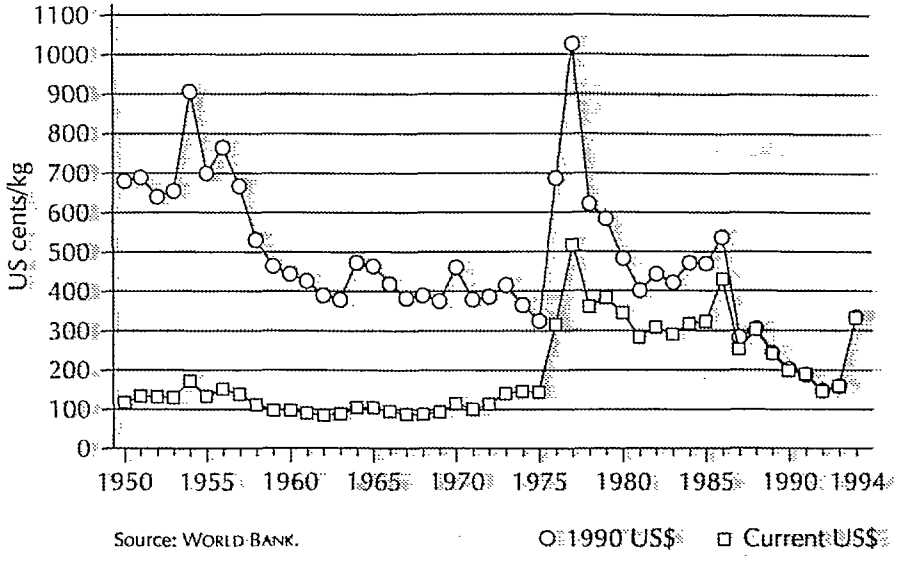
Graph 6. World cocoa prices since 1950 (ICCO average daily price).



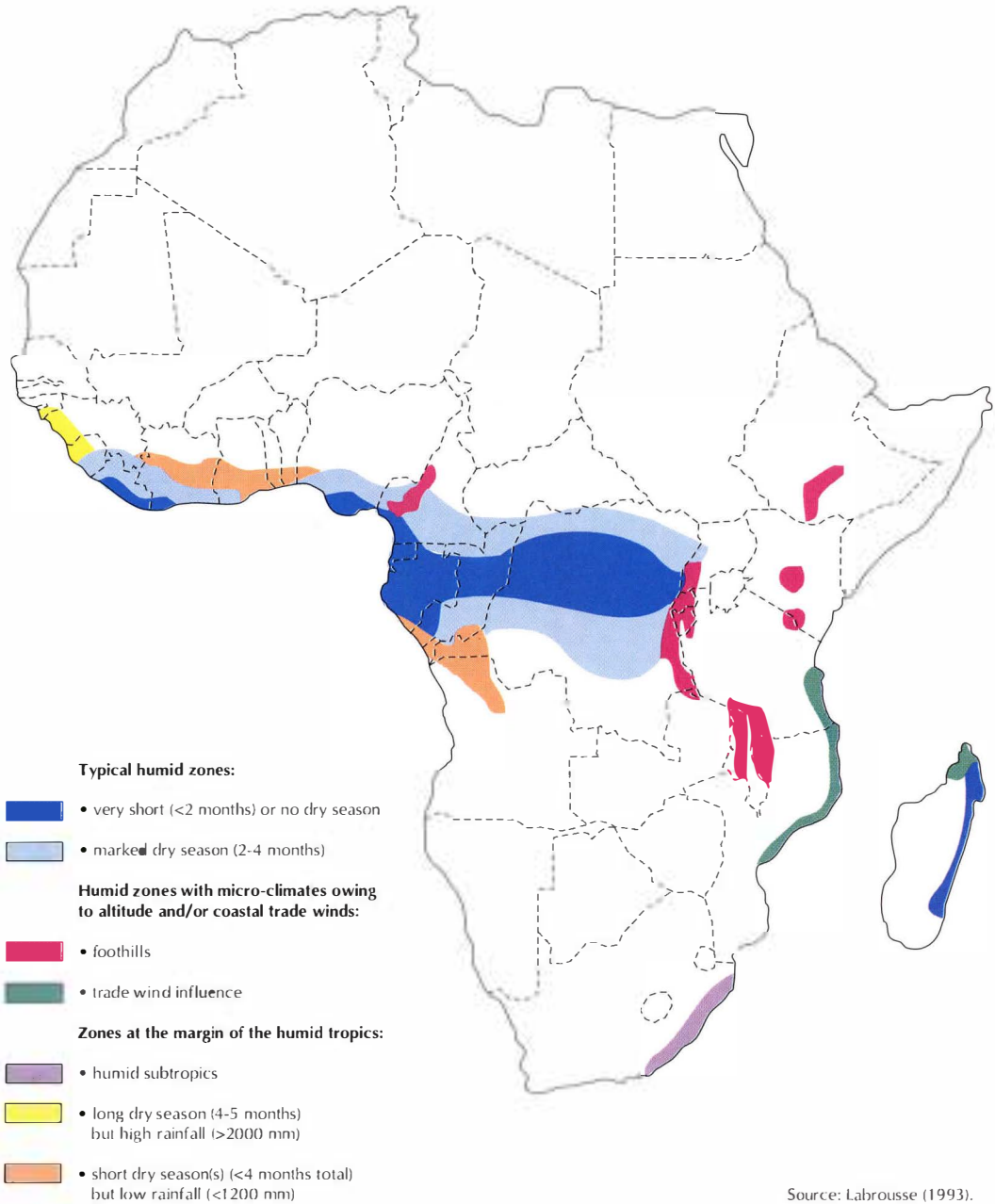
Graph 7. World banana prices since 1950 (Central and South American, f.o.b. USA).



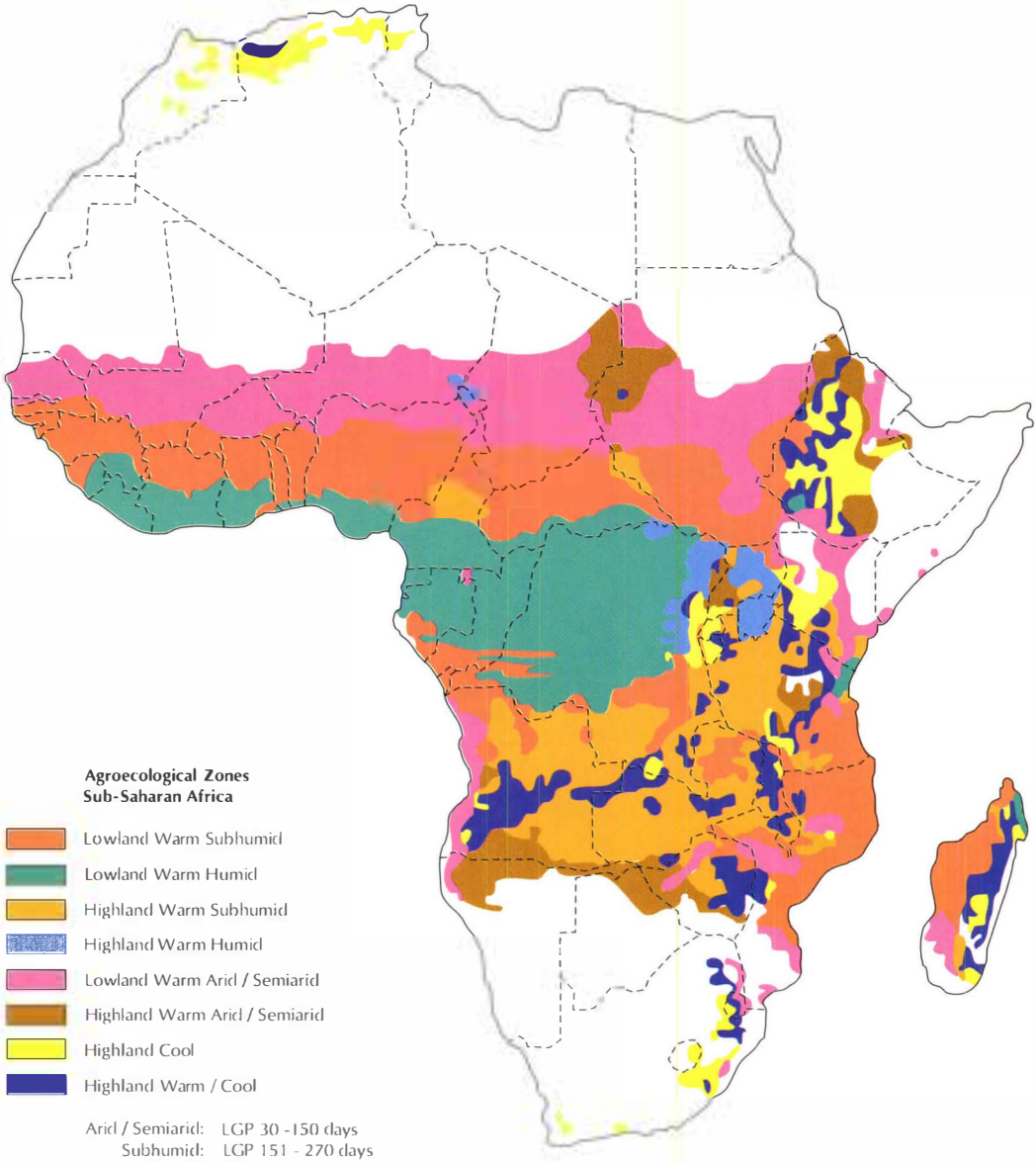
Graph 8. World cotton prices since 1950 (cotton outlook "A index").



Graph 9. World coffee prices since 1950 (ICO indicator for other mild arabicas).



Source: Labrousse (1993).



Arid / Semiarid: LGP 30 -150 days
Subhumid: LGP 151 - 270 days
Humid: LGP 271 - 365 days
Warm: LGP Temperature over 20 °C
Cool: LGP Temperature 5 - 20 °C

Lowland up to 800 m, Highland above 800 m

Source: Agroecological Studies Unit, International Institute of Tropical Agriculture.

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Agricultural Research and Innovation in Tropical Africa is an in-depth review of the role of research in the development of West and Central African agriculture. In contrast to the conventional wisdom, this vast region has been the site of successive agricultural growth dynamics, in which research has played a key role. Yet outside of the agro-industrial sector, the adoption of complete "technical packages" has been rare. Innovation in smallholder agriculture has, instead, been partial and selective, following patterns unanticipated by the research system, that reflect constraints operating at the farm level: labor scarcity, limited access to capital, and a combination of agricultural and economic risk. Although a favorable economic environment has been essential for growth and innovation, there is no magic formula concerning the types of institutions most suited to the task. For output markets, the issue seems less one of public versus private, than of reliability. Upstream, both input supply and the availability of improved planting material appear to depend either on outright public support, or else on a vertically integrated crop sector. Agriculture in this region cannot hope to respond to the challenges lying ahead without major efforts by national and international research. Foremost among the challenges is competitiveness in world and local markets, against a background in which both sustainability of production systems and constraints at the farm level are better integrated into research strategies.

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