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Restoring and Maintaining the Productivity of West African Soils: Key to Sustainable Development

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Restoring and Maintaining the Productivity of West African Soils: Key to Sustainable Development

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Table of Contents

Page

Executive Summary vii

Part I – Introduction 1

1. Problem Definition 1
   (A. Uzo Mokwunye, E.M.A. Smaling, and A. de Jager)
   - 1.1 Agricultural Development in West Africa: An Apocalyptic Outlook 3
   - 1.2 Demographic Pressure: The Social Time Bomb 4
   - 1.3 Raising International Awareness 5
   - 1.4 Objectives of the Study 5
   - 1.5 Methodology 6
   - 1.6 Reader's Guide 6

Part II – Diagnosis: Farming Systems and Soil Fertility 9

2. Farming Systems in West Africa 11
   (K. Acheampong, A. de Jager, and B. Honfoga)
   - 2.1 General Characteristics 11
   - 2.2 Agricultural Production Systems 15
3. Nutrient Stocks and Flows in West African Soils 22
   (E. Rhodes, A. Bationo, E.M.A. Smaling, and C. Visker)
   - 3.1 General 22
   - 3.2 Nutrient Stocks at Different Spatial Scales 22
   - 3.3 Nutrient Flows 27

Part III – Tools: Policy and Technology Options 33

4. Economic Policies and Fertilizer Market Development 35
   (H. Gerner, A. de Jager, J. F. Teboh, B. Bumb, and N. N. Dembele)
   - 4.1 Influence of Global Policies on Soil Fertility 35
   - 4.2 Structural Adjustment Programs in West Africa 37
   - 4.3 Agricultural Markets and Intra-Regional Trade 39
   - 4.4 Fertilizer Market Development 40
5. Institutions and Support Services 49
   (K. Acheampong, H. Gerner, A. de Jager, B. Honfoga, and N. van Duivenbooden)
   - 5.1 International Organizations (International Agricultural Research Centers, IARCs) .. 49
   - 5.2 National Research and Extension Services 51
   - 5.3 Local Financing for Soil Fertility Improvement 54

D

Table of Contents
(Continued)

Page

6. Technologies for Restoring Soil Fertility 61
   (A. Bationo, E. Rhodes, E.M.A. Smaling, and C. Visker)
   6.1 Choice of Technologies 61
   6.2 Mineral (Soluble) Fertilizers 61
   6.3 Mineral Soil Amendments 64
   6.4 Organic Inputs 65
   6.5 Improved Land Use Systems 67
   6.6 Soil Conservation 70
   6.7 Integrated Nutrient Management (INM) 72

Part IV – Interventions 83

7. Turning the Tide 85
   (A. de Jager, E.M.A. Smaling, and A. Uzo Mokwunye)
   7.1 Farm-Level Constraints to Technology Adoption 85
   7.2 Farm Household Strategies Versus Government Strategies 86
   7.3 The Need for Reorientation of Valuation: Discounting Externalities 88
   7.4 The Way Forward: Interventions to Restore Soil Fertility 89

List of Abbreviations

AEZ	Agro-Ecological Zone
AFID	African Fertilizer Information Database
AFTMIN	African Fertilizer Trade, Marketing and Information Network
AROs	Advanced Research Organizations
AS	Ammonium Sulfate
CAN	Calcium Ammonium Nitrate
CEC	Cation Exchange Capacity
CGIAR	Consultative Group on International Agricultural Research
CILSS	Comité Inter Etats pour la Lutte contre la Sécheresse dans le Sahel
CIMMYT	International Maize and Wheat Center
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CMDT	Compagnie Malienne de Developpement de Textiles
CNCA	Caisse Nationale de Credit Agricole
COOPEC	Coopératives d'Epargne et Credits
DAP	Diammonium Phosphate
DMI	Desert Margins Initiative
ECU	European Currency Unit
EFZ	Equatorial Forest Zone
EPHTA	Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FCFA	West African Franc
FF	French Franc
FO	Farmers' Organization
FSSRP	Fertilizer Sub-Sector Reform Program
GATT	General Agreement on Tariffs and Trade
GO	Government Organization
GSZ	Guinea Savanna Zone
HEIA	High-External Input Agriculture
IAR	Institute for Agricultural Research
IARCs	International Agricultural Research Centers
IBSRAM	International Board for Soil Research and Management
ICRAF	International Center for Research on Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IGADD	Intergovernmental Authority for Drought and Development
IIMI	International Irrigation Management Institute

List of Abbreviations
(Continued)

IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INERA	Institut National d'Etudes et de Recherches Agricoles
INM	Integrated Nutrient Management
INSAH	Institut du Sahel
IRAT	Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières
ISLMP	International Sustainable Land Management Program
LEI-DLO	Agricultural Economics Research Institute, The Hague, The Netherlands
LEISA	Low-External Input and Sustainable Agriculture
MOP	Muriate of Potash
NACB	Nigerian Agricultural and Cooperative Bank
NAFCON	National Fertilizer Company of Nigeria
NARS	National Agricultural Research Systems
NGO	Non-Governmental Organization
NORAGRIC	Norwegian Agricultural Research Center
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
ORSTOM	Office de la Recherche Scientifique et Technique de Outre-Mer
PR	Phosphate Rock
PTD	Participatory Technology Development
SACCAR	Southern African Centre for Cooperation in Agricultural Research
SAFGRAD	Semi-Arid Food Grains Research and Development
SAP	Structural Adjustment Programs
SC-DLO	Winand Staring Centre for Integrated Land, Soil and Water Research, Wageningen, The Netherlands
SOP	Sulfate of Potash
SPAAR	Special Project in African Agricultural Research
SSA	Sub-Saharan Africa
SSP	Single Superphosphate
SSZ	Sudan Savanna Zone
SWNM	Soil, Water and Nutrient Management
SZ	Sahel Zone
TAC	Technical Advisory Committee
TSBF	Tropical Soil Biology and Fertility Programme
TSP	Triple Superphosphate
T&V	Training and Visit
UNEP	United Nations Environmental Programme
VCR	Value Cost Ratio
WAFMEN	West African Fertilizer Management and Evaluation Network
WARDA	West African Rice Development Association

6

Restoring and Maintaining the Productivity of West African Soils: Key to Sustainable Development

Executive Summary

Problem Definition

The Earth has become a Global Village, and West Africa is a slum in a dismal state of disrepair. More especially the all-important agricultural sector – the engine of economic growth – is going through unprecedented hard times. Locally produced cash crops, the main revenue earner for most governments, face increased competition from other producing regions where there have been substantial productivity increases and greater production efficiency. In some instances, consumer nations have found substitutes. Yields of food crops have steadily declined; at the same time, the number of mouths to feed is increasing more rapidly than at any other time in history. Market incentives for farmers are few because cheap imports of rice, wheat, and meat have become staples for the urban wage earners. Much-needed structural adjustment programs have had their downside effects on agriculture as the ensuing higher prices of external inputs such as inorganic fertilizers have discouraged farmers and caused them to avoid fertilizer use. Because of increased demographic pressure and decreasing yields, established practices for the restoration and maintenance of soil fertility as is typical of shifting cultivation have given way to exploitative continuous cropping. As farmers' yields decrease, area expansion is the only means available to them to increase the absolute amounts of food produced. Marginal lands are thus brought under cultivation. Deforestation, uncontrolled erosion, loss of biodiversity and overstocking continue to destroy an already fragile ecosystem while investments to maintain the productive capacity of the soil, i.e., its nutrient stocks, are virtually nonexistent. The net result is that more and more of the rural population is being drawn into the heart of the poverty spiral. For these people, the pains from the population, poverty, and environment nexus are all too real.

The above scenario has to be viewed in the context of a region where the inherent fertility of the soils is very low. Increased cropping intensity without replacing the nutrients that the crops remove annually has resulted in the mining of this small pool of native nutrients. Meanwhile, soil degradation, both physically and chemically, has become irreversible in many ecosystems because the soil resilience is very limited.

For the next 10-20 years, West African governments and the international community cannot afford a "business-as-usual" attitude. Sustainable development, however, calls for a clear assessment of the constraints to agricultural growth and the development and implementation of a number of interventions. This must be done soon and conscientiously. Time is not on the side of the West African people. The implementation of the interventions must be led by national governments, using the ingenuity of a properly sensitized farming community. Inevitably, the implementation also requires considerable institutional, scientific, and financial support from the international banking and donor community.

Technologies

Over the past fifty or more years, technologies to improve the productive capacity of West African soils have been generated. Unfortunately, these technologies have not been transferred to or implemented by the intended beneficiaries. The known technologies for restoring soil fertility can be grouped as follows:

- Increased and more efficient use of mineral fertilizers.
- Exploitation and use of locally available soil amendments such as phosphate rocks, lime, and dolomites.
- Maximum recycling of organic products, both from within and from outside the farm (crop residues, animal manure, urban refuse, compost, etc.).
- "Improved" land use systems, based on both indigenous and science-based technologies (rotation in addition to intercropping, agroforestry and related tree-based farming systems, increased use of species that can fix nitrogen from the atmosphere, alternatives to slash-and-burn so that fallows can be improved, etc.).
- Effective methods to control wind and water erosion, tailored to indigenous knowledge and using local biological and physical resources.
- The concept of "integrated nutrient management," which translates into the use of most efficient and attractive combination of previously known technologies, tailored to local farming systems and to specific agroecological niches that play a role at different system levels: regional (subhumid vs. semiarid), district (peri-urban vs. rural), watershed (rainfed uplands vs. valley bottoms), and farm (home garden vs. plots farther away).

Constraints

Agriculture can only be persistent and sustainable when the technologies are developed with the participation of the end users (and taking into consideration these clients' needs, means, and circumstances). As much as possible, local institutions should lead the way but with adequate support from external research and development institutions. Sustainability is also enhanced by the existence of an enabling policy environment. Constraints that impinge on one or more of the technologies previously listed are as follows:

- Mineral fertilizer use is hampered by unavailability of capital and credit, by national and international disincentives, by poor marketing and pricing, and by gender bias.
- Use of much cheaper soil amendments is hampered by lack of awareness and misconceptions on the returns to investment in soil fertility restoration using local resources, by low availability of identified local resources, and by lack of institutional support and extension.
- Use of organic inputs is limited mainly by lack of labor and sheer relative scarcity as a result of multiple uses.

- Non-adoption of "improved" land-use systems is exacerbated by limited knowledge on the need to integrate land use systems into farming systems and thus increase farmers' awareness and perception of the benefits, while specifically highlighting the role of women; by failure to recognize that tree systems and such other long-term investment packages require clear-cut land tenure arrangements.
- Labor availability, perceived high investment cost, reluctance to accept a long payback period, and lack of clear-cut land tenure arrangements are the major constraints to adoption of soil conservation measures.
- The constraints to integrated nutrient management are combinations of aforementioned constraints; major constraints at this time are limited awareness and perception by researchers, extension workers and (to a lesser extent) farmers, and the open questions that are still to be answered regarding the agronomic performance of integrated nutrient management practices, i.e., is the whole greater than the sum of its parts?

Interventions

The nature of the technology-constraint combinations has led to structuring of intervention at three levels, i.e., **supranational and regional (West Africa), national and district, and village and farm.** The major interventions proposed at the different operational levels are summarized below:

Supranational and Regional Level

- Revisiting impacts of Structural Adjustment Programs (SAP) and the General Agreement on Tariffs and Trade (GATT) in view of the need for positive incentives on fertilizer use and agricultural production.
- Raising awareness and arriving at a general consensus regarding the use of phosphate rock as a capital investment to enrich the phosphorus pool in West African soils (The World Bank Initiative in this respect is to be lauded).
- Developing and promoting economic valuation and discounting of externalities (productivity loss by not implementing anti-erosion policies, failure to consider the residual effect of phosphate rock, export of nutrients to other regions, impact of practices on greenhouse effect, and global climate change).
- Raising awareness of the threat of gross migration and the necessity for urgent action to promote survival through, e.g., worldwide funding of a "Marshall Plan" for West Africa.
- Promoting meaningful interdisciplinarity in research and development efforts through broad-based ecoregional consortia.
- Fostering regional collaboration on all issues where economies of scale would prove beneficial (e.g., common procurement of fertilizers; coordinated production and distribution of phosphate rocks).
- Developing and implementing agricultural market development policies, including promotion of crop diversification, improvement of domestic and export market structures, and market information.

5

- Formulating and implementing policy directed at creating economically viable off-farm employment in rural areas (e.g., processing units for oil and karité, small-scale manufacturing).
- Implementing and coordinating large-scale soil conservation investment schemes that integrate erection of structures with systems to improve soil fertility (e.g., use of phosphate rock in districts where stone lines have been erected).

National and District Level

- Establishing, at a high political level, Natural Resource or Soil Fertility Management Units to design and implement strategies for the effective development and management of natural resources with special attention to soil fertility restoration and maintenance.
- Reinforcing national agricultural research and extension systems and encouraging collaboration with all members of the farming community, including nongovernmental organizations.
- Creating an "enabling environment" that promotes agricultural growth: action on credit schemes, post-harvest operations that add value to farm output, output marketing schemes including, where necessary, price guarantee schemes, clear-cut land tenure arrangements, support to institutional and physical infrastructure, fine-tuning fertilizer recommendations for specific crop-soil combinations, and other nonfinancial incentives.
- Developing an inventory of natural resources available in the country for use in increasing soil fertility.
- Developing policies that reward the maximum use of organic inputs for increased biomass production and that optimize the use of external inputs in the rural and peri-urban sector.

Village and Farm Level

- Promoting a participatory approach to technology generation and validation as the only way to achieve greater adoption.
- Promoting financial, technical, and moral support to women's groups.
- Promoting "nutrient-saving" and "nutrient-adding" as opposed to "nutrient mining" technologies, where appropriate, while sensitizing farmers to the advantages accruing from adoption of these technologies (e.g., use of energy-saving stoves, kraaling on fields rather than in stables, N-fixing fodder species to be mixed with phosphate rocks through composting, planted stone bunds, fencing off fallows periodically).
- Promoting fertility buildup and intensified production on land that is of high potential such as land in close proximity to homestead and compost pit (relatively highly fertile) and where labor and water are available, in order to give land without such advantages a recuperative period.

The Way Forward: The Role of the International Fertilizer Development Center-Africa

Since its inception in 1987, the Togo-based Africa Division of the International Fertilizer Development Center (IFDC-Africa) has gained most valuable knowledge on soil fertility and fertilizer use within West Africa. IFDC-Africa has established two networks on fertilizer trade and marketing (African Fertilizer Trade, Marketing and Information Network, AFTMIN) and on soil fertility management (West African Fertilizer Management and Evaluation Network, WAFMEN) to anchor its two programs – Policy Reform, Market Research and Development Program and Watershed Management Program.

IFDC-Africa has conducted detailed **fertilizer sector studies** in Benin, Togo, Burkina Faso, Niger, Ghana, and Mali. These studies address issues related to fertilizer demand, procurement, and domestic marketing. Complementary studies have also been conducted in Ghana and Mali on such **policy issues** as food security and fertilizer use, agroeconomic potential of fertilizer use, and pricing and macro-economic policy environments. These detailed studies conclude with recommendations for all players in the national fertilizer sector. Program scientists conduct follow-up activities to help ensure that policymakers act upon these recommendations. In 1994 the Federal Government of Nigeria commissioned IFDC to design a program for the liberalization of the fertilizer sector. Recently, IFDC-Africa completed a study on Ghana titled "Ghana Fertilizer Privatization Scheme: Private Sector Roles and Public Sector Responsibilities in Meeting Needs of Farmers." In November 1994 IFDC-Africa organized a seminar on the use of locally occurring phosphate rocks for soil fertility improvement in West Africa; the proceedings of this seminar have been published.

This accumulated knowledge is valuable and is beginning to have an impact on the "character" of agriculture in the respective countries. It is also apparent that an action-oriented approach by governments to tackle the problems of degraded soils, deforestation leading to loss of biodiversity and desertification, and stagnant or declining yields has proved elusive. IFDC-Africa is firmly convinced that the restoration of soil fertility is key to West Africa's resurrection and is prepared to cooperate with West African governments to design and implement programs that would remove the aforementioned constraints and pave the way to sustainable development.

Part I – Introduction

1. Problem Definition

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Part I – Introduction

1. Problem Definition

1.1 Agricultural Development in West Africa: An Apocalyptic Outlook

The "information super-highway" has turned the Earth into a Global Village where West Africa is a slum in a dismal state of disrepair. Agriculture has always been the mainstay of the economies of West African countries. It is this all-important agricultural sector whose growth has declined or, at best, stagnated. Locally produced cash crops face increased competition from other regions where the efficiency in production has increased, and the yields have dramatically risen. In some instances, consumer countries have developed substitutes. Very low yields characterize most food crops, especially those produced in the drier zones of the region. Nations that were capable of producing enough food to feed their people thirty years ago now depend on food aid. This limited food production is against the backdrop of population increases that are among the highest in the world. Market incentives for farmers are few because cheap imports of rice, wheat, and meat provide alternatives for the urban wage earners. Much-desired structural adjustment policies have had their downside effects especially on the price of farm inputs. Escalating prices resulting from currency devaluation and subsidy removal have not encouraged farmers to use external inputs such as mineral fertilizers. The vagaries of climate have usually adversely affected agriculture in West Africa. However, normal adverse effects associated with long-term changes in climate have given way to more drastic changes occurring in the short term and which are induced by human beings. Thus, such practices as massive deforestation and large-scale burning of fallows have had adverse impacts on climate. Figure 1.1 illustrates the annual rainfall trends in Niamey, Niger, over the past 2-3 decades. The sometime considerable within-season and short-distance variation in rainfall, a major cause of farmers' risk-averse attitude, has increased.

The aforementioned adverse climatic conditions coupled with the inability of farmers to replenish nutrients that the crops have removed from the soils have led to low productivity per unit area. Food crop farmers, forced by the need to produce more for a growing population, have lost the stability once associated with a shifting cultivation system. The situation today is thus characterized by the expansion of cultivated area, deforestation, bush burning and overstocking. With low incentives, farmers are unable or unwilling to invest in maintaining the productive capacity of the soil. The net effect is that soil fertility levels in the region, which already are very low for geological reasons, have become depleted to the extent that yields of food crops and forages have slumped to very low levels.

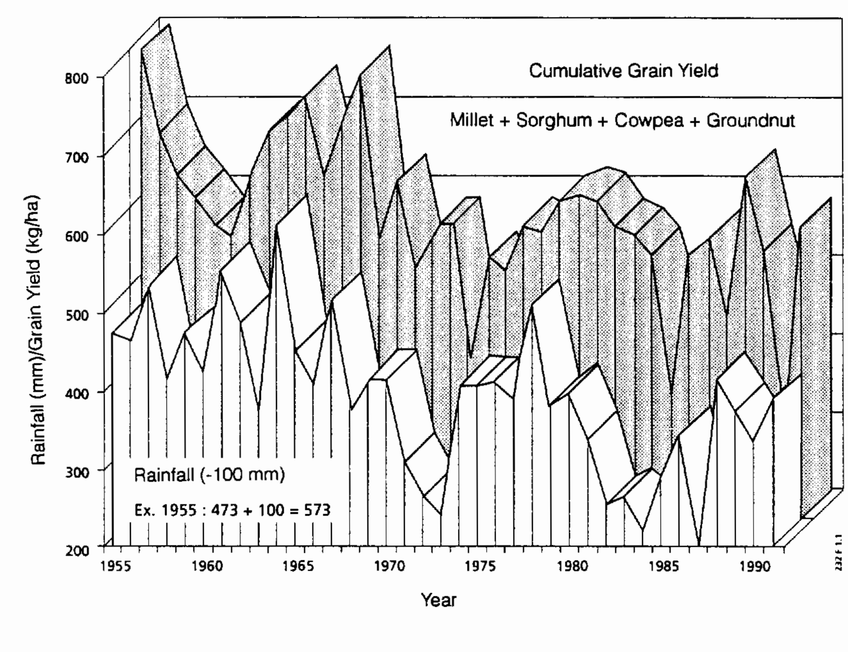
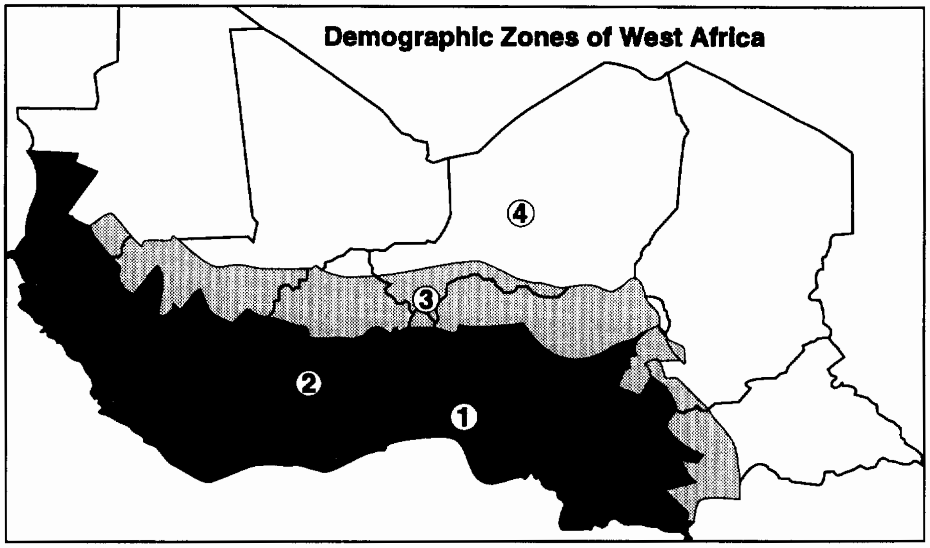


Figure 1.1 Annual Rainfall Totals in Niamey, Niger, Over the Past 30 Years (Delvaux et al., 1993).

1.2 Demographic Pressure: The Social Time Bomb

Since 1960 the West African population has more than doubled from 85 million to 215 million people in 1993, which corresponds to an annual growth rate of 2.7%. In Table 1.1 the population projections for West Africa are compared with those for sub-Saharan Africa and the world as a whole.

In West Africa, the projected growth rates are the highest not only in sub-Saharan Africa but also in the entire world. Population densities within West Africa vary widely, i.e., from 2 inhabitants km^{-2} in Mauritania to 110 inhabitants km^{-2} in Nigeria. With an average population density of 31 inhabitants km^{-2}, the population density in West Africa is still relatively low compared with that of Asia (75 inhabitants km^{-2}) but much higher than that of North Australia, which has a similar topographical and agroecological setting. Next to total population, the distribution of the population between rural and urban areas and between landlocked and coastal countries is expected to change dramatically (Figures 1.2 and 1.3).



	Share of Total Surface Area (%)	Share of Total Population (%)		Total Population Growth Rates (%)	City Dwellers Ratios (%)		Urban Population Growth Rates (%)
		1960	1990	1960/90	1960	1990	1960/90
Zone 1	7	35	41	3.2	25	55	5.9
Zone 2	25	29	28	2.6	10	30	6.4
Zone 3	13	27	25	2.4	8	32	7.5
Zone 4	55	9	6	1.7	6	22	6.0
Region	100	100	100	2.7	14	40	6.3

Figure 1.2 Population Development in West Africa Between 1960 and 1990 (Snrech, 1994).

Table 1.1 Population Projections, 1990 - 2010

	Total Population					
	Millions			Annual Growth Rate (%)		
	1990	2000	2010	1980-1990	1990-2000	2000-2010
World	5,295	6,228	7,150	1.8	1.6	1.4
SSA	486	658	874	3.1	3.1	2.9
West Africa	192	265	358	3.2	3.3	3.1

Source: World Development Report, various issues.

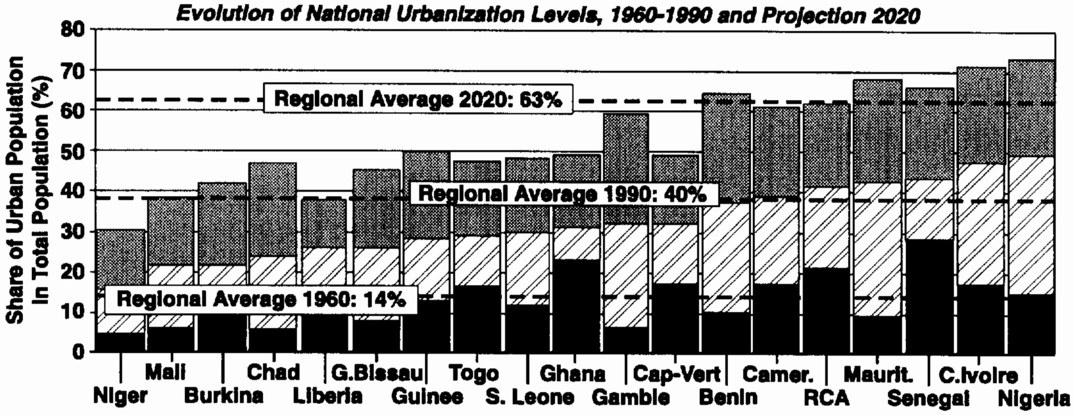


Figure 1.3 Expected Division of Population Between Urban and Rural Areas in 2020 (Snrech, 1994).

1.3 Raising International Awareness

During the next 10-20 years, if West African governments and the international community adopt a "business-as-usual" attitude, it would not be far-fetched to predict that there would be gross migration from the drier countries bordering the Sahara Desert to the more humid countries farther south. This would probably be followed by mass starvation.

Meanwhile, people of goodwill can only hope that international commitment on the implementation of Agenda 21, the legacy of the 1992 UN Conference of Environment and Development, will not waver. Agenda 21 describes a series of environmental issues to be addressed and avenues to be followed to move closer to sustainable development by the year 2000. Chapter 10 ("Integrated Land Use Planning and Management") addresses an integrated approach to planning "to facilitate the allocation of land to the uses that provide the greatest sustainable benefits and to promote the transition to a sustainable and integrated management of land resources. In doing so, environmental, social, and economic issues should be taken into consideration." This statement is then translated into four specific objectives, aimed at the review and strengthening of (a) integration of environmental, social, and economic policies, (b) systems of planning, management, and evaluation, (c) institutions and coordinating instruments, and (d) participation of all involved in the decisionmaking process. Chapter 14 ("Promoting Sustainable Agriculture and Rural Development") specifically deals with sustainable agriculture and rural development. Program area "J" deals with "sustainable plant nutrition to increase food production," and singles out the African continent as the one that loses soil fertility at an alarming rate.

A scenario for sustainable development calls for the rapid but forceful implementation of a number of interventions. National governments must take the lead with the able support and ingenuity of a properly sensitized farming community. However, these efforts must inevitably require considerable financial, institutional, and scientific support from the international banking and donor community.

1.4 Objectives of the Study

Since its inception in 1987, the Togo-based Africa Division of the International Fertilizer Development Center (IFDC-Africa) has gained most valuable knowledge on soil fertility and fertilizer use within West Africa. Building on earlier work by pioneers (NARS, FAO, IRAT/CIRAD), IFDC-Africa has undertaken and published several country-specific studies, which describe the nature of soil fertility and the fertilizer sector in its broadest possible context. IFDC-Africa has established networks on fertilizer trade (AFTMIN) and on fertility management (WAFMEN). These networks have brought together stakeholders from both the public and private sectors to be apprised of the need to restore and maintain the fertility of the soils. Considering the amount of accumulated knowledge, the time has arrived to convince governments and the people of the need and the urgency to implement soil fertility restoration and maintenance programs.

Therefore, the objectives of the present exercise are as follows:

- To collate existing information on farming systems and soil fertility issues in West Africa, thereby highlighting the urgency of the problem of poor soil fertility (Part II; literature study).
- To collate existing information on policies, infrastructure, and technologies that can directly or indirectly improve soil fertility (Part III; literature study).
- Based on the foregoing, to systematically develop a multidisciplinary, multiscale framework for action (Part IV). This framework lists the major constraints to the implementation of soil fertility policies and technologies and the appropriate scales at which interventions to remove these constraints should be taken.

1.5 Methodology

This report is the work of a multidisciplinary team, consisting of IFDC agronomists, soil scientists, sociologists, socioeconomists, and consultants from the region and two Dutch institutions, the Dutch Agricultural Economics Research Institute (LEI-DLO) and the Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO). The draft report was then reviewed by a team of independent, knowledgeable "Dutch West Africans."

Apart from summarizing published and unpublished work by IFDC, the literature review included targeted searches in CD-ROM and the archives of CAB International for materials from annual reports and specific studies by the various national research systems, the CGIAR centers active in the region (ICRISAT, IITA, ILRI, WARDA), and other IARCs such as CIRAD and ORSTOM. The SPAAR database on agricultural projects in West Africa was also consulted. Humid, Savanna and Sahel teams were formed to search for information from the less-accessible literature (so-called grey literature). As is usual with studies of this nature, time was the enemy, and the literature search is far from being exhaustive. We hope that readers will identify critical missing information that can be included in future publications.

It must be stated that the amount of information in the literature was rather unevenly distributed over the region. For countries such as Gambia, Guinea-Bissau, Cape Verde, Guinea, Liberia, and Chad, very little information was available; whereas, there was, relatively speaking, a mountain of information on Ghana, Nigeria, Burkina Faso, and Mali. Secondly, many studies often provide no clues as to whether results can be extrapolated to other parts of the region that have similar environments. This holds true especially for the results of farming systems research.

Throughout the report, reference is made to West Africa's different agroclimatic zones (Table 1.2). The four agroclimatic zones are separated by growing-period isolines that run more or less east-west (Figure 1.4). When relevant, the Sahel will be subdivided into a northern and southern zone. The Guinea savanna is usually classified as the moist savanna, and the Sudan savanna is the dry savanna.

1.6 Reader's Guide

In Part II, "Farming Systems and Soil Fertility," the predominant farming systems and their characteristics are described (Chapter 2), followed by

Table 1.2 Agroclimatic Zones and Length of Growing Period

Sahel Zone	Between the Sahara and the 90-day growing-period isoline;
Sudan Savanna Zone (SSZ)	Growing period between 90 and 165 days;
Guinea Savanna Zone (GSZ)	Growing period between 165 and 270 days;
Equatorial Forest Zone (EFZ)	Growing period > 270 days.

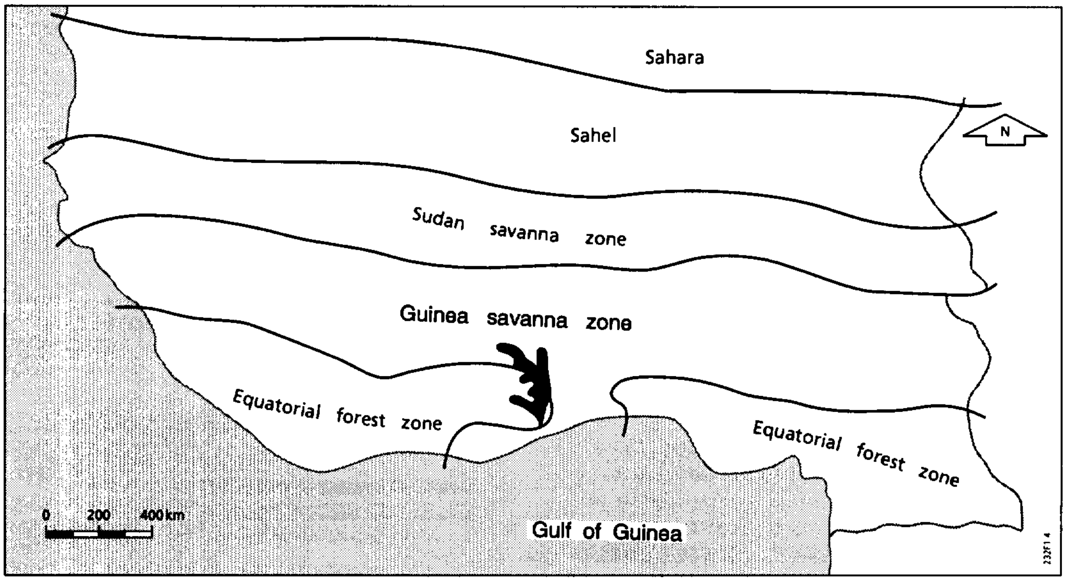


Figure 1.4 Agroclimatic Zones in West Africa (After Andriesse and Fresco, 1991).

an overview of the nutrient stocks and nutrient flows in West African soils (Chapter 3). Part III, "Policy and Technology Options," presents the available tools to address the soil fertility problems in West Africa. Chapter 4 deals with the macro-economic environment and available policy instruments at the international, regional, and national levels; in Chapter 5 institutions and support services to restore soil fertility are described. Chapter 6 presents the "state-of-the-art" of available technologies to address the soil fertility situation in West Africa. In Part IV, "Interventions," the available technical, policy, and economic tools are integrated into a set of recommended interventions to turn the tide and to develop a viable and sustainable agricultural sector in West Africa.

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Part II – Diagnosis: Farming Systems and Soil Fertility

2. Farming Systems in West Africa

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Part II – Diagnosis: Farming Systems and Soil Fertility

2. Farming Systems in West Africa

2.1 General Characteristics

2.1.1 Household Composition and Strategies

The multiplicity of crops grown, even by a single household, underscores the invalidity of the simplifying assumption that the goal or sole aim of the limited resource farmer is survival. Different farm households and, indeed, individuals within the same household may have different aims. In general, most farmers pursue some combination of the following objectives: securing an adequate food supply; earning a cash income to meet other material needs; avoidance of risk or survival in an uncertain environment; provision for the future, old age, and the welfare of dependents; and achievement of status within the community (Upton, 1987; Ellis, 1988). Thus, the degree of importance that a farmer attaches to any or a combination of these objectives, within the existing technical constraints, greatly influences the amount of resources to allocate to soil fertility improvement.

The basic social unit of production, which invariably constitutes the unit of consumption, is the compound or farm household, a physical entity which is usually organized along familial or lineage lines. A traditional household or compound generally consists of a male head of household and his wife or wives, their children and grandchildren. Reports indicate that this traditional complex family unit is gradually dividing into simpler nuclear family units (Benoit-Cattin, 1977), with women increasingly assuming the responsibility as heads of household. This trend has partly been found to be a consequence of out-migration, especially of the younger generation (Baanante et al., 1989; Thompson et al., 1990). These developments have implications for soil fertility improvement because they influence the allocation and use of land and labor, the two most important resources available to the resource-poor farm household.

2.1.2 Land Tenure

Because of their territorial character, land tenure systems in West Africa have deep roots in local traditions. Among the rural farming population, land is regarded as the most important asset for three principal reasons: (a) land is primarily tied to livelihood, therefore, ownership or control of land defines people in their relations to the surrounding community, (b) land ensures a community's stability and continuity, serving as a secure base for retreat, and (c) land ownership influences employment and establishes a rural person's contribution to society.

These social realities about land notwithstanding, land ownership in most parts of West Africa is generally vested in the state and controlled at the village or community level by the traditional chief or headman (Norman et al., 1981). Farm families and individuals generally exercise only usufructuary rights to land they cultivate and may pass on these rights to their siblings depending upon the prevailing system of inheritance. There are a few other forms of land acquisition. Southgate (1990) reports that in some areas in Mali, usufructuary rights to land can be acquired simply by clearing and cultivating the land. The same holds true for parts of southwestern Nigeria (Mokwunye, personal communication). Under this system of land acquisition, the incentive has been strong for settlers to move to previously uncultivated areas and to clear the land quickly, thereby strengthening their claims and weakening those of other potential users.

Recent reports, including in-depth studies by IFDC in Ghana, Togo, and Niger (Acheampong, 1990), suggest that new subcategories of land tenure arrangements are emerging in response to increased demand for arable land, heightened by rapid growth in human and animal populations. The IFDC study found that, although more than 75% of the area cropped by the study sample during the survey year was classified as family or individually owned, new categories such as individually borrowed, individually rented, family borrowed, and family rented are becoming increasingly common (Table 2.1). It was also found that a tendency towards individualization of farmland is gradually being institutionalized, casting doubt on the

Table 2.1 Number and Areas of Farm Plots by Gender of Manager, Land Tenure in Three Different Countries

Gender of Land Tenure Plot Manager	Type of Tenure	Ghana (EFZ) No. of Plots	Ghana (EFZ) Total Sample Area ha	Ghana (EFZ) Total Sample Area %	Togo (SSZ and GSZ) No. of Plots	Togo (SSZ and GSZ) Total Sample Area ha	Togo (SSZ and GSZ) Total Sample Area %	Niger (Sahel) No. of Plots	Niger (Sahel) Total Sample Area ha	Niger (Sahel) Total Sample Area %
Men										
	Family owned	79	22.1	73	286	205.9	78	170	311.1	87
	Family borrowed	3	0.5	2	31	24.2	9	5	5.5	2
	Family rented in	3	2.2	7	8	9.6	4	1	0.5	0
	Individual owned	11	3.8	12	16	11.0	4	16	38.9	11
	Individual borrowed	1	0.2	1	24	13.4	5	-	-	-
	Individual rented in	3	1.4	5	-	-	5	-	-	-
	Total sample	100	30.2	100	365	264.1	100	192	356	100
Women										
	Family owned	108	24.7	82	39	12.1	58	20	20.8	49
	Family borrowed	6	0.8	3	1	0.3	2	-	-	-
	Family rented in	8	2.1	7	1	0.1	0	1	0.8	2
	Individual owned	8	1.6	5	2	0.6	3	24	20.6	49
	Individual borrowed	3	0.6	2	32	7.7	37	-	-	-
	Individual rented in	2	0.4	1	-	-	-	-	-	-
	Total sample	135	30.2	100	75		100	45	42.2	100
Total sample										
	Family owned	187	46.8	78	325		76	190	331.9	83
	Family borrowed	9	1.3	2	32		9	5	5.5	2
	Family rented in	11	4.3	7	9		3	2	1.3	0
	Individual owned	19	5.4	9	18		4	40	59.5	15
	Individual borrowed	4	0.8	1	56		7	-	-	-
	Individual rented in	5	1.8	3	-		-	-	-	-
	Total sample	235	60.4	100	440		100	237	398.2	100

Source: Acheampong (1990).

continued validity of the general characterization of farmlands in West Africa as communally owned or clan-centered. The corollary, however, is that inequality may be growing because there may be many people out there (such as women in the Togolese sample) whose access to land may be restricted to borrowing or renting from other farmers.

These developments have both negative and positive ramifications on farmers' readiness to invest in their farmlands. On the positive side, the increasing significance of fields under individual rather than family control, however minimal, may provide the collateral to enhance farmers' access to credit, while encouraging investment and proper land management. This is because when farmers own the land, there is often the tendency to use it in a sustainable way (Dudley et al., 1992).

On the negative side, it is reasonable to believe that farmers who rent or borrow farmlands may be exacerbating the problems of land degradation because: (1) the incentive for a tenant farmer to make medium- or long-term investment in a rented piece of land may be curtailed because benefits from such investments may not necessarily accrue to him/her but rather to the landlord. This is especially so, if the tenancy agreement requires that the land reverts to the owner after two or three years' cropping, (2) there is always the tendency for tenant farmers to over-exploit farmlands, and (3) landlords may determine the type of crop to be grown by the tenant farmer and, for that matter, the type of soil fertility maintenance strategy to be adopted. Luning (cited in Norman et al., 1981) has documented that in some parts of northern Nigeria, tenant farmers are dissuaded from applying organic fertilizer because such application gives an implied hint that the tenant might be nurturing the intention of holding on to the control of the land. In another study, Hopkins (1975) reports that in Senegal, land is rarely rented for more than one year at a time; therefore, its over-exploitation by tenant farmers is encouraged.

In the Sahel, Sudan Savanna Zone (SSZ) and Guinea Savanna Zone (GSZ), increasing tension between producers of food crops and livestock raisers is becoming the norm. Large areas of natural pastures are required to achieve the various objectives of livestock production: meat production, draft power and soil fertility maintenance. For instance, in the Sahel it is estimated that 40 ha of natural pasture is required to maintain the fertility of fields for crop production (Breman et al., 1990; Breman, 1987). In the process of securing property rights, the interests of the livestock producers must be considered.

Securing property rights through legal protection systems that are demand driven and closely linked to the existing traditional system will encourage adoption of long-term investment and production strategies.

2.1.3 Capital

The capital stock of the farm household such as tools and equipment, farm animals, and seeds plays a significant role in shaping the type of farming system used by members in a given household. As shown in Table 2.2, manual labor and a few handtools such as hoes, machetes, and dabas are all that is available for most West African farmers to carry out their farming activities. Ownership and, by implication, use of modern farm equipment such as tractors and power tillers are virtually nonexistent. The modern equipment that is available is usually owned by men. However, an increasing proportion of the farm household own or is beginning to make use of animal traction equipment, mainly plows and carts. A significant proportion of farmers engage in off-farm work of some sort to generate additional income to supply their needs and also to invest on their farms. This is particularly true in the SSZ and Sahel where rainfall and other climatic conditions restrict cropping activities to only 5-6 months of the year.

Table 2.2 Mean Sociodemographic Characteristics of Sample Farmers From Three Regions in West Africa

Region (Zone)	Gender	No.	Age (Years)	Formal Schooling (Years)	Household Size	Fertilizer Use (% of Farmers)	% of Farmers Owning: Equipment	Handtools	Animals[a]	Off-Farm Employment (% of Farmers)
Ghana (EFZ)	Men	54	39.0	7.8	6.4	21	7.4	100.0	50.0	30
	Women	67	41.8	4.1	5.8	9	0.0	94.0	49.0	30
	Total	121	40.6	5.7	6.0	14	3.3	96.7	50.0	30
Togo (SSZ)	Men	96	45.7	0.8	11.1	79	7.3	100.0	98.0	32
	Women	29	40.0	0.2	8.9	29	0.0	93.1	90.0	72
	Total	125	44.4	0.7	10.6	68	5.6	98.4	96.0	42
Niger (Sahel)	Men	80	43.5	2.2	8.9	34	6.5	98.9	85.0	35
	Women	31	42.1	0.0	4.2	19	0.0	97.3	87.0	0
	Total	111	42.8	1.5	7.6	32	4.7	98.4	85.0	26

a. Ghana: mainly poultry; Togo: mainly pigs; Niger: mainly sheep, goats, cattle, donkeys, camels, and poultry.

Source: Acheampong, 1990 + SFRP-data.

2.1.4 Labor and Gender

A significant proportion of farm labor is provided by family members including children. Farm labor may also be hired and compensated for in one form or another, or sought from friends and relatives, depending on the urgency and the task to be performed. Because of regional differences, it is difficult to generalize about gender division of labor in agriculture. Land preparation, weeding, pest control, and fertilizer application represent significant task specialization of men regardless of agroecological zone or region (Baanante et al., 1990). In most of the agricultural production systems labor is one of the limiting factors (Veeneklaas et al., 1991). Reports of extreme seasonality of labor requirements and labor peaks for farm tasks such as land preparation, weeding, and harvesting have been published (Matlon, 1985; Runge-Metzger, 1988), underscoring the point that any introduction of soil fertility and, for that matter, yield-enhancing technologies must always be supported with labor-efficient technologies.

The triple role of West African women in the agricultural sector, i.e., crop production, processing, and marketing, has been well documented. In recent times this awareness has put women farmers in the center stage in agricultural intensification and environmental conservation forums. Women farmers in West Africa constitute almost 55% of the agricultural labor force, manage between one-third and one-half of all farms, and produce between 50% and 60% of food consumed in the region (Date-Bah, 1985; Saito, 1991). However, the general literature on agricultural development in the subregion suggests that governments' agricultural policies and programs often bypass women and, thus, make them a highly marginalized group. Accumulating evidence indicates that, compared with men, women have even more limited access to agricultural technology and essential support services, including extension and credit (Saito, 1991), and are more likely than men to cultivate marginal lands (Due and Summary, 1982).

Cultural variations in the region make generalizations about the causes of the continuing gender inequality in agricultural resource allocation and use extremely difficult. One thing is certain, however, the inequality is widespread and is generally rooted in cultural and religious factors, including strong traditional beliefs that discourage a questioning attitude. Traditional customs and practices that accentuate the marginalization of women manifest themselves in several forms, including gender-segregated crop production responsibilities and division of labor. Details vary among cultural groups, but in areas where markets have developed for farm products [such as cocoa and coffee in the Equatorial Forest Zone (EFZ) and cotton in the SSZ], men tend to specialize or focus on cash crop production and leave women to be responsible for the production of food crops mainly for home consumption (Saito, 1991) and for sale of surpluses in good years (Baanante et al., 1990).

These segregation practices have wide implications for the promotion of various crops and soil management practices and targeting of research and extension services. For example, because most of the food crops grown by women are consumed in the household, women would be less likely than men to have the financial resources to invest in technologies for agricultural intensification and soil conservation. Consequently, women farmers' contribution to land degradation would be substantial. Secondly, because research and extension activities tend to focus more on export cash crops (which fall in the domain of men) than on food crops, benefits flowing from these essential services will generally bypass women.

Furthermore, agricultural technologies developed and introduced are rarely geared to, or even cognizant of, the special needs and constraints of women. In some cases such technologies tend to increase the burden of women (Cleaver and Schreiber, 1992) and even accelerate land degradation. For example, in some parts of the SSZ and Sahel, introduction of the plow for land preparation (an overwhelmingly task specialization of men) has significantly reduced the labor requirement of men. At the same time however, use of the plow has tended to increase the area to be sown to crops and increased the labor requirement of women (sowing being a task specialization of women, using traditional technologies). This situation may result in pieces of prepared land being uncultivated and thus highly vulnerable to erosion.

Another problem facing the West African woman farmer is access to male labor. This problem is exacerbated by out-migration of men and the increasing popularity of nuclear families and female-headed households. Adherence to gender-specific division of labor implies that tasks such as land preparation and erosion control measures are not properly done or done at all. Their effects on land degradation can be very substantial.

Although the evidence of systematic bias against women in terms of access to farmland is not conclusive, there are indications that in some cultures women rarely have titles to the land they crop. Acheampong (1990) reports that among the Moba-Gourma ethnic group in the SSZ of Northern Togo, women farmers have virtually no tenurial security to the land they crop and are more likely than men to crop on land borrowed from other members of the community (Table 2.1). Thus, the likelihood of such women not adopting recommended land management practices is very high. Well-coordinated policies and programs are needed to alleviate the physical and sociocultural barriers facing women farmers so that they can achieve their full potential in the agricultural production effort.

2.2 Agricultural Production Systems

2.2.1 Rainfed Crop Production Systems

Cropping practices have evolved over the years and usually reflect human adaptation to the changing environment. Current estimates indicate that about 80% of all farmland in West Africa is multiple cropped. Not only is multiple cropping dominant throughout the region, but it is also a practice that continues to undergo modifications by the practitioners (usually the limited-resource farmers) in response to changing physical and socioeconomic environments.

In the EFZ, more than 60 crop species may be planted on one farm, though 20-30 is probably more realistic (Richards, 1985). Tree crops, tubers, cereals, and assorted vegetables are grown for home use and also for sale. Both sole and multiple cropping are practiced in this zone. The crop mixture is complex and may consist of maize, cassava, cocoyam, plantain, and vegetables (pepper, tomatoes, etc.). Smallholder farming systems with plantation crops such as cocoa, oil palm, coffee, and sugar can be found in this zone. On plantation crops, relatively high levels of external inputs (mainly insecticides and pesticides) are used (Beets,1990). A more detailed description of the farming systems in the EFZ can be found in the work of Okigbo and Greenland (1976).

The rainfed cereal-based farming system is most common in the SSZ and Sahel. Millet- and sorghum-based intercrops dominate the cropping system in the drier SSZ and Sahel. Other important crops are cotton (the number one cash crop in the Sahel and the SSZ), groundnuts, bambara beans, cowpeas, and sesame. In general, few improved crop varieties are grown by farmers (Matlon, 1985; Nagy et al., 1986). In the GSZ, maize- and/ or cassava-based intercrops are common.

In the Sahel and SSZ, concentric ring-farming is a common feature with high-intensity farming closer to the village or homestead, decreasing in intensity with increasing distance from the homestead (Prudencio, 1983). On the fields close to the homesteads, permanent cultivation takes place, often with early maturing crops, and a continuous application of manure, domestic refuse, and compost is practiced. In the outer circle farther away from the homesteads, hardly any nutrient inputs are applied on cereals, and continuous cultivation gives way to a form of shifting cultivation. Various forms of agro-forestry practices can be found, including dispersed trees in annual crop fields (acacia/millet) in the Sahel Zone and fodder trees in combination with cereals in the SSZ. An account of the soil fertility of these ring-based subsystems is given in Chapter 3.

2.2.2 Livestock Production Systems

In the Sahel and SSZ, various livestock production systems can be identified (Wilson et al., 1983). They include:

- Systems characterized by a high degree of mobility of the animals and a wide range of animal species and production objectives, basically common in the Sahel zone;
- Systems characterized by a sedentary pattern of livestock raising with a tendency to concentrate on one particular activity, common in the Sudan zone;
- Intermediate systems consisting of a combination of the aforementioned systems.

In the nomadic systems, animals are kept mainly for meat and milk production, while the animals raised under the more sedentary systems are primarily to aid the crop production process: animal traction and manure. For example, Nagy et al. (1986) have documented that on the Mossi Plateau of Burkina Faso, a significant portion of the farm work is done by farm animals, especially the donkey. Unlike in the drier zones, climatic constraints and diseases do not permit livestock raising on an appreciable scale in EFZ. The few animals kept in this zone (mainly poultry and small ruminants) are not fully integrated into the cropping system. Animals in this zone, therefore, are generally kept for home consumption and may be sold as a last resort to raise money to meet financial exigencies.

In the Sahel zone livestock production takes place mainly in pastoral systems with hardly any use of external inputs. The productivity of these systems is generally rather low. The harsh conditions of the Sahel have proven to be advantageous for this low-input form of animal production: no or limited competition with arable farming and large quantities of rangeland vegetation. In the SSZ where sedentary systems are more common, draught animals were primarily raised (often entrusted to herdsmen for most of the year). Increasingly, however, farmers have been obliged to keep a sedentary herd in non-cropped kraals where the wastes can be concentrated and used for soil fertility improvement. Low fodder quality in these systems is a major limitation to animal production since animals are fed mainly on crop residues. The increase in the number of animals kept under the sedentary systems is an indicator of the diminished size of dry-season grazing grounds for mobile herds in SSZ (Traoré and Breman, 1993). This has become a serious source of conflict between herders and crop farmers.

Sustainability and increased productivity of the livestock production systems can be attained mainly through an increase in the controlled production of high-quality animal feeds. This implies increased intensification and a further reduction of the mobile character of the production systems (Breman and Niangado, 1994). However, recent calculations show that the Value/Cost Ratio for meat production based upon fertilized fodder crops is only 1.1 (Wooning, 1992), which is mainly due to stagnating prices of meat and increasing prices of fertilizers. Minor policy changes, however, can change a V/C Ratio considerably, particularly if such changes affect both the "V" and the "C" (see also 4.1.2)

2.2.3 Crop-Livestock Production Systems

The raising of livestock in combination with the production of food crops is fast becoming an important system (crop-livestock interactions) in the SSZ and GSZ. Meat, animal traction, and manure are the major outputs of the livestock component, mainly consisting of cattle (oxen), donkeys, small ruminants, and poultry (chicken and guinea fowls). A greater interaction between crops and livestock, with the goal of improving resource-use efficiency and increasing productivity appears to be a feasible option in most of the mixed farming systems. This may result in a shift from cattle to small ruminant-based farming systems (van Duivenbooden, 1995). It is recognized, however, that the use of animal traction may be an essential factor in a further intensification of mixed production systems. Aspects that need attention are increased soil fertility to increase crop and livestock productivity, incorporation of forage crops into the cropping system, optimal use of crop residues and byproducts, and forms of livestock husbandry geared toward the maximum recycling of manure and urine (McIntire et al., 1992). However, several conflicting interests have been identified: subhumid conditions of both the SSZ and the GSZ favor the production of crops and low-quality forage; the need for manure for improved crop growth demands kraaling, which means that there is little manure for the forage; animals compensate for the poor quality of the fodder by grazing for longer periods; straw, which is needed to capture urine is currently used as fodder; use of animal draught reduces opportunities for milk production (Traoré and Breman, 1993).

2.2.4 Irrigated Crop Production Systems

Irrigated and naturally flooded land can potentially sustain high crop yields, provided there is adequate drainage of saline and acid water and sufficient input of nutrients. In terms of hectarage and total production, irrigation is not very important in West Africa. Increases in productivity of rainfed agriculture (for example, through application of fertilizers and manure) will have a much greater impact on total food production than an increase in area irrigated. For one thing, irrigable areas are only restricted to limited potentially suitable locations. In addition, the high construction and maintenance costs of irrigation systems are serious constraints to a further extension of the irrigated area in the region. The largest areas under irrigation can be found in Nigeria, the inland Niger delta in Mali (Office du Niger), the deltas of major rivers, and some scattered wetlands, such as Vallée du Kou in Burkina Faso. All over the Sahel, from Bafata in Guinea Bissau to Birni N'Konni in Niger, small-scale irrigation is practiced. A limited percentage of the many inland valleys in West Africa is irrigated; the rest is flooded during part of the season. Mangrove areas and the Sierra Leonean bolilands are also naturally flooded. The major crop is wetland rice. Receding water in the lower inland Niger delta allows cultivation of flood-retreat sorghum and grasses for the transhumance livestock of the Sahel and SSZ.

2.2.5 Peri-Urban Production Systems

As of 1990, 40% of the West African population lived in cities, compared with 14% in 1960. An estimated 60% of the subregion's population is projected to be living in urban centers by the year 2020 (Snrech, 1994). Urbanization is associated mainly with migration from the landlocked countries of Mali, Burkina Faso, and Niger to the coastal countries. This rapid process of urbanization has provoked some specific changes in agricultural production systems in West Africa.

Because demand for food and other primary products such as fuelwood is concentrated in urban areas, the physical distance between production and consumption centers is increasing. This has given rise to considerable changes in rural-urban interactions (Gould, 1988). The changes include: increasing flows of goods from production centers to the urban centers; reduction of available labor force in agricultural production centers; increasing cash flows from urban to rural areas (remittances); increasing number of female-headed households when males assume urban jobs; increasing nutrient export from rural areas into urban centers; and limited return of organic materials to the agricultural production centers.

In apparent reaction to the increasing urban population, peri-urban farming systems have emerged and are expected to assume greater importance in the years ahead. Studies of urban and peri-urban farming systems in West Africa are scattered and scanty, but there is evidence that smaller towns are surrounded by intensively cultivated land, while larger urban centers have conspicuous inner and outer zones where cultivation of food crops and market gardening are being pursued vigorously (Swindell, 1988). Around these major towns, a wide spectrum of production systems can be found ranging from household subsistence to large-scale commercial farming. In general, there is a tendency toward more intensive production systems in peri-urban areas. In the inner circles of the peri-urban fringes, existing homegardens can be further developed and commercialized to provide additional income, using marginal land and labor (Hoogerbrugge and Fresco, 1993).

So-called urban agriculture is thus becoming a feature of the areas around major West African cities. Vegetables and fruits are grown on land unsuited for building purposes and on undeveloped public and private lands (IDRC, 1993). In addition, intensive livestock production systems for milk and meat production are operational around and within city limits. Currently, limited external inputs are used in urban agriculture, and the precarious land situation creates uncertainty about long-term viability; hence, urban farming hardly receives any government assistance. Despite these problems, urban and peri-urban agriculture have some inherent advantages:

- Easy combination of farm and nonfarm activities within the same family;
- Decreased distance to large and diverse urban markets;
- Increased opportunities to produce high-value, more perishable horticultural products;
- Cash-saving and income generation for urban-based families with limited employment opportunities;
- Creation of specific potentials to recycle accumulated nutrients in urban areas through the use of wastes (Lardinois and van Klundert, 1994).

Given the estimated rapid rate of urbanization, a further development of urban- and peri-urban agriculture can be expected, especially in the coastal countries. Within the peri-urban fringes, an increased agricultural production of staples and diversification to include high-value products will be realized through further intensification of the production process. In vulnerable areas (limited soil and water resources and other biophysical constraints), intensification may lead to declining soil fertility, increased erosion, and depletion of water resources. On the other hand, especially in many peri-urban areas, the ingredients for a process of sustainable intensification of production are potentially present. Significant returns to inputs, possibilities for diversification to high-value and marketable crops and income-generating activities outside agriculture may lead to sufficient financial returns to agricultural production and, thus, permit investments in soil conservation measures and nutrient replenishment techniques. Some evidence of this potential is seen in Hausa-Fulani towns like Kano and Zaria, where intensive but highly profitable peri-urban farming has long been practiced in densely populated areas (Swindell, 1988; Mortimore, 1993). As in Asia, it may be expected that urban and peri-urban agriculture will increasingly develop into highly intensive production of high-value perishable products, whereas staple food production will be concentrated in the high-potential rural areas. In the non-coastal countries, the urbanization process will develop less rapidly and, thereby, result in a relatively limited development of urban and peri-urban agriculture.

2.2.6 Forestry and Fisheries

Forestry and fishing are important agricultural activities in West Africa. Fishing is an especially important economic activity in the coastal countries, and fish is a relatively cheap source of protein in the diet and can be a substitute for meat. The forest in coastal West Africa has always been a major source of both wood and nonwood products that contribute enormously to the economies of the various countries. Forests provide wood to meet the energy requirement in both rural and urban areas. In addition, forests also provide building materials and produce organic materials that enrich the soil (Verlinden-Bognetteau et al., 1992). In many farming systems in West Africa, agroforestry is practiced in a variety of ways (Chapter 6).

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Farming Systems in West Africa

The basic social unit of production and consumption, the compound or farm household, is gradually dividing into simpler nuclear family units.

Capital stock of farm households in the form of tools and equipment is generally very low.

Secured long-term usufructuary or property rights to land through legal protection systems that are demand driven and linked to existing systems will encourage farmers to adopt proper land and nutrient management practices.

Women's contribution to the agricultural sector in West Africa does not match their equivalent access to productive resources and information.

Lip-service and isolated gender projects should give way to well-coordinated policies and integrated programs aimed at lowering physical and sociocultural barriers to women's access to farmland, inputs, credits, and extension services.

In the Sahel and Savanna zone a wide variety of crop- and livestock-based production systems occur.

Integration of crop and livestock production systems will be of increasing importance when addressing problems of land degradation and use of natural resources.

Intensive peri-urban agriculture will be of increasing importance in the coastal countries.

There is limited scope for further development of irrigated agriculture in West Africa.

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3. Nutrient Stocks and Flows in West African Soils

3.1 General

An important aspect of soil productivity is determined by the nutrient stocks of the soil. Nutrient stocks are derived from mineral and organic sources, and these sources have different degrees of availability to plants. A high content of weatherable minerals (feldspars, micas) and a high organic matter content are, generally speaking, features of a rich and productive soil. A high mineral reserve is a reflection of rich parent materials, such as young volcanic rocks and alluvial deposits. Soil organic matter levels and decomposition rates of organic matter vary according to soil type, climate, vegetative cover and management. Next to its role as a nutrient store, organic matter also improves soil structure, stimulates soil biological activity, and adsorbs mineral nutrients. A classical survey by Birch and Friend (1956) yielded a median value of 4% organic matter for 570 topsoils in East Africa. In comparison, different studies of West African soils gave a median value of 0.5% (Penning de Vries and Djiteye, 1982; Bationo and Mokwunye, 1991). These median values are, however, characterized by large standard deviations; this indicates that within the regions mentioned, considerable variation exists at lower spatial scales.

Nutrient stocks are subject to continuous change. Natural and man-induced processes result in increases or decreases in nutrient stocks. Thus, in addition to the static concept of nutrient stocks measured at any point in time, there is the dynamic concept of nutrient flows. Table 3.1 shows common terminologies used to differentiate between nutrient stocks and flows. At each spatial scale, nutrient flows can be described by the sum of inputs that may exceed, be equal to, or be lower than the sum of outputs. In other words, nutrient flows reflect the nutrient balance. In sparsely populated areas, at a time t=1, nutrient stocks may still be close to those at an earlier point in time t=0, but in densely populated agricultural areas, one is more likely to encounter either surpluses or deficits.

Table 3.1 Characteristics of Nutrient Stocks and Nutrient Flows

Nutrient Stocks	Nutrient Flows
Actual soil fertility[a]	Soil nutrient balance/budget
Static (fertility at a specific time)	Dynamic (fertility change between time periods)
Poor vs. rich in nutrients	Nutrient mining vs. accumulation
Productivity (today)	Sustainability (tomorrow)
Total potentially plant-available nutrients	Sum of nutrient inputs - sum of nutrient outputs

a. Measured at a point in time.
Source: Smaling et al. (1996).

3.2 Nutrient Stocks at Different Spatial Scales

3.2.1 Macro-Level: Countries, Agroecological Zones

Subsequent to the classical book by Nye and Greenland, (*The Soil Under Shifting Cultivation*, 1960), nutrient stocks of the major West African soils have been described by, among others, Ahn (1970), Driessen and Dudal (1989), and Windmeijer and Andriesse (1993). A comprehensive review of soil fertility work in semiarid West Africa is Pieri's *Fertilité des Terres de Savanes* (1989). Many on-station soil fertility studies have been conducted in West Africa, including those at Samaru, Nigeria (Jones, 1971; 1976), Bambey, Senegal (Charreau and Nicou, 1971; Ganry and Bideau, 1974), Saria, Burkina Faso (Pichot et al., 1981), M'Pesoba, Mali (Pieri, 1973), Tarna, Niger (Pichot et al., 1974), IITA (IITA Annual Reports), and Sierra Leone (Odell et al., 1974). Individual research papers were published mainly in the anglophone *Journal of Agricultural Science (Cambridge)*, in the francophone journal *l'Agronomie Tropicale*, in the publication series of ORSTOM and CIRAD/IRAT, and in conference proceedings such as Kang and Van der Heide (1985), Mokwunye and Vlek (1986), Mokwunye (1991), and the CIRAD-initiated proceedings *Savanes d'Afrique, terres fertiles?* Indispensable for those involved in pasture production in the Sahel and SSZ is the work executed in the context of the project "Production Primaire au Sahel," edited by Penning de Vries and Djiteye (1982): *La productivité des paturages sahéliens. Une étude des sols, des végétations et de l'exploitation de cette ressource naturelle.* Van Duivenbooden (1992) reviewed this and other literature for data on crop nutrient uptake.

The mineral nutrient stocks of West Africa's vast interior plains and plateaus are low because, in a geological time horizon, the area is "old." It has undergone various erosion cycles but lacked the volcanic rejuvenation that is typical of, for example, the Rift Valley area. As a consequence, soils are often strongly weathered and leached and often overlie ironstone hardpans (*Fr: cuirasse*), which even feature at the surface in places. The soils' clay fraction is of the so-called low-activity type, dominated by kaolinite, halloysites, and/or iron and aluminum oxides (Ssali et al., 1986). They often have an effective cation exchange capacity (ECEC) of less than 8 meq/100 g clay, implying that the cation exchange properties of the soils are largely determined by their organic matter content. The foregoing implies that essential plant nutrients such as P, K, Ca, Mg and trace elements, which are derived from the parent rocks, have become increasingly scarce, and the soil's cation exchange complex has gradually been occupied by hydrogen and aluminum ions, which are responsible for the low pH of many soils. Based on the degree of weathering and leaching, four major soil orders can be distinguished (Deckers, 1993). They are also shown in Figure 3.1, which forms a part of the FAO Soil Map of Africa (scale 1:5,000,000). The major soil orders are briefly described below. Soil classification is based on the revised FAO Legend (FAO, 1989).

Ferralsols – Ferralsols are predominant in Sierra Leone and Liberia. The characteristic of

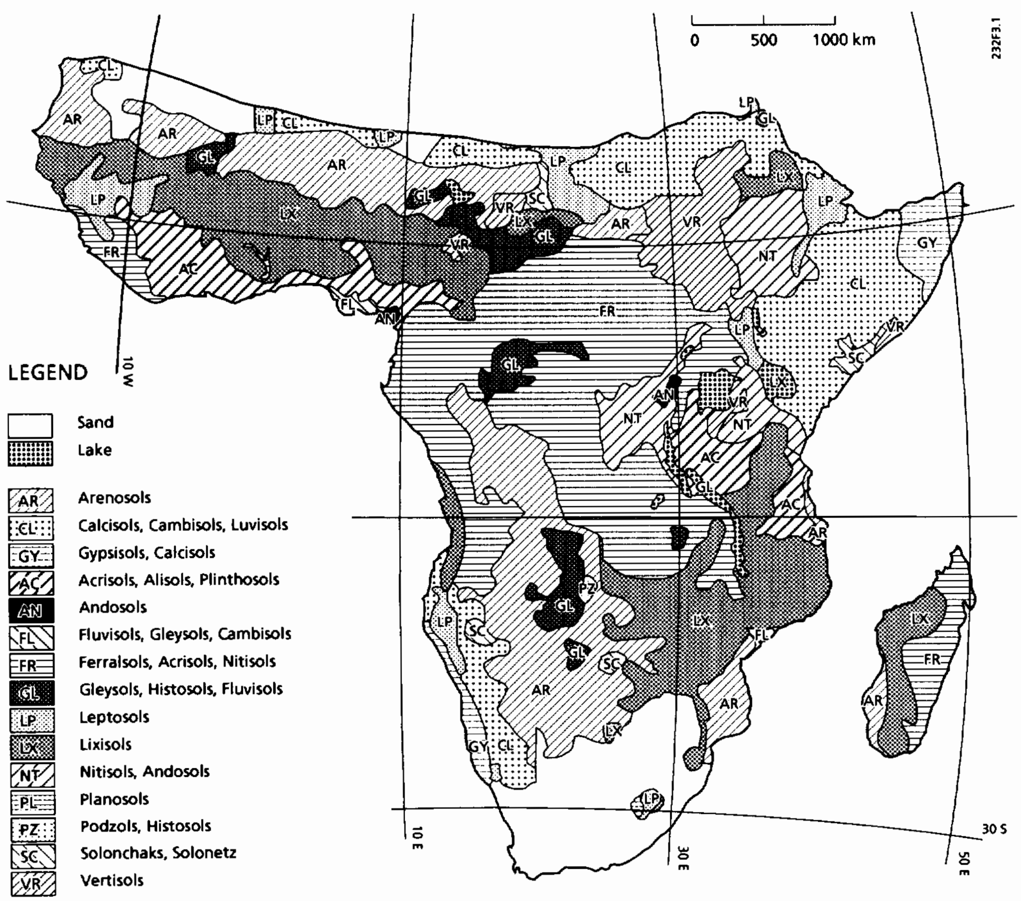

Figure 3.1 Soils of Sub-Saharan Africa (Scale 1:5,000,000) (Source: FAO, 1989; Deckers, 1993).

Ferralsols is advanced weathering, which results in soil material consisting of kaolinite, quartz, and hydrated oxides. The capacity to supply nutrients to plants and the capacity to retain nutrients (CEC) are both low. The low retention capacity has marked consequences for fertilizer management, especially nitrogen, which should be applied in small amounts at any one time to avoid leaching. Phosphate fertilizers are fixed by free iron and aluminum oxides. Low amounts of organic matter and high leaching losses of bases result in low buffering capacity of the soils. Low buffering capacity implies low capacity to retain plant nutrients and generally low pH values. Physically, Ferralsols are excellent soils. They are well drained and have a good structure and deep profile. Rooting depth is almost unlimited, which compensates for their relatively low water- holding capacity.

Acrisols – Acrisols occur in the southern part of the Savanna Zone (the so-called Southern Guinea Savanna Zone), which occupies southern Guinea, most of Côte d'Ivoire, southern Ghana, Togo, Benin, Nigeria, and central Cameroon. Acrisols are characterized by an enrichment of clay in the subsoil (textural B horizon). This horizon has a high water-holding capacity, but the higher density may limit biological activity and root penetration. The structure of the surface soil is very weak, and internal drainage may be hampered by the compact textural B horizon. Special care is therefore needed to protect Acrisols from soil erosion. Acrisols are less weathered than Ferralsols; the mineral reserve, however, is low. Nitrogen tends to leach and trace elements are deficient. Because aluminum is present, phosphate fixation may result.

Lixisols – Lixisols form a belt in SSZ and northern GSZ between the Acrisols and the Arenosols. Lixisols have a clay accumulation horizon that has a low capacity to store plant nutrients but is well saturated with cations. The soil pH of Lixisols is medium to high, and aluminum toxicity does not occur. Because of their low storage capacity for cations, Lixisols may become depleted rather quickly under normal agricultural use. The physical properties of Lixisols are generally better than those of Acrisols. Low organic matter content is a major constraint in Lixisols.

Arenosols – Arenosols form an almost continuous belt in West Africa; they stretch from northern Senegal, Mauritania, central Mali, and southern Niger through Chad. The soil material of Arenosols is composed mainly of quartz; it has a low water-holding capacity and nutrient content, low nutrient retention capacity, and deficiencies of minor elements, which are normally bonded to clay or organic matter (zinc, manganese, copper, iron). Deficiencies of sulfur and potassium are common, whereas fertilizer efficiency is hampered by leaching of nitrogen and potassium. Arenosols contain more bases, but the poor water-holding capacity severely limits crop growth and performance. Arenosols tend to be weakly structured, which explains compaction of the subsoil and the high incidence of water/wind erosion of the topsoil.

Table 3.2 summarizes work published in Windmeijer and Andriesse (1993), who collated nutrient stocks of 86 soils across different agroecological zones. Differences between AEZs are very marked. Apparently, higher rainfall in the EFZ enhanced weathering and leaching of bases, which led to low-pH soils. Abundant moisture also favors high biomass production, which in turn brings about higher soil organic carbon and nitrogen contents. Phosphorus reserves depend on both mineral stocks (determined by parent material) and organic stocks. Because the latter is higher in the EFZ, total P is also higher in this AEZ. In the Nigerian GSZ, comprehensive studies on the distribution of P forms revealed that organic P constituted 41% of the total P (Ayodele and Agboola, 1983). In the SSZ, organic carbon and total N are very low because of low biomass production and high rates of decomposition. Because mineral reserves of P are low, crop yields on land that is continuously cultivated will always be very low unless nutrient sources containing P are added to the system. Apart from low P stocks – the result of low mineral reserves – many soils with low-activity clays and high contents of iron and aluminum oxides tend to strongly fix P. It was found that the soils in the SSZ have a relatively low capacity to immobilize added P (Bationo and Mokwunye, 1991). In the wetter AEZs, P fixation can play a more important role since these soils are more clayey and the amounts of aluminum oxides are higher.

3.2.2 Meso-Level: Watershed, Toposequence

The vast plains and plateaus of West Africa are dissected by narrow inland valleys (*Fr: bas fonds*),

Table 3.2 Nutrient Stocks and Other Fertility Indicators of Granitic Soils in Different Agroecological Zones in West Africa

Agroecol. Zone	Depth (cm)	pH-H_2O	Org. C (g/kg)	Total N (g/kg)	Total P (mg/kg)	Cation Exchange Capacity (mmol/kg)	Base Saturation (%)
Equatorial	0-20	5.3	24.5	1.60	628	88	21
Forest Zone	20-50	5.1	15.4	1.03	644	86	16
Guinea	0-20	5.7	11.7	1.39	392	63	60
Savanna Zone	20-50	5.5	6.8	0.79	390	56	42
Sudan	0-20	6.8	3.3	0.49	287	93	93
Savanna Zone	20-50	7.1	4.3	0.61	285	87	90

Source: Windmeijer and Andriesse (1993).

which led researchers to develop toposequential and hydrosequential partitioning of the area into (pluvial) Uplands, (phreatic) Footslopes, and (fluvial) Valley bottoms (Moormann et al., 1977; Millington et al., 1985; Raunet, 1985; Vierich and Stoop, 1990; WARDA, 1991; Andriesse and Fresco, 1991; Windmeijer and Andriesse, 1993). The soils described in Section 3.2.1 belong to the Uplands and cover more than 80% of the land. Soils of the Footslopes are mainly poor, sandy derivatives of those of the Uplands, but higher groundwater tables during part of the year give them a specific agricultural significance. Soils of the Valley bottoms can be anything between fertile and infertile, depending on the parent material and the sediment load of the floodwater. The specific hydrological conditions make Valley bottoms suitable for swamp rice and even double cropping in the EFZ and GSZ. Drainage density is highest in the EFZ, which includes a relatively high percentage of Valley bottoms, including extensive wetlands such as the bolilands in Sierra Leone.

For the vast Sahelian pasturelands, Penning de Vries and Djiteye (1982) found a subdivision into sandy soils, shallow detritic soils, and fluviatile soils to be most functional. These groups occupy about 50%, 30%, and 20%, respectively, of the total area of the Sahel. Sandy soils are deep and homogeneous; detritic soils are shallow, loamy, heterogeneous and erosion-prone, whereas fluviatile soils are deep and clayey.

Figure 3.2 shows a toposequence at WARDA's research station in the GSZ near Bouaké, Côte d'Ivoire (Hakkeling et al., 1989). Nutrient stocks in the different components of the toposequence are shown in Table 3.3. Fertility is highest in the Bottomlands, followed by the Uplands. The sandy Footslopes have a very low fertility. Agricultural potential of the different components is mainly determined by these nutrient stocks and by hydrological conditions.

3.2.3 Micro-Level: Farm and Plot

Nutrient stocks of individual plots within farms and village territories can differ considerably; the reasons range from differences in soil texture and land use history to microclimatic differences. Farmers, notably those in the drier AEZs, tend to cherish microvariability. Heterogeneity at plot level is often seen as an asset by those who are resource-poor, risk-averse, and are pursuing food security per se rather than bumper harvests (Brouwer et al., 1993; De Steenhuijzen Piters, 1995). An example is the use of (abandoned) termite mounds, which represent spots of relatively high fertility in the Uplands and the Footslopes. Sierra Leonean farmers often use abandoned Footslope mounds as swamp rice nurseries. Too many termite mounds may,

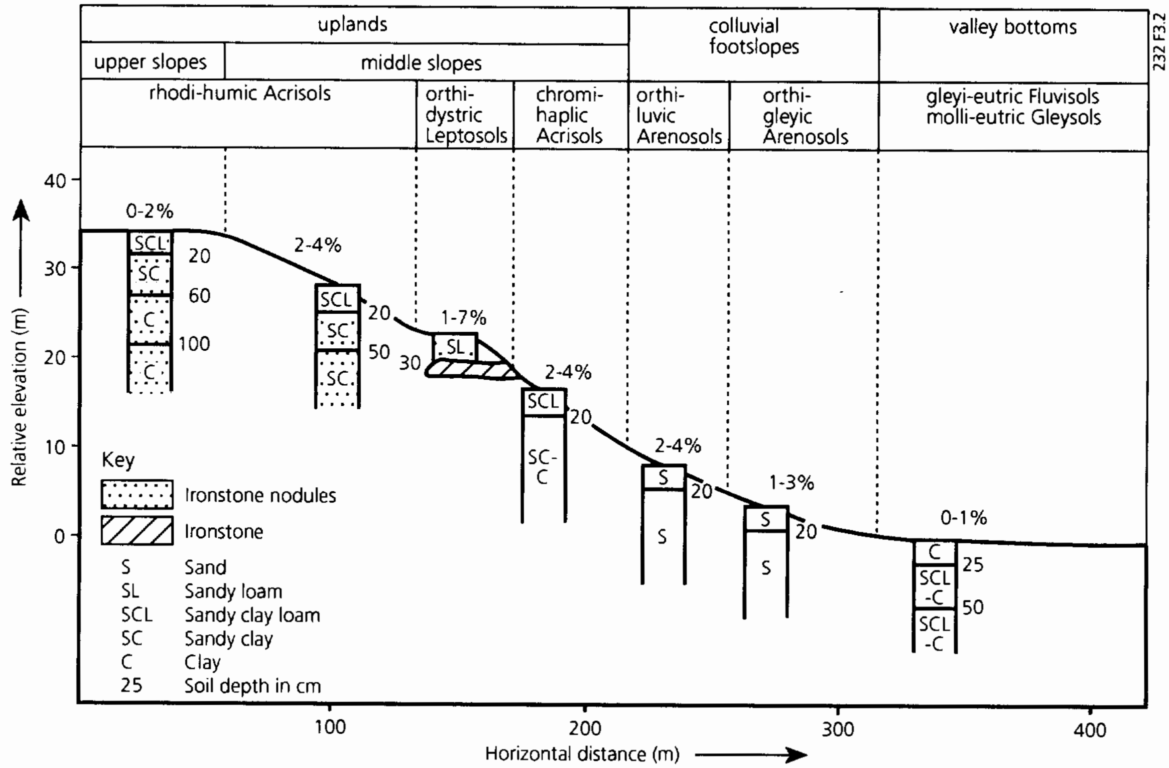

Figure 3.2 Toposequence at the WARDA research station, Bouaké, Côte d'Ivoire (Source: Hakkeling et al. (1989).

Table 3.3 Nutrient Stocks and Other Fertility Indicators of the Different Components of the WARDA Toposequence

	Depth (cm)	pH-H_2O	Org. C (g/kg)	Total N (g/kg)	Available P (Olsen, mg/kg)	Cation Exchange Capacity (mmol/kg)	Base Saturation (%)
Uplands	0-20	6.3	7-21	0.6-1.2	4-18	40-110	63-73
	20-40	5.9	7-10	0.5-0.8	2-3	40-108	28-41
Colluvial footslopes	0-20	6.0	3	0.3	3.0	25	57
	20-40	5.8	n.d.	n.d.	0.5	15	41
Valley bottoms	0-20	5.8	21	1.7	15.0	141	64
	20-40	6.3	7	0.6	4.0	103	65

Source: Hakkeling et al. (1989).

however, also accelerate water erosion (Janeau and Valentin, 1987).

Another example of farm-level heterogeneity is the ring management farming systems in the SSZ, as was already mentioned in Section 2.2.1. Prudencio (1993) described the system for the Mossi Plateau of Burkina Faso. One can theoretically recognize three subsystems:

- The *champs de case* in the first ring, representing the plots just around the homestead; the farm houses.
- The *champs de village* in the second ring.
- The *champs de brousse* in the outer ring, including bush fallow grazed by animals.

The *champs de case* in the vicinity of the homesteads often receive substantial amounts of nutrients from animal manure and household wastes. Hence, soil productivity remains at a relatively high level. Sédogo (1993) studied the different nutrient stocks of microlevel subsystems in Burkina Faso. The results are summarized in Table 3.4. Similar examples were reported 20 years ago from southeastern Nigeria, where high population density, humid climate, and sandy soils forced farmers into high-intensity agriculture on plots directly adjacent to their homesteads (Lagemann et al., 1976).

3.3 Nutrient Flows

3.3.1 Inputs Versus Outputs

Long-term equilibrium (inputs = outputs) is typical of more or less "closed" systems, such as tropical rain forests in the EFZ and undisturbed savannas in the GSZ. Slight disturbances do not necessarily disrupt equilibria, as in the case of traditional long fallows. A nitrogen cycle budget for West Africa using 1978 data, for example, showed that noncultivated systems fix 15-20 times the amount fixed in cultivated systems (Robertson and Rosswall, 1986). When land is not scarce, the farmer can leave a plot as soon as its productivity decreases, only to shift to a neighboring plot that has been idle during previous years. The latter plot has gained free fertility through atmospheric deposition, the recycling of nutrients from deep horizons by roots, and biological fixation. This fragile balance is, however, broken in most parts of West Africa as a result of decreased fallow periods caused by increasing population pressure.

Perennial agro-ecosystems in the EFZ, dominated by high-input cash crops (cacao, coffee, oil palm), may be close to equilibrium for some nutrients if management and fertilizer levels are high and losses due to leaching and erosion are reduced (e.g., mulching, cover crops, minimum tillage).

Controlled grazing of improved pastures, especially those that include leguminous species, may also lead to an equilibrium situation. The same holds true for extensive grazing systems, as long as stocking rates are a reflection of the carrying capacity of the particular area. This is, however, no longer the case in most parts of the SSZ and the Sahel (Breman and Niangado, 1994).

Positive nutrient budgets are largely restricted to situations where within-farm movement of nutrients, such as the earlier-mentioned concentration of manure and household waste in homegardens or in concentric rings close to settlements (McIntire et al., 1992; Prudencio, 1993), occur. Floodplains,

Table 3.4 Nutrient Stocks of Different Subsystems in a Typical Upland Farm in the Sudan-Savanna Zone

	$pH\text{-}H_2O$	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	Exchangeable K (mmol/kg)
Champs de case	6.7-8.3	11-22	0.9-1.8	20-220	4.0-24
Champs de village	5.7-7.0	5-10	0.5-0.9	13-16	4.0-11
Champs de brousse	5.7-6.2	2-5	0.2-0.5	5-16	0.6-1

Source: Sédogo (1993).

valley bottoms, and irrigated land may receive more nutrients than they lose in the case of high-input rice or vegetable cultivation and in the case of water erosion in the upper reaches of the river basin. In the vicinity of towns and agro-industrial sites, crops may receive substantial amounts of organic wastes and compost originating from nearby sources, which may cause nutrient surplus conditions.

In present-day West Africa, increasing population pressure, the concurrent opening up of marginal lands, and the reduction of fallow cycles have caused mineral nutrient reserves and organic matter contents to gradually deteriorate to alarmingly low levels. Most soil fertility specialists in West Africa agree that, on average, nutrient outputs exceed nutrient inputs.

A study commissioned by FAO on the N, P, and K balance for 35 crops in 38 sub-Saharan African countries revealed that the mean annual losses per hectare were approximately 22 kg N, 2.5 kg P, and 15 kg K in the period 1982-84 (Figure 3.3; Stoorvogel and Smaling, 1990; Stoorvogel et al., 1993). Table 3.5 shows the aggregated nutrient budgets for the West African countries. Nutrient depletion is relatively severe in densely populated Nigeria and the other coastal countries such as Ghana and Côte d'Ivoire, where agriculture is intensive and less than 30% of the land was considered fallow in 1983 (FAO statistics). In the Sahelian countries, nutrient depletion is not severe because there is little in the system in its native state that could be depleted; if nutrients do not exist, they cannot be mined.

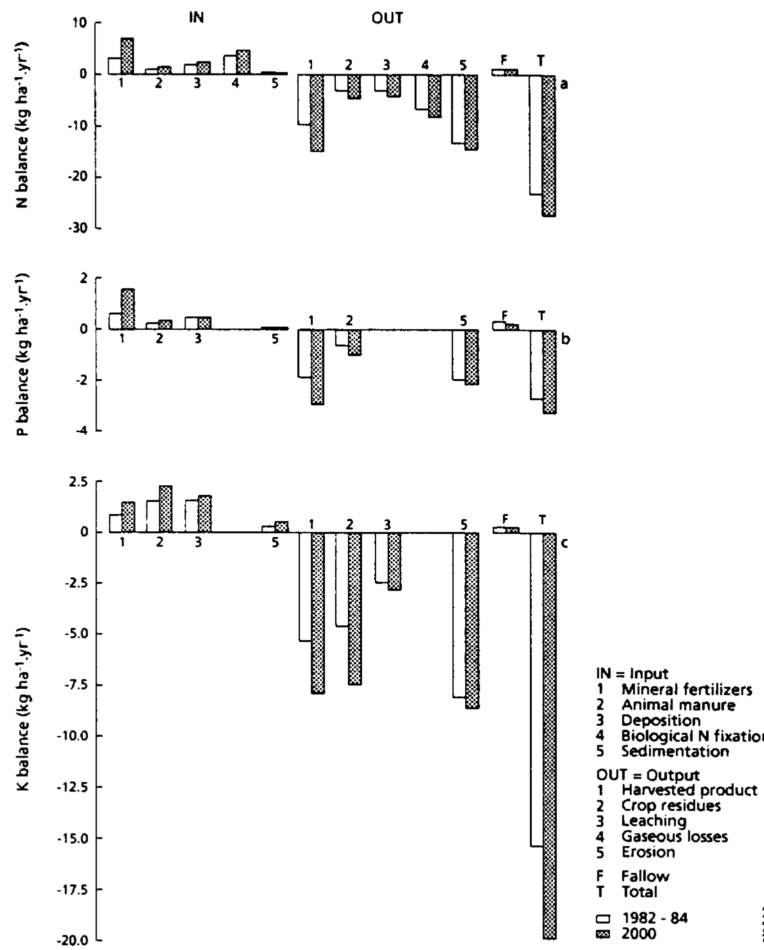

Figure 3.3 Nutrient Balance for Sub-Saharan Africa (Source: Stoorvogel et al., 1993).

Figure 3.3 shows that the sum of nutrient inputs (*IN 1-5*) is low for all nutrients. With an application rate of less than 10 kg of nutrients/ha, fertilizer use (*IN 1*) is extremely low. This is especially true for the quantities of K used. Inputs from organic manure and biological fixation (N) cannot offset the losses that occur under existing conditions. The nutrients found in the harvested parts of the crop alone (*OUT 1*) often exceed the sum of all inputs. Because losses from leaching and erosion are considerable, the overall nutrient balance is negative.

Figure 3.3 also shows that because of its mobility, the N budget is adversely affected by leaching. Gaseous losses as a result of volatilization are also severe. These account for the "non-useful" loss mechanisms *OUT 2-5*. Nitrogen flows are highly affected by climatic factors. Soil moisture and temperature largely determine the period and intensity of organic matter decomposition. Leaching of soil and fertilizer nitrates, surface runoff as a result of topsoil compaction, denitrification, and the effectiveness of biological N fixation are all, to a considerable extent, governed by rainfall characteristics. Burning of crop residues or fallow vegetation is also very detrimental to the soil organic matter and

Table 3.5 Country N-P-K Budgets in 1983

Countries	Arable ('000 ha)	Fallow (%)	N	P	K
				(kg/ha)	
Benin	2,972	62	-14	-1	-10
Burkina Faso	6,691	50	-14	-2	-10
Cape Verde	n/a				
Cameroon	7,681	50	-20	-2	-12
Gambia	326	29	-14	-3	-16
Ghana	4,505	24	-30	-3	-17
Guinee	4,182	68	-9	-1	-6
Guinea-Bissau	n/a				
Côte d'Ivoire	6,946	31	-25	-2	-14
Liberia	745	15	-17	-2	-10
Mali	8,015	72	-8	-1	-6
Mauritania	846	79	-7	0	-5
Niger	10,985	47	-16	-2	-11
Nigeria	32,813	18	-34	-4	-24
Senegal	5,235	53	-12	-2	-10
Sierra Leone	1,842	43	-12	-1	-7
Togo	1,503	49	-18	-2	-12

Source: Stoorvogel and Smaling (1990).

nitrogen status; furthermore, the heat generated may kill N-fixing *Rhizobia* bacteria.

The P budget is relatively easy to maintain or improve because the element is relatively immobile. Phosphorus applied as fertilizer or derived from slowly soluble phosphate rocks may have significant and lasting residual effects, a feature often overlooked in calculations of the economics of P application. The lack of mobility may, however, also become a disadvantage in soils with high contents of low-activity clays and iron and aluminum oxides, which form strong bonds with phosphate ions and render them virtually unavailable for crop uptake.

The K budget is an intermediate case between N and P. K is most mobile in sandy and highly leached soils, which have a low cation exchange capacity. Crop residues, especially cereal straws, contain relatively large percentages of K (Bationo and Mokwunye, 1991). Removing them from the field thus adversely affects the total K balance.

Nutrient Stocks and Flows in West African Soils

Soil fertility is conceptualized here as the product of the organic and mineral nutrients.

In the soil fertility debate, one should differentiate between the static concept of nutrient stocks with different degrees of plant availability and the dynamic concept of nutrient flows that enhance or decrease the nutrient stocks over time.

Soil fertility is scale dependent: it may decline in West Africa as a region, but it may be stable or increase in farmers' home gardens.

Macro-level: the vast majority of soils of the West African interior plains and plateaus are soils with (very) low nutrient stocks.

Meso-level: floodplains and valley bottoms are the most fertile and productive parts of inland valley systems.

Micro-level: fields around the homestead have much higher nutrient stocks than those located farther away.

Land use systems in West Africa with equilibrium or surplus nutrient budgets are very scarce and mainly manmade.

Negative nutrient budgets imply that the inherently low West African nutrient stocks are being further depleted.

When nutrient depletion has reached a point where the soil can no longer compensate for what the crop has removed, production slumps. Ultimately, the environment is the loser.

Very low availability of one nutrient inhibits the uptake of the more available nutrients, which may then be lost to the environment.

Positive nutrient balances occur where soil fertility is maintained and where climatic conditions are favorable and, thereby, encourage farmers to invest in soil conservation and the enhancement of crop production.

Independently, Van der Pol (1992) studied nutrient balances in southern Mali and reported losses of 25 kg N and 20 kg K ha^{-1} yr^{-1}. Gaseous losses (*OUT 4*) and erosion (*OUT 5*) together were responsible for 40% of total losses. Even though the doubling of *IN 1* and *IN 2* reduced *OUT 2* and *OUT 5* by 50%, it did not prevent the values for the N and K balance from being negative. In the region, low nutrient stocks and on-going depletion (nutrient mining) are now generally regarded as some of the subcontinent's major survival issues. More details on nutrient budgets for pasture systems in the SSZ and the Sahel are provided by Penning de Vries and Djiteye (1982) and Breman (1994).

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Part III – Tools: Policy and Technology Options

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Part III – Tools: Policy and Technology Options

4. Economic Policies and Fertilizer Market Development

4.1 Influence of Global Policies on Soil Fertility

4.1.1 General

For the developing West African economies, agricultural policies of the developed countries (U.S.A., EU, and Japan) have a protectionist character and distort supply and, thus, prices on the domestic and international markets. Since agricultural imports in developed countries are controlled through tariffs and nontariff measures, consumers pay, and domestic producers receive much higher prices than world market prices. For example, in 1991 in the European Union, sugar, milk, and wheat prices were at least 2.2 times higher than world prices; in the United States, sugar and milk prices were at least 2 times higher than world prices; in Japan, rice prices were 4.8 times higher than world prices (OECD, 1993, p.12). Due to the absence of such a protectionist policy in West Africa, agricultural producers in this region have to compete with highly subsidized agricultural products on the international market. In addition, these farmers have limited access to export markets. Meanwhile, relatively cheap food imports and food aid from Europe and the United States continue to have negative consequences on marketing conditions for local farm products, and they induce changes in consumption patterns of mostly urban dwellers towards nonlocal grains like wheat. The overall result is that profitability at the farm level of food crop production is seriously threatened. Without incentive, farmers have reduced willingness and confidence to invest in agricultural production. Production based on a short-term goal that leads to soil nutrient mining is one of the dramatic consequences. Nutrient mining, as has already been indicated, has serious impacts on the future potential food-producing capacity in the region.

Two cases are presented to illustrate in greater detail the immense impact of these global policies on the development of the agricultural sector in West Africa.

4.1.2 Case: The Livestock Sector

Since livestock production in the coastal countries has traditionally been limited due to higher incidence of sleeping sickness, regional beef trade from the Sahel to the coastal countries has emerged. The total demand for beef in the coastal countries has increased, mainly because of a high population growth rate. However, the actual consumption per capita actually declined from 8.5 kg/capita/year in 1980 to 5.9 in 1990 because of a declining purchasing power, which resulted from an economic crisis (Solagral and Iram, 1993).

In the past 10 years, the structure of the imports by the coastal countries has changed dramatically. In Côte d'Ivoire, live Sahel imports declined from 65% in 1980 to 29% of the total supply in 1990, whereas imports from outside Africa increased from 15% to 44% in the same period (Holtzman and Kulibaba, 1992). In 1992, the EU had become the most important supplier of non-African beef and captured 95% of the total import market. The main reason for this development was the average EU export restitution on beef of 670 FCFA/kg. This resulted in a price decrease of EU exported beef from 1.35 ECU/kg in 1980 to 0.56 ECU/kg in 1991. As a result, the average beef prices at the retail level in the coastal countries also decreased dramatically: in Côte d'Ivoire from 1,160 FCFA/kg in 1980 to 885 FCFA/kg in 1991 (Holtzman and Kulibaba, 1992). As a result of this EU agricultural policy, the competitive position of Sahel beef was seriously decreased.

Under the pressure of a consortium of NGOs, the EU implemented a 15% reduction of the export restitution in June 1993, followed by three successive reductions of 5% each in the period until January 1994. Initial observations show that since the inception of the restitution reductions, actual exports from EU to West Africa declined by 13% in 1993 compared with 1992 levels (for Côte d'Ivoire the rate of decrease was 43%). At the same time prices for live cattle rose by 60%-100%, and the trade between the Sahel countries and coastal countries increased in 1994. It is, however, argued that a further reduction of the EU subsidies is necessary to achieve a considerable improvement in the competitive position of the livestock sector in the Sahel countries (Attema, 1993).

Market protective measures by West African countries have thus far been rare. High levies in Senegal for EU products have succeeded in protecting the nation's livestock and fisheries sector. It appears, however, that protective measures by individual countries, acting alone, are not very effective. For instance, both Ghana and Benin have served as transit countries for large amounts of EU beef destined for the neighboring countries. Protective measures taken by, e.g., Côte d'Ivoire can only be effective if the measures are taken as a joint regional initiative.

It should also be noted that regional policies have had noticeable impacts on the development of the livestock sector. For example, the devaluation of the CFA franc at the beginning of 1994 has evidently led to a great increase in the cattle exports in the direction of Ghana (Helden et al., 1995). Additionally, the price increases of so-called exportable bulls can be attributed, to a large extent, to this devaluation. For traditional cattle-exporting countries such as Burkina Faso and Mali, future internal policies will determine if the increased competitiveness resulting from the devaluation can be maintained. Certainly, the cattle-importing countries within the FCFA-zone face a doubling of import prices of cattle and meat products from outside the FCFA-zone.

In summary, it is important to note the negative influence of policies of the beef-exporting countries of the North on the total demand for beef and the price-setting mechanism in beef markets in West African coastal countries. These policies have serious impacts on the development of the beef production sector in the Sahel countries. Lower prices and reduced outlet possibilities, combined with higher input prices, discourage necessary long-term investments in more sustainable and intensive production systems (Breman, 1992; Breman and Niangado,1994).

4.1.3 Case: Fertilizer Aid Versus Trade

All West African countries import finished fertilizers, and only three countries (Senegal, Côte d'Ivoire, and Nigeria) import fertilizer raw materials for the local production of fertilizers. With the exception of these fertilizer manufacturing countries, aid-financed fertilizers have played a very important role in the supply and introduction of fertilizers to West African farmers. For most of the other countries, fertilizer aid accounted for more than 75% of their fertilizer supply during the 1980s. West European countries, West Africa's traditional trading partners, were principally involved in the supply of aid-financed fertilizers.

A major problem in connection with loans and grants for fertilizer aid has been the different procedures adopted by some bilateral and multilateral donors and agencies. Conditions imposed by fertilizer aid donors, such as limitations with respect to origins and types of fertilizer products, have led to inefficient fertilizer procurement and marketing systems. For the food crop sector, especially, there has been gross inefficiencies in the procurement and marketing systems with little or no participation by the banking sector (Gerner and Harris, 1993).

Current trends tend to suggest that West African countries will, in the future, receive less fertilizer aid and will need to strengthen their own fertilizer procurement and financing systems. Fertilizer aid to sub-Saharan Africa has already been considerably reduced and, in addition, less and less attention is being paid to this region. Between July 1994 and March 1995, West Africa received only 5% of all fertilizer aid allocated to sub-Saharan Africa. Total fertilizer aid to SSA still amounted to 400,000 mt or 60% of SSA's total fertilizer imports (IFDC-Africa Fertilizer Information Database).

4.1.4 Influence of GATT on Agricultural Development and Soil Fertility

Since the 1950s, the main goal of the General Agreement on Tariffs and Trade (GATT) has been to reduce tariffs on imports and subsidies on exports imposed by various countries. The underlying philosophy of the GATT is to reduce protection and enhance free trade among developing and developed countries. To reduce tariff and non-tariff barriers to world trade, the last round of negotiations was initiated in Uruguay in 1986. To quote the Organization for Economic Co-operation and Development (OECD, 1993):

"The Uruguay Round is the most comprehensive and hence complex Round of GATT negotiations ever undertaken. The Round seeks to advance trade liberalization in traditional areas, extend the liberalization process to areas not covered at present by the GATT, and tighten up multilateral rules and dispute settlement procedures and enforcement mechanisms. In short, it aims to make the world trading system fairer and more transparent."

One of the aims of the Uruguay Round is to reduce tariffs on imports and subsidies on exports by about one-third. In addition, it also has provisions to reduce nontariff barriers on imports, such as the voluntary export restrictions applied on, among others, textiles/clothing and cassava, and to recognize intellectual property rights. OECD (1993) and Goldin et al. (1993) have estimated that trade liberalization under the Uruguay Round will create annual global benefits of about $213- $270 billion. A large proportion of these benefits will accrue to consumers in the OECD countries.

The implementation of the Uruguay Round will influence West African agriculture in several ways. On the one hand, through reduction of import tariffs by the rest of the world, opportunities for higher income, employment, and foreign exchange earnings for African exports will be created, especially for cocoa, cotton, and coffee. However, since these commodities do not carry as large tariffs as grain imports do, benefits of such liberalization may be relatively small. Furthermore, increased production by many small countries may lead to decreased prices for tree crops in the world market (Goldin et al., 1993). On the other hand, because the GATT will reduce subsidies on grain and other food exports or tariffs on food imports, it will lead to increased food prices in the world markets. Hence, many African food-importing countries will have to pay higher prices for food imports. Considering that a relatively small part of West Africa's total food consumption is from imports, (averaging 14%), GATT will not have a major impact on food supply. More important is the prospect of an increase in the demand for locally produced cereals. Goldin et al. (1993) estimated that the net effect of these changes may lead initially to a reduction in rural incomes and higher food prices for urban consumers in the short and medium term. However, in the long run, increased costs of food imports will improve price incentives and thereby create a favorable environment for the development of domestic agriculture.

Another challenge following the GATT agreement is the removal of trade barriers between countries in the region, which gives more scope for the promotion of regional economic cooperation including trade (Stoneman and Thompson, 1994). It is widely accepted that transforming a domestic market into a regional one provides economies of scale; industries can respond to the increased demand by becoming more efficient and, thus, more competitive internationally. Regional cooperation will increase food security in the region and can also promote standardization of, for instance, fertilizer products and quality control and, thereby, further increase the competitiveness. The improvement of roads, telecommunications, and banking services that connect neighboring countries is basic to the development of regional cooperation.

It is difficult to assess the overall effect of the GATT agreement on the soil fertility situation. On the one hand, the agreement could stimulate increased investments in the agricultural sector because of higher world market prices of some of the commodities (like grains and oil products). On the other hand, increased competition from food crops produced in other regions could lead to short-term reduction in rural income. This scenario could negatively influence profitability levels and therefore reduce investments in soil fertility. It is obvious that, in either case, adequate national policies need to be pursued to increase productivity in the agricultural sector.

4.2 Structural Adjustment Programs in West Africa

In the post-independence era, many West African governments introduced interventionist policies to promote growth, equity, and political goals (FAO, 1994). These policies resulted in control of prices (including exchange rate and interest rate), restrictions on trade and private sector activities, creation of government monopolies and parastatal agencies for input and output marketing, and introduction of subsidies on inputs and outputs, especially food subsidies for urban populations. Over time, such restrictive policies and programs led to inefficient resource use and unsustainable fiscal and balance-of-payment deficits. A fiscal deficit means that public expenditures are higher than public revenues, which increases the demand for public borrowing and donor aid. Balance-of-payment deficit means that a country imports more than it exports, which increases the demand for foreign exchange and, thus, increases pressure on the exchange rate.

To restore the equilibrium in the balance of payments and to reduce budget deficits, the International Monetary Fund and the World Bank introduced structural adjustment programs (SAPs) in many African countries. The key objectives of SAPs were to lay a solid foundation for economic growth primarily through two means. They were:

1. Initially, **stabilization measures** aimed to reduce the fiscal and balance-of-payment deficits over the medium term.
2. Second, **supply-side, efficiency-enhancing measures** were applied at the sectoral levels (FAO, 1994).

Recommended fiscal measures included reduction in public expenditures, for example, subsidy removal on inputs and food products and the increase in public revenues through increased taxes such as import duties. Currency devaluation was introduced as the most favorable measure to reduce the balance-of-payment deficit. Currency devaluation increases the price of imported goods and makes domestically produced goods relatively cheaper. The implementation of these measures was accompanied by balance-of-payments support from donors.

Systematic studies on the impact of these measures on soil fertility maintenance are scarce. Veeneklaas et al. (1991) showed that for the Fifth Region of Mali, the effects of a 50% increase in output prices were negligible. Most of this analysis is based on inferences drawn from direct and indirect empirical evidence and analytical concepts. The impact on the agricultural sector of three SAP measures, namely, currency devaluation, subsidy removal, and fertilizer privatization are examined below. All West African countries devalued their national currencies in the 1990s, most of them removed fertilizer subsidies, but only a few transferred the fertilizer marketing functions completely to the private sector.

The region can be divided into countries with a fixed exchange rate system belonging to the FCFA zone (Bénin, Burkina Faso, Cameroon, Côte d'Ivoire, Mali, Niger, Senegal, and Togo) and countries with floating currencies, such as Ghana, Sierra Leone, Gambia, and Nigeria. The FCFA, which is pegged to the French Franc, was devalued in January 1994, whereas the Cedi (Ghana) and Naira (Nigeria) have depreciated over the last decade. Devaluation has affected the agricultural exports directly and the food crop subsector indirectly:

- Devaluation was a necessary tool to provide new impetus to the **agricultural export sector** (e.g., cotton, cocoa, coffee) and to restrain the importation of cheap food products. The cotton sector in the FCFA countries was losing money before the 1994 devaluation, and cocoa/coffee farmers were not interested in investing in measures to increase production and also to maintain product quality because of the low prices they were receiving. Following devaluation, the prices of export crops have increased sufficiently to compensate for increase in prices of fertilizers.
- It is generally believed that **food crop** farmers in many West African countries would benefit from devaluation because the process would induce a higher demand for local food crops at even slightly higher prices. This could provide an incentive for increased crop production. In reality the slight increase in food crop prices has not compensated for increased fertilizer prices. For soils that are inherently infertile, additional food crop production is more likely to come from the cultivation of more marginal lands. Cultivation of marginal lands damages the environment through increased soil erosion and deforestation. It would thus appear that the structural adjustment measures have not created the incentive needed to motivate food crop farmers to invest in more sustainable agricultural production systems that require more labor and capital outlays.

In summary therefore, it can be said that currency devaluation has increased the profitability of the export sector, which could promote the use of fertilizers and overall investments in soil fertility. By contrast, in the food crop subsector, currency devaluation has not produced an increase in income of farmers and therefore has not led to an overall improvement in soil fertility or to an enhanced incentive for farmers to invest in long-term soil fertility improvement.

The removal of fertilizer subsidies in most West African countries has, at best, resulted in a stagnation of fertilizer use in the food crop subsector:

- All FCFA countries, except Togo and Niger (30%-50% subsidy on food crop fertilizers), had removed fertilizer subsidies by the early 1990s. As a result, fertilizer use stagnated or tended to decline. It is expected that fertilizer consumption on food crops will drop further if the price increases brought about by the 1994 devaluation of the FCFA are fully charged to farmers and if food prices do not rise sufficiently to compensate for the higher fertilizer prices.
- In Ghana, depreciation of the Cedi combined with subsidy removal in the early 1990s drastically increased fertilizer prices and decreased fertilizer use because the increased costs were fully charged to farmers (Bumb, et al., 1994; Gerner et al., 1995).
- Nigeria still provides subsidies of 80%-90% on fertilizers. Farmers, who had access to these cheap fertilizers, were only partly affected by the persistent devaluation of the Naira in the early 1990s and, therefore, fertilizer use did not decrease. Neighboring countries such as Niger and Benin routinely benefit from cheap fertilizer from Nigeria. As a result, the Government of Niger could not remove subsidies on its stock of fertilizers in order to remain competitive with the products from Nigeria. The Government of Nigeria, however, is burdened with an unsustainable subsidy budget, which climbed to US $300 million in 1994. The government is therefore considering a phased reduction of fertilizer subsidies and subsequent liberalization/privatization of fertilizer procurement and distribution (IFDC-Africa, 1994a).

All in all, the removal of fertilizer subsidies has resulted in a further reduction of the already low Value/Cost Ratio (VCR) for fertilizer use on cereal crops in West Africa (Gerner et al., 1995). Thus, the subsidy issue for fertilizers in West Africa may need to be revisited.

The **supply-side efficiency-enhancing measures** in the field of agriculture and fertilizers included removal of restrictions on private sector participation (market liberalization), abolition or privatization of commodity boards, abolition of government monopoly on input distribution and output marketing, and the decontrol of input and output prices. At the time of producing this review, several barriers that prevent the attainment of open and competitive output and agri-input markets still exist. These will be dealt with in subsequent subchapters.

4.3 Agricultural Markets and Intra-Regional Trade

Antle (1983) has noted that if farmers do not have efficient output markets, they will resist investing in new and more productive technologies. Therefore, development of regional trade and improvement in output markets are very essential for the promotion of sustainable agricultural production systems.

Regional trade in West Africa is induced by resource complementarity and policy differences between countries. The informal trade between the Savannah and the Forest Zones is based on **natural resource complementarity**. Thus, items such as kola nuts, fish, cowpea, onions, vegetables, tubers, fruits, dried fish, and cereals feature prominently in regional trade (Gabre-Madhin, 1991). Egg (1989) reports that these products account for 33% of total agricultural trade flows in West Africa. For local cereals, Coste (1989) estimated that 15% of marketed millet and sorghum, 12% of marketed maize, and 5% of marketed paddy rice are regionally traded. Despite the past protectionist trade policies, informal regional trade has flourished in West Africa, and traditional trader networks, based on mutual trust, have been maintained.

With the birth of the modern state, **different national pricing and marketing policies** have induced new trade flows, periodic twin markets on both sides of the border, warehouses in border towns, and parallel currency exchange markets. These policies also explain the flows of re-exports of imported food products, such as rice, wheat flour, sugar, tomato paste, and condensed milk from the more open economies to the more protectionist economies. Trade flows induced by policy differences are dominated by a small group of big traders, who have access to both foreign and domestic bank finance and operate on a large scale in different countries. Unlike trade flows based on resource complementarity, policy-induced regional trade is unstable and risky because of frequent policy changes in West Africa (Egg, 1989).

Structural adjustment programs stimulate regional trade flows based on resource complementarity and reduce policy-induced regional trade flows. Local cereals, tubers, fruits, vegetables, onions, dried fish, and livestock products are expected to gain market shares as currency devaluation and the GATT agreements increase the prices of imported food items.

The spatial organization of local agricultural marketing systems comprises permanent urban and periodic rural markets. Traditional **urban food marketing systems** supply consumers with local cereals and tubers produced within a few kilometers of urban centers or in producing zones where road infrastructure is well developed. However, most market traders do not have adequate financial resources to import food directly from world markets. Thus, imports are handled by the same big traders who dominate policy-induced trade flows in West Africa.

Likewise, the collectors and wholesalers dominate most rural marketing systems in West Africa. The mostly itinerant collectors obtain their supplies from farmers and sell them to wholesalers. The wholesalers, who live in rural towns, aggregate the offerings of the many rural collectors and sometimes individual farmers for distribution to urban centers or export markets. These marketing arrangements have some inherent cost problems. In Mali, Dembélé (1994) found that rural marketing systems are characterized by high collection and aggregation costs and unstable prices due to poor road systems, variable marketed surplus, lack of adequate financing of collectors and wholesalers, and the meager size of individual transactions.

Lack of investments in road infrastructure, communication infrastructure, and agro-processing facilities to add value to products and the absence of common grade standards, weights, and measures constrain the development of efficient agricultural product markets. In particular, investments in agro-processing seem promising, when one considers the enhanced demand in urban areas and increases in prices of imported products after devaluation of the local currency.

The following two examples indicate that agro-processing has the potential to increase the farmgate price of raw crops if farmers are able to deliver high quality crops to processors:

- Malian farmers increased the value of good quality paddy from FCFA 70 to FCFA 82 per kg (after deducting milling costs) when they milled their paddy at harvest (Diarra, 1994).
- For traders in Chad, the processing of dried tomato into powder reduced transportation costs by 36% and increased the profit (after deducting processing costs) from FCFA 762 to FCFA 1818 per bag (Gaston, 1994).

However, the development of the processing industry requires the standardization of grades, weights, and measures to reduce transaction costs for both raw and processed food products.

In summary, the currency devaluation in West Africa and the liberalization of agricultural pricing and trade regimes are expected to increase the market share of local raw and processed food products. However, the benefits of these measures will be limited if marketing costs are not reduced through adequate investments in road infrastructure, rural processing industries, and the standardization of grades, weights, and measures.

In addition, governments must make market information available to all market participants and develop marketing and managerial skills of traders to improve coordination of product flows between rural and urban markets, and at the same time, between national and regional markets.

4.4 Fertilizer Market Development

4.4.1 Fertilizer Consumption

With the exception of Nigeria, fertilizer consumption is extremely low in West Africa. In the Sahelian countries, consumption appears to be lower than in the countries of the EFZ (Table 4.1). In most countries fertilizer consumption rose between 1970 and 1979/1980. The trend has since varied from country to country. A decline in consumption after 1980 can be observed in 7 out of 16 countries. In addition to removal of subsidies in the early 1990s, the economic crisis brought about by declining agricultural production and the improper functioning of the marketing boards of some cash crops may have contributed to this decline in fertilizer

Table 4.1 Fertilizer Consumption in West Africa

Country	Fertilizer Consumption (Hundred Grams Per Hectare of Arable Land)				
	1970[a]	1979/80	1985	1989/90	1992/93
Sahelian Countries					
Burkina Faso	3	15	46	58	60
Chad	7	3	23	15	26
Mali	29	69	129	54	103
Mauritania	6	67	103	116	82
Niger	1	8	10	8	4
Senegal	20	83	55	55	72
The Gambia	n.a.	130	n.a.	n.a.	44
EFZ Countries					
Benin	33	5	66	18	82
Cameroon	28	46	81	41	30
Côte d'Ivoire	71	172	118	113	132
Ghana	9	43	44	31	38
Guinea	18	4	2	11	47
Guinea-Bissau	n.a.	7	n.a.	n.a.	10
Liberia	55	92	100	107	n.a.
Nigeria	3	57	108	121	175
Sierra Leone	13	36	20	3	26
Togo	3	43	69	83	183

a. Average for 1969-71.

Source: World Bank, World Development Report, several editions.

consumption. Again, with the exception of Nigeria, fertilizers in most countries are used on cash crops. A good example is Burkina Faso where 65% of the NPK and 55% of the urea is applied to cotton alone (Van der Linde et al., 1993).

4.4.2 Fertilizer Product Selection

Fertilizer product selection in West Africa is highly influenced by historic and traditional trade linkages. Many West African countries have fertilizer product lists and specifications that fail to provide farmers with access to the most cost-effective fertilizer nutrients available in the world market today.

Straight fertilizers are the most widely produced and traded products on the world market. The market for straight fertilizers is transparent because detailed transaction data are regularly published in the weekly commodity press. Urea is the only straight fertilizer traded widely in West Africa. Western Europe has not been a traditional source of straight phosphate fertilizers such as triple superphosphate (TSP) and diammonium phosphate (DAP) (Table 4.2). The same is true for muriate of potash (MOP), the straight potash fertilizer. Because West Africa's traditional European trading partners do not routinely supply these products, farmers have been denied access to high-analysis straight phosphate and potash fertilizers. In general, farmers have to buy the more expensive compound fertilizers, such as those produced for cotton.

Blended fertilizers (mix of straight fertilizers that are chemically nonreactive) are rapidly gaining importance in West Africa and offer a real alternative to the traditionally used complex fertilizers. Although in principle the blending could be done by the farmer, in reality the blending occurs at a blending plant. One of the merits of the blending process is its flexibility: a blender can offer specific formulae, tailored to crop and soil conditions, at

Table 4.2 Overview of Straight and Compound Fertilizers Available in West Africa

	Straight			Compounds		
					Complex	
	Nitrogen	Phosphate	Potash	Blends	Sulfuric Acid-Based	Nitric Acid-Based
Grades	Urea AS CAN	DAP SOP SSP	MOP SOP	Mix of Urea, DAP and MOP	14-23-14 12-22-12 15-15-15	23-15-5 20-20-0 15-15-15
Major suppliers	Europe Nigeria Middle East	North and West Africa U.S.A. Middle East	Canada FSU Eastern Europe	West and South Africa	West Africa Eastern Europe	Western Eruope

Source: IFDC-Africa.

almost no additional cost, thereby responding better to farmers' needs than the traditional complex fertilizers (IFDC-Africa, 1994). Blenders generally take advantage of the large number of suppliers of straight fertilizers in the world market to procure large quantities in bulk, thereby benefiting from the economies of scale.

Complex fertilizers are another form of compound or multinutrient fertilizers. Unlike blends, complex fertilizers are obtained through a chemical process, based on the sulfuric acid- or the nitric acid-route. In Table 4.2 the major types of fertilizers used in West Africa and the suppliers are presented.

4.4.3 Fertilizer Manufacturing in West Africa

In West Africa, only three[1] countries have fertilizer production capacities: Nigeria, Senegal, and Côte d'Ivoire (Table 4.3). The fertilizer production facilities can be divided into (1) fertilizer granulation plants that process raw materials into a straight or complex fertilizer (NPKs) and (2) blending plants. Blending plants do not produce fertilizer nutrients. Table 4.3 presents the names, locations, year of installation, fertilizer types produced, installed capacity, and the average capacity utilization of the granulation and bulk-blending plants.

[1]A blending plant is scheduled to be operational in Benin in the near future.

In the first half of the 1990s, Nigeria and Côte d'Ivoire established blending plants. Blends from Nigeria are consumed domestically, whereas the blends from Côte d'Ivoire are mainly exported throughout the region. Currently, blends are becoming well accepted in certain countries in West Africa (Burkina Faso and Senegal are examples) and have become real alternatives to traditionally used complex fertilizers (S. Diouf—personal communication).

Nutrients in the locally granulated fertilizers partly come from indigenous resources and partly from imported raw materials. Nutrients in the imported raw materials thus drain foreign exchange. Taking into account this definition, the West African granulation plants produce only 272,000 tonnes of N, 330,000 tonnes of P_2O_5, and no K_2O.

The shortfall in local nutrient production is met through importation of raw materials for fertilizer production and the importation of finished fertilizers (Table 4.4). West Africa imports about 52% of fertilizer nutrients consumed, and 48% is available from domestic production.

4.4.4 Agromineral Deposits in West Africa

Several countries in West Africa have phosphate deposits (McClellan and Notholt, 1986) (Figure 4.1). The phosphate deposits in West Africa can be divided into developed and undeveloped. The developed deposits, of which only a few are

Table 4.3 The Structure of Fertilizer Production Plants in West Africa

Country:City	Name	Year of Installation	Type of Fertilizers	Installed Capacity (tonnes/year)	Average Capacity Utilization (%)
Nigeria: Kaduna	FSFC	1976	SSP	100,000	20
Nigeria: Port Harcourt	NAFCON	1987	Urea	450,000	90-100
Nigeria: Port Harcourt	NAFCON	1987	NPKs	330,000	61
Nigeria: Kaduna	F&C	1989	Blends	200,000	36
Nigeria: Minna	MNL	1990	Blends	200,000	28
Nigeria: Kano	KASCO	1990	Blends	30,000	38
Nigeria: Madobi/Kano	ANCC	1993	Blends	200,000	3
Nigeria: Maiduguri	YERWAFERT	1995	Blends	200,000	-
Nigeria: Port Harcourt	NAFCON	1995	Blends	200,000	-
Senegal: M'bao	ICS	1983	NPKs/TSP/DAP	250,000	90
Côte d'Ivoire: Abidjan	Hydrochem C.I.	1990	NPKs	110,000	50-70
Côte d'Ivoire: Abidjan	Hydrochem C.I.	1991	Blends	110,000	60-70
Benin: Cotonou	Hydrochem C.I.	1995	Blends	280,000	-

Source: IFDC-Africa, 1994, personal communication.

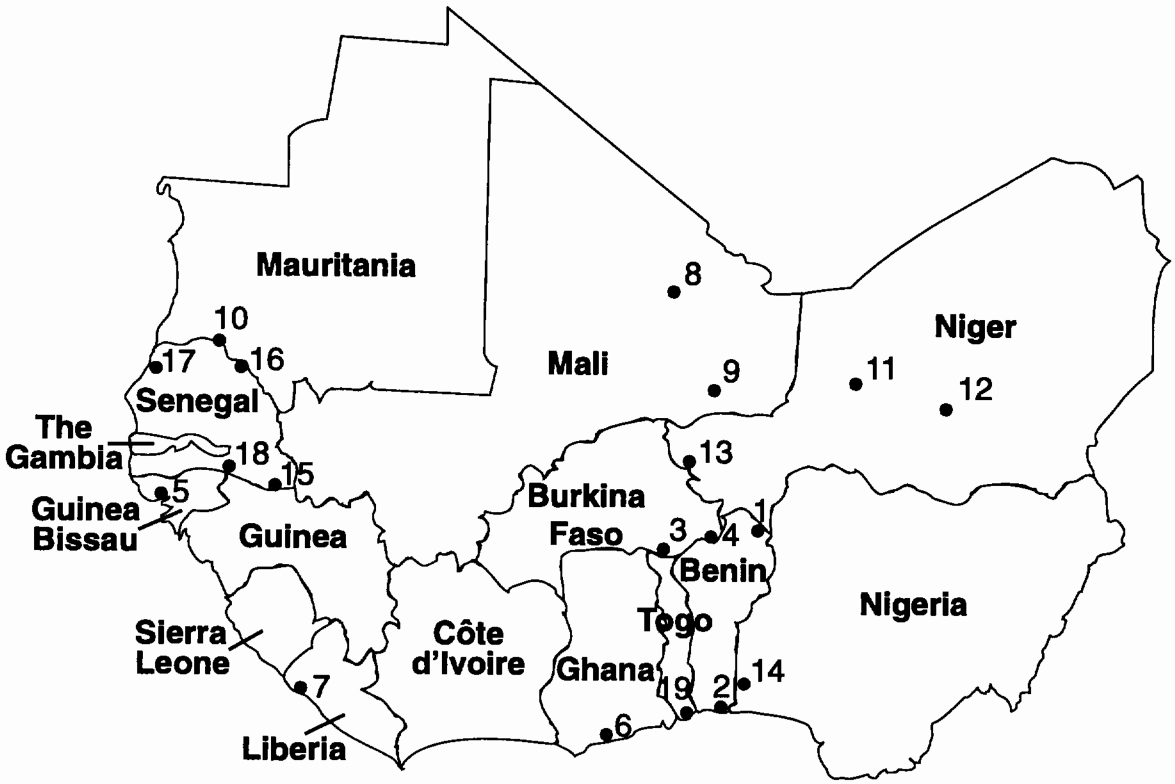
Table 4.4 Estimated Nutrient Supply and Consumption in West Africa (early 1990s, tonnes)

	N	P_2O_5	K_2O	Total
Production	272,000	334,000	0	606,000
Export outside region	109,000	198,000	0	307,000
Available	163,000	136,000	0	299,000
Consumption	284,000	185,000	160,000	629,000
Shortfall	121,000	49,000	160,000	330,000

Source: IFDC-Africa Fertilizer Information Database (AFID).

currently exploited, include those that are currently producing phosphate rock on a commercial basis and those that are producing for the local market. The Hahotoe-Kpogame deposit in Togo and the Taiba deposit in Senegal are producing phosphate rock on a commercial basis for the international market. Both deposits are known for their high-grade concentrates (35%-38% P_2O_5) with low contents of iron, aluminum, and magnesium that result in low product quality. A part of the Senegal deposit is transformed in Senegal itself into phosphoric acid, TSP, DAP, and compound fertilizers (of these fertilizers a portion again is sold within the region). After being washed, all Togo phosphate rock is exported. The Kodjari deposit in Burkina Faso, the Tilemsi deposit in Mali, and the Tahoua deposit in Niger have been opened and produce for the local market a limited amount of phosphate rock for direct application (van Kauwenbergh et al., 1991). By far the largest category of the West African phosphate deposits is undeveloped. In most cases, there are little interpretative data on the economic geology of the deposits. Research data are particularly sparse on the reactivity or direct-application agronomic potential of the rock that occurs in many of these deposits (van Kauwenbergh et al., 1991).

Exploitation of the undeveloped phosphate reserves is a logical move, considering the low levels of phosphate in West African soils and the increasing inaccessibility of imported fertilizers to farmers. In countries with substantial reserves, there may be some potential for establishing small-scale compaction or granulation plants. The feasibility of new compaction and granulation plants is severely limited by the current small size of the domestic fertilizer markets.



Phosphate Rock Deposits

Benin
- 1 Mekrou
- 2 Pobe

Burkina Faso
- 3 Arly
- 4 Diapega–Kodjari

Guinea Bissau
- 5 Farim–Saliquinhe

Ghana
- 6 Sekondi

Liberia
- 7 Bambuta–Bomi Hill

Mali
- 8 Assakerei
- 9 Tilemsi

Mauritania
- 10 Bofal–Loubboira

Niger
- 11 Aschia Tinamou
- 12 Tahoua
- 13 Tapoa

Nigeria
- 14 Abeokuta

Senegal
- 15 Gambia–Namel
- 16 Matam
- 17 Taiba–Thies
- 18 Ziguinchor

Togo
- 19 Akoumape–Hahotoe

Figure 4.1 Phosphate Rock Deposits in West Africa.

4.4.5 Public Versus Private Procurement and Distribution

In many West African countries, public organizations are responsible for the procurement and distribution of fertilizers to farmers:

- In **Nigeria**, fertilizer producers sell all products bound for the domestic market to the Federal Government. Shortfalls in domestic demand are imported by the Federal Government. The Federal Government then distributes fertilizers to the local Government administrations, who sell the fertilizers at highly subsidized prices.
- In **francophone West Africa,** the parastatal **cotton** companies procure "cotton" fertilizer on the international market. The exceptions are Senegal and Côte d'Ivoire, where local producers supply fertilizers to the companies who then distribute them to village associations. The village associations perform the functions of retailing. Cotton organizations in Mali and Benin also distribute fertilizers to the food crop sector. For the **food crop sector**, some West African countries, such as Togo, Burkina Faso, and Niger, have special fertilizer distribution services. The agency in Burkina Faso does not procure fertilizers but is primarily involved in the distribution of aid-funded fertilizers. Food crop farmers in Burkina Faso outside the cotton areas only have access to fertilizers when there is fertilizer aid.

As already indicated, some countries have continued to subsidize fertilizers. For example, in 1994, fertilizers were heavily subsidized in Nigeria (80%-90%) and moderately in Togo (40%-50%), and Burkina Faso (30%-40%). The private sector has quickly responded to the market opportunities created as a result of huge price differences between countries in the region:

- In 1990, for instance, private Hausa traders in Niger, who were also dealing in other commodities such as cereals, cowpea, and cooking oil, imported from Nigeria by parallel trade about 18,800 mt of fertilizers, representing more than 80% of Niger's requirements; 5,000 - 10,000 mt found its way to Mali and Burkina Faso (Martinet et al., 1994).
- In 1994 the private sector procured subsidized fertilizers from Burkina Faso for Malian farmers. It is also rumored that Ghanaian farmers benefited from cheap fertilizers from Burkina Faso and Togo. As a result, the Burkina Faso fertilizer stock, which was estimated to be for 3 years, was consumed in one season.

In addition to these spontaneous developments within the private sector in response to market opportunities, some West African countries have instituted a deliberate policy to transfer the procurement and distribution functions from the public to the private sector:

- In Ghana, the state withdrew completely from fertilizer procurement and distribution. The initial enthusiasm within the private sector soon gave way to despair. Persistent currency devaluation raised fertilizer prices and drastically reduced demand. As of 1995, only one supplier was importing fertilizers for a much-reduced Ghana market (Gerner et al., 1995). The private sector has fared better in other countries. In Senegal and Mali, the state withdrew in all sectors except for the cotton sector. Farmer organizations in the Office du Niger rice-delta in Mali procure their fertilizers directly from the private sector via Senegal, Abidjan, or Nigeria. It is to be noted that there is no subsidy involved in the formal private input dealer networks in Ghana, Niger, Senegal, and Mali (Diouf, 1995).
- In countries such as Togo and Benin, the state only transferred a part of the distribution functions to the private sector. In Togo, for instance, the Government issues the tender that can be responded to by a restricted number of local companies, which eventually provide the fertilizer to the Government at the port of Lomé. In Benin, a private company distributes cotton fertilizers directly to the farmers' associations on behalf of the cotton company.
- In Cameroon, the private sector was highly interested in entering the fertilizer market in the late 1980s and early 1990s within the context of the Fertilizer Sub-Sector Reform Program

(FSSRP). The private sector operated in a favorable investment climate characterized by a fixed FCFA-FF exchange rate and subsidy on fertilizers. Operations ran smoothly until the early 1990s when there was a drop in fertilizer consumption because the coffee growers were not paid by their cooperatives and thus could not pay for fertilizers delivered on credit by the private sector.

Planned privatization is often introduced with other policy measures, such as currency devaluation and subsidy removal. These measures have tended to reduce considerably the market opportunities for the private sector. On the contrary, the private sector should not be deprived of its market opportunities but rather supported to perform its role in an open and competitive environment. Such an environment provides maximum advantage to the farmers. All indications are that it is possible for liberalization and subsidies to coexist in the fertilizer sector.

In many countries, the fertilizer market is too small to benefit from economies of scale that can reduce import costs and promote competition in the market. In these countries, it may not be advisable for the government to transfer the procurement functions completely to a private sector

Economic Policies and Fertilizer Market Development

Protectionist policies pursued by Western countries and Japan tend to hinder investments in the West African agricultural sector and therefore limit opportunities for soil fertility improvement.

There is clear evidence that West African countries will receive less fertilizer aid and will need to strengthen their own fertilizer procurement and financing systems.

The implementation of the GATT agreements will only have a positive impact on soil fertility if adequate national policies are developed and implemented to increase productivity of the agricultural sector.

Development of a regional agricultural policy and investments in infrastructure to stimulate open internal trade and provide initial protection for most vulnerable products is required to facilitate development of a sustainable agricultural sector in West Africa.

Following devaluation, export crop farmers who seemed to have benefited most have tended to invest more in practices to improve soil fertility, whereas resource-poor food crop farmers have been reluctant to allocate their scarce resources to the purchase of labor- and time-consuming and risky soil fertility inputs with no ensured payoff.

Restrictive import policies in many West African countries deprive importers of the opportunity to procure fertilizers in a competitive market and therefore deny farmers access to cost-effective fertilizers.

Fertilizer market improvement projects will not be successful unless West African Governments ease unnecessary restrictive fertilizer specifications. Competition must be promoted by involving new suppliers to reduce significantly the cost of nutrients to farmers.

The fertilizer subsidy issue should be revisited. Fertilizer subsidies can operate in a liberalized market provided they are properly administered so that they minimally distort market operations, thereby permitting farmers to benefit from lower fertilizer prices.

An example of improved subsidy administration is when subsidies are infused at the point of entry of fertilizer products, and the scheme is administered by a fiduciary bank on behalf of the government.

Fertilizer pricing (e.g., subsidies and tariffs) policies should be determined in consultation with neighboring countries to prevent subsidies from going to the farmers in those neighboring countries.

monopoly. Establishment of a mixed (public-private) procurement office may offer a solution.

4.4.6 Effective Subsidy Administration in a Privatized Fertilizer Market

It has been stated earlier that the issue of fertilizer subsidies for West African countries may need to be revisited. This section is an attempt to summarize the thinking among workers in the region. Contrary to popular opinion, fertilizer subsidies can be properly administered in a privatized fertilizer market. The key is to ensure that subsidies are infused only at the point of production or importation for ease of administration. The Government of Cameroon has had positive experiences with an effective subsidy administration scheme in a privatized fertilizer market. The subsidy fund turned from a source of corruption and inefficiency under the old public monopoly to a positive financial incentive for a liberalized procurement system. In 1987, when fertilizer liberalization was introduced, the Government of Cameroon designated a commercial bank as the fiduciary bank to manage a subsidy fund on its behalf. The fiduciary bank does not pay the subsidies to importers directly but disburses the funds to an importer's commercial bank, once a shipment has arrived at the port.

Fertilizer subsidy could play a critical role in promoting private sector participation in the fertilizer sector in Nigeria, for instance, by reducing commercial risks associated with the business activities of bankers, dealers, and farmers. In addition, subsidy reduces the working capital needed by dealers and farmers and, hence, lowers the threshold to enter the fertilizer market. This promotes competition and increases farmers' demand for fertilizers. Based on an improved subsidy administration scheme, an appropriate scheme to facilitate the importers' access to foreign exchange could also be designed (IFDC-Africa, 1994a). Even if a subsidy scheme were introduced, it should be viewed as a short-term measure. There should be a clear plan to remove the subsidy once the market is established.

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5. Institutions and Support Services

5.1 International Organizations (International Agricultural Research Centers, IARCs)

5.1.1 Engagement of IARCs in West Africa

The Green Revolution, which eliminated hunger in Asia and parts of Latin America, is the product of the hard work of the international agricultural research system. The 16 international agricultural research centers (IARCs), which comprise the Consultative Group on International Agricultural Research (CGIAR), are primarily commodity-improvement centers concentrating on basic and applied research where they have a comparative advantage as compared with national agricultural research systems (NARS) (Jahnke et al., 1987). Three CGIAR centers – The International Institute of Tropical Agriculture (IITA), The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the West African Rice Development Association (WARDA) – are located in West Africa. Also located in the region is the Africa Division of the International Fertilizer Development Center (IFDC-Africa). The International Fertilizer Development Center (IFDC) is a nonassociated member of the CGIAR. Several other CGIAR centers such as the International Center for Research on Agroforestry (ICRAF), International Irrigation Management Institute (IIMI), International Livestock Research Institute (ILRI), International Maize and Wheat Center (CIMMYT), and the International Food Policy Research Institute (IFPRI) have active programs in West Africa. Over the past 20 years, the CGIAR system has spent about one-third of its resources in Africa, and West Africa has been a major beneficiary of this commitment by the system. For two decades the centers have made considerable progress in the field of agricultural research. For example, IITA's disease-resistant cassava varieties dominate the fields of sub-Saharan Africa. The revitalized WARDA is working with national agricultural research systems using a task force mechanism to promote research and development work on rice. Perhaps the greatest accomplishment of the system can be seen in the sheer number of national scientists who have been trained. West African NARS are still weak by world standards, but the efforts of the IARCs have substantially improved the capacity of the West African NARS. The efforts of these IARCs will augment those of the NARS, AROs and NGOs to revitalize West African agriculture. Some of the planned activities of the IARCs are described below.

5.1.2 Regional Initiatives of International Organizations

To meet the challenges identified by Agenda 21 and address the issues of research on the management of natural resources, the CGIAR has devised an ecoregional approach to research. The ecoregional approach has three key components (TAC, 1993):

- Applied and strategic research on the foundations of sustainable production systems;
- Improvement of productivity by incorporating appropriate global research activities;
- Strengthening of cooperation with national partners and the development of transnational mechanisms of collaboration.

Ecoregional programs are ideally suited to the varied environments of West Africa. The new emphasis on partnerships (between CGIAR, NARS, AROs, NGOs and other IARCs) puts the NARS in the center of the planning and executing phases of the CGIAR research agenda.

5.1.2.1 The Desert Margins Initiative (DMI) and The Ecoregional Program for Humid and Sub-Humid Tropics of Sub-Saharan Africa (EPHTA)

The International Convention on Desertification and its Implementation Annex for Africa provide the frame of reference for the ecoregional program, called the Desert Margins Initiative (DMI). ICRISAT has been assigned the convening role for this ecoregional initiative, which involves four West African NARS and several IARCs, NGOs, and AROs. The DMI will address three issues:

- Develop sustainable pastoral grazing systems for dryland regions;
- Manage water and nutrient resources more effectively within the rainfed farming, mixed tree/crop/livestock systems, and natural and plantation woodlands;
- Design policies and institutional options for improved natural resource management.

It is hoped that addressing these issues will achieve the key goal of enhancing the food security of poor rural populations while alleviating poverty by halting or reversing desertification (Sivakumar and Wills, 1995b). DMI is still in its planning stages. An Interim Steering Committee, including representatives from NARS (Burkina Faso, Kenya, Botswana), regional organizations (INSAH/CILSS, IGADD, SACCAR), NGOs, UNEP, ICRISAT, ICRAF, ILRI, IFPRI, IFDC, and ORSTOM, has been established to foster the planning process.

The overall goal of the Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa (EPHTA) is to foster regional collaboration in agricultural research among the CGIAR centers, NARS, and other development agencies to make research more relevant and cost effective. IITA has the lead role in developing the program that will involve the establishment of three consortia. These are the Moist Savanna Consortium, the Humid Forest Consortium, and the Inland Valley Consortium. IITA has the responsibility of forming the first two consortia while WARDA has already established the Inland Valley Consortium. It is anticipated that research and development work will be carried out at "benchmark sites" in well-characterized "benchmark areas." A task force, drawn from several NARS, regional institutions, IARCs and the FAO, is working to develop the plan for EPHTA.

5.1.2.2 Soil, Water and Nutrient Management Research Initiative (SWNM)

Several documents – Greenland et al. (1994) and the CGIAR's response to UNCED/Agenda 21 – have emphasized the need to establish a coordinated research program on the management of soils, water, and nutrients. The notion of harnessing the resources of several institutions to tackle the problems of natural resource management in a selected environment was the driving force behind the 1992 meeting in Lomé of a group of scientists from IFDC, IBSRAM, ICRAF, TSBF, and TropSoils. This "consortium" prepared a proposal entitled "A program for improving food production and combating desertification in the Sudano-Sahel, Sudanian, and Sudano-Guinean zones of West Africa." The discussions that followed the presentation of the goals of this proposal subsequently led to the involvement of both CGIAR and non-CGIAR centers in the development of a worldwide program that would encourage land users to apply technologies and sustainable management systems that would: (1) increase long-term productivity, (2) reduce poverty, and (3) conserve and enhance the quality of land and water resources both on-site and off-site. It is envisaged that this global program will link and complement the ecoregional programs.

Four consortia – Combating Nutrient Depletion; Managing Acid Soils; Managing Soil Erosion; and Optimizing Soil Water Use – are in the process of being established. Of particular interest to West Africa is the Combating Nutrient Depletion Consortium, which is scheduled to begin its research and development activities in the moist savannas of West Africa. For West Africa, IFDC and the Institute for Agricultural Research (IAR), Zaria, Nigeria, are the co-conveners of this consortium. The activities will be carried out within the context of the IITA-led Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa (EPHTA).

5.1.2.3 Phosphate Rock (PR) Initiative

The use of PR as a capital investment for restoring and maintaining the long-term productivity of soils is at the heart of this initiative. In 1994 the World Bank, IFDC, and ICRAF initiated the first phase of a study designed to assess the feasibility of supporting sub-Sahara African agricultural development through investment in the replenishment of soil phosphorus using local phosphate rock sources. The completion of an "issues paper" was followed by the implementation of case studies involving three countries. Of particular interest to West African agriculture is the case study conducted in Burkina Faso. The objectives of this study were: (1) to demonstrate that soil P capital replenishment expenditures may be considered investments in natural resources instead of recurrent costs of agriculture, (2) to identify and valuate the externalities associated with production and use of imported P fertilizers and local PRs to improve price comparisons, (3) to determine costs of exploitation and application of PR materials in the selected countries, (4) to identify and review the policy and infrastructure implications, and (5) to review the status of technology for PR application and farmer participation and adoption.

5.2 National Research and Extension Services

5.2.1 National Research on Soil Fertility

Key to developing and modernizing the agricultural sector in West Africa is the generation and adoption of plant nutrient technologies that have the potential of raising the productivity of land, labor, and capital to appreciable levels without adverse effects on the environment. Agricultural research within West African NARS that focuses essentially on soil fertility restoration and maintenance has not received the needed attention. Table 5.1 shows that as of May 1995, less than 50% of West African NARS had five or more on-going research and development projects that focus on aspects important for soil fertility restoration and maintenance (SPAAR, 1995). In this regard, Mali, Nigeria, and Ghana may be singled out as countries that have so far demonstrated the will to address the problem of soil fertility as an agricultural research priority.

Table 5.1 Current Research and Development Projects in West Africa That Focus on Aspects Important for Restoring Soil Fertility by Agroecological Zone

	Agroecological Zone				
Countries	Sahel	Savanna	Equatorial Forest Zone	Not Specified	Total
Benin	NP	2	2	4	8
Burkina Faso	3	1	NP	1	4
Gambia	1	NP	NP	-	1
Ghana	NP	5	5	2	12
Guinea	NP	3	-	-	3
Côte d'Ivoire	NP	-	2	4	6
Liberia	NP	NP	1	-	1
Mali	9	4	NP	4	17
Niger	2	NP	NP	-	2
Nigeria	3	1	3	7	14
Senegal	1	-	1	2	4
Sierra Leone	NP	-	-	2	2
Togo	NP	2	NP	1	2

NP = Not present

Source: Adapted with modifications from SPAAR Database (1995).

Traditionally, research related to soil fertility was carried out to determine the rate of application of fertilizers. Results of such trials have often been the sole basis of farm-level fertilizer recommendations, without taking into account the shortcoming of these trials (controlled circumstances, no interaction with existing soil-fertility management practices, etc.) But there are signs that the NARS, having benefited from intensive capacity-building efforts, are beginning to adopt more recently developed research methodologies, which could provide better insight into soil fertility management problems. These new approaches include research using an agroecological approach and a farming systems approach involving farmer participation in the development of technologies. There is gradual adoption of computer models that take into account long-term processes (simulation models) or competition for alternative land uses at a regional level (multicriteria models; e.g., van Duivenbooden, 1995). Most of the research on restoring soil fertility has been location specific with little attention to the surrounding environment. For instance, in valley bottoms, fertilizer recommendation rates generally refer to the quantities of fertilizer needed to grow a crop of rice without considering the nutrients that may be available to the rice crop as a result of the erosion of sediments from the top slopes within the toposequence. Recently, however, a so-called multiscale approach has been proposed to examine land use systems with the goal of developing sustainable cropping systems (Andriesse et al., 1994).

5.2.2 Extension Services

The past decade has witnessed substantial investment in the improvement of the capacity of African countries to conduct agricultural research. It was rightly felt that the IARCs needed strong partners within the NARS for development of improved technologies. There is increasing concern that in spite of this massive investment, the limited-resource farmers in West Africa are still faced with productivity declines and an environment that is being subjected to greater stress.

Extension services that effectively transfer agricultural technologies to farmers are critical for sustainable agricultural development. However, except for a few success stories, such as the single commodity extension service for cotton in the CMDT zone in Mali and elsewhere in francophone West Africa (Cleaver and Schrieber, 1992), extension services have not performed well because of a variety of structural and institutional constraints. In several national extension systems in West Africa, frontline extension workers are under-paid, under-trained, ill-equipped, under-motivated, and often over-burdened with responsibilities, which are not directly related to increasing the knowledge base or awareness of the limited-resource farmer. Wiggins (1986) summarized the plight of extension workers as "sad figures, abandoned in the bush with little or no support, infrequently supervised, with no message worth passing on to farmers, and with few incentives to get on with the work."

As a result, farmers do not appreciate the work of extension workers and only make use of them when the farmers sense a direct benefit from such association, such as having access to subsidized inputs. It is essential that extension workers acquire the basic technical competence to conduct participatory field experiments to know whether recommended technologies are feasible and profitable for farmers. They must be in a position to diagnose problems and abnormalities, advise on possible solutions and assess, jointly with the farmer, the profitability and suitability of technology options. In effect, extension workers must be in a position to provide "a menu of options from which farmers would choose to suit their specific circumstances, rather than deliver prescriptive composite technologies" (Cleaver and Schrieber, 1992). This underlines the need to raise the competence of the frontline extension staff in the domain of soil science, agricultural economics, communication skills, group formation, and local resource mobilization.

The structure of extension services in many West African countries desperately needs to be reorganized to make them more cost-effective and efficient. In this regard, it may be necessary to consolidate and unify the multiple subsector and the single commodity extension services to meet the often more complex and variable needs of farmers. With the assistance of the World Bank, such a unified extension system operates today in Burkina Faso and Togo. The system is also being tried in Ghana and Nigeria. Evidence seems to suggest that this so-called modified T&V system is cost effective and appropriate for meeting the needs of farmers (Bindish et al., 1993). The success of this, however, is largely dependent on availability of well-trained and motivated staff, including subject matter specialists, who are woefully lacking in the extension systems of most West African countries.

Current trends in several countries show a diminishing role for public extension services and an increasing focus on privatization of extension services. This is a welcome trend. It should be noted, however, that, given present circumstances, most of the issues of concern to the small-scale, mainly food-crop producers, may not be adequately addressed by a privatized extension system. Efficient and effective public extension services are therefore required to assist the majority of the producers involved in the food-crop subsector.

5.2.3 The Role of Non-Governmental Organizations (NGOs) and Farmers' Organizations (FOs)

The failure of a large number of government-implemented projects to have an effective impact on traditional farming systems in general and on the well-being of the farm household has fueled the process of searching for alternative intervention channels. In recent years, therefore, the role of the Non-Governmental Organizations (NGOs) as effective agents of change has become more crucial.

The term, NGO, is generic. Within this umbrella is a collection of a wide variety of organizations with divergent backgrounds, origins, objectives, and sizes. In general, however, it can be stated that at the heart of the desire for intervention by NGOs in rural communities is the principle of empowerment for local communities, promoting self-reliance, and alleviating poverty (Reijntjes et al., 1992).

Various studies have shown that the involvement of NGOs in the complicated processes of initiating, facilitating, and guiding necessary changes in the farming systems is essential because:

- NGOs' activities tend to be participatory in comparison with those carried out by Government Organizations (GOs). This gives NGOs a good orientation toward clients' needs;
- NGOs' activities empower grassroots organizations and resource-poor farmers in the long term;
- NGOs are involved in a range of activities such as agriculture, physical infrastructure, education, health and nutrition, which enable them to put agricultural technologies into context with "total" rural development;
- NGOs are capable of working successfully in marginal areas (Wellard et al., 1990).

Experiences show that NGOs are particularly successful in the development of diagnostic methods (Chambers, 1989; Richards, 1985), innovations in techniques of adoption of technologies and management practices (Reijntjes et al., 1992), development of alternative dissemination methods, training methodology, and promoting farmers' organizations. A more indirect role of NGOs can be observed in their role as advocates and lobbyists, individually or through a network of NGOs. However, in West Africa, this aspect of NGO influence is still of limited importance.

On the other hand, NGOs rarely address wider scale structural factors that underline rural poverty. For example, when dealing with development of sustainable land use systems, the solutions for the problems often go far beyond the capacities and mandate of the NGOs involved. In West Africa, the NGOs are not immune to the problems associated with limited capacity for agricultural technology development and dissemination. Their activities in various parts of the same country remain uncoordinated because of poor information exchange. NGOs often have short-term funding cycles.

Although NGOs in West Africa are already involved in a wide variety of activities related to the development of sustainable agriculture and soil conservation (Wellard and Copestake, 1993; Gubbels, 1993), a more active role in this area is anticipated. Activities and interventions of all organizations have to be based upon a general policy framework and a common research and development agenda for the particular country involved. Since this spirit of cooperation is absent in most countries in West Africa and relations between GOs and NGOs are not well established, special attention needs to be paid to joint planning and implementation of programs between GOs and NGOs. Such joint activities could include the replacement or supplementation of dwindling extension services by NGOs; NGOs assisting GOs in diagnosing farmers' problems; and contracting by the NGOs of GOs researchers' time (Farrington and Bebbington, 1994).

Apart from NGOs, local Farmers' Organizations (FOs) also may play an essential role in agricultural development. The following specific roles for FOs can be distinguished:

- Interface between research and extension for an accurate assessment of the production and living conditions of the resource-poor farmer population;
- Pressure group on GOs and NGOs to orient the work to the needs of the rural poor;
- Active role in the generation and extension of agricultural technologies in programs they control and administer themselves (Bebbington et al., 1994).

It is assumed that strong FOs can have a positive effect on efficiency, effectiveness, equity and demand orientation of interventions of GOs and NGOs. Currently organizations from outside the farming community (e.g., GOs and NGOs) still operate as farmers' representatives instead of doing their job of empowering the farmers to represent themselves. However, at this moment in West Africa, only a very few self-sustaining, member-driven FOs exist with appropriate management capacity. There is therefore a need for outside intervention to support local institution building to catalyze a demand-driven process of agricultural development and to combine work in participatory agricultural problem-solving with strong sociopolitical and local institution building orientation (Gubbels, 1993).

5.2.4 Research-Extension-Farmer Linkages

Effective linkages between research, extension, and farmers are crucial for agricultural development because they ensure that research addresses farmers' priority needs and problems; farmers and extension workers keep abreast of research developments; available technologies are adapted to suit local agroecological and socioeconomic conditions;

and above all, researchers and extension workers make use of indigenous knowledge, and also obtain feedback on the relevance and performance of improved technologies (Merril-Sands and Kaimowitz, 1989).

The crucial importance of information/knowledge in the adoption process is exemplified by a recent study of the extension system in Burkina Faso (Bindish et al., 1993). The study reported that for seven of twelve practices, the largest proportion of sample farmers who had not adopted a practice explained their decision in terms of insufficient knowledge of the practices. This gives a cause for concern as it suggests weaknesses in the mechanism for the delivery of extension information. This weak system for information dissemination is, of course, characteristic of several countries in the region even though almost every country has devised some kind of "extension" service to develop this linkage function between the research system and farmers.

In West Africa, only limited formal and informal links exist between national research institutes, extension services, and farm households. For such commodities as cotton, the flow of information from research institutes to extension services and eventually to farm households has, to some extent, been developed. The reverse flow of information, e.g., needs assessment and evaluation of technology under field conditions, has been much less developed. Joint planning and coordination of activities (e.g., research agenda) with participation of all three parties are virtually nonexistent.

The switch that many NARS are currently making from commodity-oriented research to Farming Systems Research, which includes implementation of on-farm research, will facilitate intensive direct contacts of researchers with rural farm households. Also many NARS are increasingly implementing Participatory Rural Appraisals for the purpose of research planning and design. Incidentally, other methodologies originating from NGOs, like Participatory Technology Development (PTD) (Haverkort et al., 1991) and Farmer-to-Farmer Workshops (Ashby, 1985; Chambers, 1989) are also receiving attention in government research and extension services.

Since most of the interventions regarding improvement of soil fertility are complex, affect the total farming system, and are site-specific, it is essential that farmers play a key role in problem identification and technology development. The significance of this is amplified by the success that IFDC achieved in the village of Gobery in southeast Niger (IFDC, 1994). The role of researchers, extensionists, and NGO field workers is to contribute to and improve local capacities to adjust to changing conditions through experimentation and adaptation of technologies. This process of PTD may facilitate the implementation of external interventions, mediate in decisionmaking, and assist in formulating policy about external interventions, thereby empowering social groups to gain greater access to and control over resources and decisionmaking (McCall, 1987). In addition, adoption of PTD-methodology ensures that appropriate existing indigenous knowledge is taken into consideration during the development of "external" technologies.

5.3 Local Financing for Soil Fertility Improvement

5.3.1 Financial Services to Farmers

5.3.1.1 General Overview

The development of sustainable production systems requires cash for capital investments on such items as stonebunds and terraces and for the purchase of agri-inputs such as soluble fertilizers, phosphate rocks, and improved seeds. Capital investments, which have a long-term effect on the productive capacity of the soil, are made at a given point in time but result in a flow of benefits over several years and crop seasons (Gerner and Baanante, 1995). Agri-inputs, on the other hand, have an important and immediate effect on crop yield, productivity, and profitability in the growing season in which they are applied. Expenditures on these agri-inputs and on labor for crop management practices are recurrent operating costs rather than investments. Where capital investments have been made, there is a tendency for the profitability of agri-inputs to increase and, thereby, increase the repayment capacity of farmers if credits were initially available.

In sub-Saharan Africa, the need for external financing for investment in agriculture is clearly highlighted by several authors (La-Anyane, 1983; Lele, 1984; Mellor et al., 1987). These authors have assessed constraints to agricultural development and have identified low capital input as posing perhaps the greatest problem. The issue of external financing aside, there is the problem of the adequacy of credit and financial institutions.

Unfortunately, it would seem that most available soil management technologies such as the erection of stonebunds are capital-intensive. Several authors, however, have argued that credit is not an effective instrument for promoting a soil fertility capital investments program. Stocking (1988) states that credit facilities should not be used to finance classical soil conservation strategies from which little or no effect is perceived in the short term. This is also confirmed by Reardon and Vosti (1992), who mention, e.g., that:

- Credit markets in many fragile areas are quite underdeveloped; there are high interest rates and limited access for smallholders;
- The loan size to construct large investments might exceed the capacity of local creditors or even village credit groups, especially if many households require loans at the same time;
- Borrowers and creditors may not perceive (and there may not be) a clear immediate payoff to these investments; hence, the risk of default may be greater.

It has already been stated that since 1994, IFDC and ICRAF have worked with the World Bank to develop the concept of the use of West Africa's phosphate rocks as capital investment to recapitalize the fertility of the soils. In November 1994, participants from 12 West African countries met in Lomé and declared their support for this approach. They also recommended that capital investments should be made by the public sector with support from the international community. All agreed that the recurrent costs of maintaining the fertility of the soil should be borne by farmers.

Unlike the case with capital investments, credit facilities can be very useful for financing recurrent operating costs of activities that have immediate effects. The financing of recurrent operating costs can be obtained from a range of formal and informal institutions (Table 5.2). The appropriateness of these financial services differs for cash-crop and food-crop farmers.

5.3.1.2 Formal Financial Services

In many West African countries, the supply-driven, top-down approach of **institutional lending** to the small-scale food-crop subsector has consistently failed for the following reasons:

- Many concessionary loans were diverted to other sectors and did not reach the small farmer for whom the program was intended (Braverman and Guasch, 1986).
- Capital sources provided by international donors and the national governments were often seen as gifts by the borrowers and not as credit that needs to be repaid.
- Institutional lending induced the financing of marginally profitable activities for which the borrower does not want to invest his own capital, thereby inducing repayment problems.
- Institutional lending resulted in very low recovery rates, which is the self-explanatory indication of the failure of this kind of credit. In Nigeria, for example, loan recovery of the Nigerian Agricultural and Cooperative Bank (NACB) averaged about 50%-60% during the last 20 years (IFDC-Africa, 1994).

When debt rescheduling became more difficult under the structural adjustment program, several agricultural banks had to limit their agricultural loan portfolio. In Ghana, for instance, advances to the agricultural sector from commercial and secondary banks decreased from about 30% in 1984 to 15% in 1989 (Ministry of Agriculture, 1991). In Togo, the Caisse Nationale de Credit Agricole (CNCA) went bankrupt in 1990. The CNCA in Burkina Faso was restructured in the early 1990s and presently serves mainly the cash crop subsector.

Institutional lending is limited to cash-crop farmers, who can provide the necessary bank guarantees and are more familiar with the banking formalities. In addition, institutional lenders rarely provide loans to women farmers, who produce the bulk of food consumed in the region.

Commodity marketing and processing companies provide agri-inputs (seeds, pesticides and fertilizers) on credit to organized (male) farmers

Table 5.2 Rural Financial Services in West Africa

Type of Credit Systems	Form of Credit	Crops/Target Farmers	Accessibility	Repayment	Interest Rates (% p.a.)
Formal Financial Services					
Institutional lenders	cash	cash crops/large scale	very low	low	moderate (10%-30%)
Commodity marketing and processing companies	farm inputs	cash crops/small scale	limited	high	low (5%-10%)
Farm services companies	farm inputs	cash and food crops/ small scale	limited	low	low (5%-10%)
Agricultural Development Projects/ Village Development Funds	farm inputs/cash	cash and food crops/ small scale	limited	low-high	moderate (10%-15%)
Informal Financial Services Money lenders	cash	not specified	good	high	very high (100%)
Traders	cash	crop marketed/ small scale	good	high	high
Landlords	cash/land tenancy	annual crops/ small scale	fair/good	high	high
Rural credit/savings groups	cash	all crops/members	fair/good	high	moderate (10%-15%)
Rural labor/credit associations	cash/labor	similar farming systems/ members	fair/good	high	nil or very low

Source: Adapted from Stevens and Jabara (1988) and IFDC-Africa (1995a).

for the cultivation of a specified area of cash crops, such as cotton and tobacco (IFDC-Africa, 1995b). Reimbursement is automatic and sure through the purchase of the crop produced. Agri-input supply is limited to cash crops, but the Compagnie Malienne de Developpement de Textiles (CMDT) is an exception by also providing cereal-fertilizers to the cotton growers.

Farm services companies, which operate mainly in the English-speaking countries, Ghana and Nigeria, had a specific role in the state-controlled agri-input supply systems in the 1980s. However, their role has been limited with the liberalization of the economy, thus private traders are induced to service the countryside.

Supervised credit is often provided through the **Agricultural Development Projects** and/or special rural credit programs, such as Fonds de Développement Villageois for rice farmers in the Office du Niger zone of Mali. Repayment rates are often high in the early stages of these projects but considerably reduced a few years later.

5.3.1.3 Informal Financial Services

The major differences between the informal and formal financial services are the greater accessibility and the high repayment ratio of the former, which are two very important criteria for a sustainable financial system. Borrowers need to have access to credit and the lenders need to be assured of repayment. Explanations for the greater accessibility and the high repayment ratio can be found in the use of own capital resources and community savings and the provision of loans to a limited number of borrowers, which allows for supervision and repayment discipline:

- Individual lenders such as money lenders, traders, and landlords use their own funds and will ensure the recovery of outstanding capital. This is a risky business and requires skills and time for which the lender must be compensated. The high interest rates charged by individual lenders partly reflect the inherent risk and time involved.

- The use of **community savings for credit services** to group members is rapidly gaining attention in West Africa. The rationale lies in the assumption that if community resources are mobilized and managed by the members themselves, accessibility and the repayment ratio will be greater. Group members themselves will develop their own savings and credit system, which fits their needs and socioeconomic conditions.

Initially, a savings and credit fund can be quite small, but members could be encouraged to increase their financial contribution or borrowing capacity (Wickrama and Keith, 1994). This concept is being promoted by one NGO in northern Togo: small savings groups collectively purchase fertilizers and receive additional loans for other inputs from the local NGO. In the last 5 years, many savings and credit groups have emerged and have been able to mobilize enormous amounts of local resources. Thus, local resources, previously lying idle in the community, are now allocated to those who need a loan. It is not surprising that the most successful savings and credit associations are owned by women, who invariably need financial services but rarely have access to formal financial services.

In several West African countries, such as Senegal, Burkina Faso, Togo, and Benin, some of the savings and credit associations are registered and have a more formal character (Cuevas and Benoit-Cattin, 1991). In Togo these Coopératives d'Epargne et Credits (COOPEC) have their regional unions and a federation, where they deposit part of their savings.

5.3.2 Providing Financial Services to Fertilizer Traders

During the 1990s, with the exception of Nigeria, fertilizer procurement in West Africa changed from a distribution/logistical activity into a more commercial activity in which the procurer had to find the necessary funds from the financial sector. Given the relative inexperience of the financial sector in West Africa, there has been noticeable reluctance in its participation in the fertilizer trade. This inexperience stems from the noninvolvement of the financial sector in the fertilizer trade because of the abundance of aid-financed fertilizers in the 1980s in most West African countries.

With structural adjustment and liberalization, fertilizer importers suddenly needed to find the necessary funds, averaging US $2.5 million per transaction of 10,000 mt of fertilizers, which is the minimum amount needed in order to benefit from the economies of scale of sea transport. Part of the program for structural adjustment was the removal of subsidies on fertilizers which, in turn, induced higher risks on fertilizer trade. Since banks traditionally are reluctant to lend to risky businesses, they demand 100% guarantees from fertilizer procurers. Both public organizations and the private sector have had difficulties in guaranteeing Letters of Credit for the importation of the optimum quantities of fertilizers. This has made fertilizer supply irregular, unreliable, and relatively expensive for most countries and, in particular, for the food crop subsector.

The following scenarios illustrate how some organizations have escaped from major financing problems.

- The cotton organizations in francophone West Africa have no major problem in obtaining bank financing because they are able to provide the needed bank guarantees. These cotton exporters also have the advantage in that they can generate foreign exchange that can be used to import agri-inputs such as fertilizers.
- Even though local fertilizer producers in Nigeria and international suppliers are assured of being paid, they require credit due to late payments by the Federal Government of Nigeria. The Federal Government of Nigeria, the only buyer of locally produced and imported fertilizers in Nigeria, annually allocates huge sums for fertilizer procurement and subsidy. Prices paid by the Government are high enough to compensate producers and traders for the additional interest charges.
- NAFCON in Nigeria and the Industries Chimiques du Sénégal/Senchim in Senegal generate the necessary foreign exchange and cash by exporting urea (NAFCON) and phosphoric acid/ solid fertilizers (Senchim).
- Hydrochem in Côte d'Ivoire obtains its foreign exchange from Norsk Hydro, a major fertilizer manufacturer, who is also a major shareholder of the plant.
- The fertilizer producers in Senegal and Côte d'Ivoire sell their fertilizers using well-supervised credit schemes to reputable traders and farmers.

Institutions and Support Services

The ecoregional programs and the CGIAR Systemwide Initiative on Natural Resources Management will, through collaboration between the CGIAR centers, NARS, NGOs, regional institutions and AROs, promote the identification of priorities and the development of programs to arrest land degradation.

Since effective extension services are an essential element in the process of technology diffusion, the upgrading and restructuring of government extension services should receive high priority.

New approaches in extension methodology and organization such as participatory technology development, farmer-to-farmer extension, and involvement of private input suppliers have to be explored.

NGOs are essential in addressing soil fertility problems since they have extensive experience in involving rural farm households to address problems in a holistic way.

NGOs and GOs must stimulate and support the establishment of farmers' organizations (FOs).

Interventions regarding soil fertility improvement require effective linkages between GOs, NGOs, and FOs with specific roles defined for the various organizations.

Adoption of Participatory Technology Development (PTD) techniques in the formal research and extension systems is required to facilitate the development and implementation of appropriate interventions to restore soil fertility.

To promote long-term productivity of the soil requires capital investments. These investments ought to be borne by national governments with support from the international community. Farmers need credit for expenditures on agri-inputs, which promote crop production in the short term. Food-crop farmers have no access to formal avenues for credit.

The most successful credit and savings associations are those operated by women.

Attractive market opportunities are required to encourage the financial sector to finance fertilizer trade.

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6. Technologies for Restoring Soil Fertility

6.1 Choice of Technologies

Concerning overexploitation of agricultural land in the Sahel and the SSZ, Van Keulen and Breman (1990) and Van der Graaf and Breman (1993) concluded that increased productivity of the land, both in animal husbandry and in arable farming, will require at least inputs of phosphorus (P) from outside the system. They argued that recycling of crop residues, manure and household wastes, regeneration of degraded rangelands, anti-erosion measures, etc., may at best prevent further deterioration of the land resource, but these measures are insufficient to stop nutrient depletion. Since this is the guiding principle of this review, it is important to distinguish between technologies that:

- **Save** nutrients from being lost from the agroecosystem such as erosion control, restitution of residues, agroforestry and recycling of household wastes and animal manure.
- **Add** nutrients to the agroecosystem, such as the application of mineral fertilizers and amendments, concentrates for livestock, organic inputs from outside the farm, and N-fixation in wetland rice and by leguminous species.

As the technical options to restore soil fertility are for eventual adoption by the farm household, the farm will be taken as the focal system level. The technologies adopted by farmers can be seen within the context of the manipulation of one or more nutrient inputs, nutrient outputs, or internal flows listed in Table 6.1, which, in fact, is an extended farm-level representation of Figure 3.3. "Farm" as used here is a physical unit with a known surface area and may refer to anything between a farmer's property of one or a few hectares to much larger, communal grazing grounds. The technologies for the restoration of soil fertility, based on the above-mentioned principles, are listed in Table 6.2.

6.2 Mineral (Soluble) Fertilizers

The use of mineral fertilizers has recently been the subject of heated debate regarding the perceived negative effects of fertilizers on the environment (Dudal and Byrnes, 1993; Conway and Pretty, 1991). Nonetheless, pioneering work by C. T. de Wit and his co-workers (Penning de Vries and Djiteye, 1982; Breman and De Wit, 1983) revealed that low soil fertility is at least as important as drought stress with respect to crop and pasture production in West Africa, especially in the Sahel and the SSZ. Meanwhile, it has been demonstrated that the judicious use of N and P fertilizers can bring about substantial yield increases in West Africa (Mokwunye and Vlek, 1986; Pieri, 1989; Van Reuler and Janssen, 1989; Van der Heide, 1989; Federal Ministry of Agriculture and Natural Resources, Nigeria, 1990; Vlek, 1990; Mokwunye, 1991; Bationo and Mokwunye, 1991; Wong et al., 1991; Sédogo, 1993; Delvaux et al., 1993; Van Reuler and Prins, 1993). Positive responses to K, S, Ca, and Mg have also, though less frequently, been observed. Responses to micronutrients were reported in the EFZ, for example, by Maduakor (1991) in Nigeria and by Rhodes and Nangju (1979) in Sierra Leone.

When farmers procure and use fertilizers, their primary goal is increased yield for that particular growing season. Fertilizers are thus not applied to build soil fertility. However, applying fertilizers could mean that (a) farmers get higher yields from the plots where the fertilizers have been applied, (b) increased biomass production protects the soil surface and may contribute somewhat to soil organic matter, (c) there is an increase in area left to recuperate (fallow) as the desired production has been realized on the fertilized plot, and (d) part of the fertilizer remains in the soil and contributes to soil fertility buildup. There are also some negative effects that may include (a) excessive application of certain types of fertilizer (urea and ammonium sulfate) may pollute the environment and cause soil acidification and (b) the application of nutrient A in the fertilizer could induce accelerated depletion of nutrients B and C, which are not included in the fertilizer because vigorously growing crops take up more nutrients than crops grown under low-input conditions. This is a point also strongly underlined by Schaber (1986) and a common problem in high-

Table 6.1 Nutrient Inputs and Outputs and Internal Flows at the Farm Level

Nutrient Inputs	
IN 1	Mineral fertilizers
IN 2	Organic inputs, subdivided into:
IN 2a	Concentrates for livestock and fish
IN 2b	Other organic feeds for livestock and fish
IN 2c	Urban and agro-industrial wastes
IN 2d	Manure obtained from outside the farm
IN 2e	Manure from farm livestock grazing outside the farm during part of the day
IN 2f	Food for the farm family obtained from outside the farm
IN 3	Atmospheric deposition in rain and dust
IN 4	Biological nitrogen fixation in leguminous species
IN 5	Sedimentation as a result of (i) irrigation, (ii) natural flooding, or (iii) partial resedimentation of soil materials eroded from upper slopes
IN 6	Subsoil exploitation by trees and other perennial crops
Nutrient Outputs	
OUT 1	Harvested crops, meat, milk, and fish, leaving the farm
OUT 2	Crop residues and manure leaving the farm
OUT 3	Leaching below the root zone
OUT 4	Gaseous losses (including denitrification, ammonia volatilization, and losses as a result of burning)
OUT 5	Runoff and erosion
OUT 6	Human feces ending up in deep pit latrines
Internal Flows	
FL 1	Crop residues fed to tethered farm animals or applied to certain plots
FL 2	Biomass from plots under pasture and fallow eaten by roaming farm animals
FL 3	Animal manure from within the farm applied to certain plots
FL 4	Crops, milk, meat, and fish obtained from the farm, eaten by the farm family
FL 5	Food remnants and farmyard manure applied to certain plots

Source: Smaling et al. (1996).

input rice and wheat production systems in, for example, China (Jiyun and Guilan, 1995). Table 6.3, which shows results from fertilizer trials in Kenya, clearly illustrates this point. The "only-P" treatment in the Nitisol increases N and K uptake, whereas the "only-N" treatment in the Vertisol increases P and K uptake. In West Africa, most fertilizers contain both N and P, but straight fertilizers such as SSP, TSP, and urea are also very common. Most fertilizers applied to cotton (Mali, Senegal, Burkina Faso, Benin, and Togo) contain a mixture of N, P, K, S, and even B.

Nutrients added in mineral fertilizers can follow three pathways:

A. They are taken up by the crop (or the tree in agroforestry systems).

B. They are lost through leaching, denitrification, erosion.

C. They stay in the soil.

The ideal situation is to maximize pathways A and C. For this to happen, there are many factors to be borne in mind. Blanket fertilizer applications, a very common practice throughout West Africa, often result in low fertilizer use efficiency. Type and amount of fertilizer must be a reflection of crop requirements, the soil's nutrient stocks, and the

Table 6.2 Restoring Soil Fertility in West Africa: Technical Options and Their Impact on Nutrient Flows Listed in Table 6.1

Technology	Fertility Effect (Table 6.1)	Adding/Saving
01. mineral (soluble) fertilizers		
- increased use	Increase of IN 1	Adding
- more efficient use	Reduction of OUT 3-5	Saving
02. mineral soil amendments		
- rock phosphates	Increase of IN 1 (P)	Adding
- lime and dolomites	Increase of pH, increase of IN 1 (Ca, Mg)	Adding
	More efficient use of P; reduction of OUT 5	Saving
03. organic inputs		
- from within the farm	Reduction of OUT 2	Saving
	Increased recycling FL 1,3,5+	Mainly saving
- from outside the farm	Increase of IN 2a-f+	Adding
04. improved land use systems		
- rotations, green manures	Increase of IN 4, reduction of OUT 2-5	Adding+saving
- fallows, woody species	Increase of IN 4,6, reduction of OUT 2-5	Adding+saving
05. soil and water conservation	Reduction of OUT 3-5	Saving
06. integrated nutrient management	Combination of IN 1-IN 5	Adding+saving

Source: Smaling et al. (1996).

Table 6.3 Yields and NPK Uptake of Maize on Three Kenyan Soils as a Function of Soil Type and Fertilizer Treatment (Long Rainy Season, 1990)

			Nutrient Uptake		
Soil	Treatment	Yield	N	P	K
		(tonne/ha)	----	(kg/ha)	---
Nitisol	$N_0 P_0$	2.1	42	5	30
(red,	$N_{50} P_0$	2.3	50	6	36
clayey)	$N_0 P_{22}$	4.9	79	12	58
Vertisol	$N_0 P_0$	4.5	63	24	95
(black,	$N_{50} P_0$	6.3	109	35	126
clayey)	$N_0 P_{22}$	4.7	70	23	106
Arenosol	$N_0 P_0$	2.5	38	7	42
(brown,	$N_{50} P_0$	2.2	45	7	47
sandy)	$N_0 P_{22}$	2.3	38	11	68
	$N_{50} P_{22}$	3.7	66	16	77

Note: N – kg/ha as CAN.
P – kg/ha as TSP.

Source: Smaling et al. (1996).

fraction of the fertilizer that is in plant-available form, which differs largely at all spatial scales, as was shown in Chapter 3. Nutrient imbalance is a major cause of low fertilizer use efficiency. There is little benefit from adding N to a soil with a low P/N ratio because P will continue to limit the yield of the crop and the added N will be wasted (i.e., follow pathway B). Increased efficiency is economically attractive and creates a "win-win" situation for importing governments, traders, farmers, and the environment. Table 6.3 clearly shows how maize responded differently to N and P fertilizers, depending on the native soil fertility (the nutrient stocks). On the P-poor Nitisol, maize responded vigorously to P in TSP but not to N in CAN. For the relatively N-poor Vertisol, the reverse was true. Other (but labor-intensive) means of increasing fertilizer use efficiency are split application, which attempts to synchronize nutrient availability with crop demand, and placement in order to put the nutrient where it is more likely to be recovered by the crop.

Rainfall characteristics largely determine the efficiency with which fertilizers can be used, particularly mobile nutrients such as N. Dry periods during the growing season may result in low fertilizer use efficiency, which further increases drought stress in the improved genotypes. Studies with labeled nitrogen have shown that uptake efficiency of N in the SSZ is low (Christianson et al., 1990). Penning de Vries and Djiteye (1982), however, found relatively high N and P efficiency in the Sahel and the SSZ. In the wetter agroecological zones containing highly permeable Ferralsols (Chapter 2.2.1), low efficiencies occur as a result of leaching. For the acid soils in the EFZ and the GSZ, continuous application of mineral fertilizers such as urea and ammonium sulfate may cause soils to reach toxic levels of soluble aluminum. Foodcrops like maize and rice, especially the improved genotypes, are more responsive to fertilizers than the small grains (millet, sorghum) and the tuber crops (yam, cassava). An important setback, however, is that improved cultivars produce fewer crop residues, which is an important product for systems that include livestock. This is especially true for the small grains in the Sudan Savanna and the Sahel.

6.3 Mineral Soil Amendments

6.3.1 Phosphate Rock

Previous research on West African phosphate rocks (PR) has focused on their suitability for direct application as an alternative to costly, soluble P fertilizers (Gerner and Mokwunye, 1995). The potential of PR lies in the fact that it (a) redresses P deficiency, (b) has a strong residual effect, and (c) does not acidify the soil. The agronomic effectiveness of PR depends on its chemical and mineralogical composition and on soil and plant factors. Several West African PRs have been successfully tested in field trials: Tahoua PR and PARC-W PR from Niger, Tilemsi PR from Mali, Kodjari PR from Burkina Faso, and Hahotoe PR from Togo (Bationo et al., 1992; Bationo et al., 1995; SAFGRAD Annual Reports; Sédogo et al., 1991). The results showed that Tilemsi PR and Tahoua PR could be viable alternatives to soluble, imported fertilizers. Research by IFDC and several collaborating national institutions has shown that partial acidulation of low-reactivity PRs such as Kodjari PR results in improved performance (Bationo et al., 1986; WAFMEN Progress Reports). The results also showed that the PRs can serve both a sustainability goal (restoring the P stock of West African soils) and a productivity goal (immediate yield increases).

Results from the West African trials formed part of the basis for the already described initiative on the use of phosphate rock as a capital investment for improving the P fertility of the soils. PR in this case is being used as a soil amendment rather than as a source of immediate supply of P for crops. With the application of PRs, the P stock in the soil (capital-P) will be increased which in the long run will increase the plant-available P (liquid-P). The underlying principle is that the direct application of PR, given the state of deforestation and land degradation, is an investment in the natural resource base, which is in the national interest (Teboh, 1995; Mokwunye, 1995).

Work at IFDC (Menon and Chien, 1989) has shown that compacting varying amounts of soluble P fertilizers with PR increases the agronomic effectiveness of the PR. This method of improving the performance of low-reactivity PRs and PRs that have high contents of iron and aluminum oxides is particularly appealing to countries in West Africa where the construction of standard phosphate fertilizer plants is not economically feasible. In countries having low annual fertilizer consumption rates, the relatively nonexpensive compaction units could be set up in strategic locations throughout the countries.

PRs seem destined to play a crucial role in upgrading the P stocks of West African soils. Farmers, however, are not yet impressed because of (a) the dusty character of the finely ground material, (b) the fact that the material only contains one macronutrient, and (c) its slow reactivity. Perhaps extension messages in the past have been too optimistic regarding the immediate reactivity of PRs. It should be noted that, except for the reactive ones such as the Tilemsi PR, most PRs are not substitutes for soluble P fertilizers. Partial acidulation and the compaction of soluble P fertilizers and PRs can resolve most of the concerns that farmers have at the moment. Extension messages to farmers should also emphasize that PRs can serve farmers' needs best under the following conditions: (a) they are applied in areas where P is the most limiting plant nutrient, (b) they are applied in areas with relatively high rainfall and rather acid soils, (c) they are applied to wetland rice either in irrigation schemes or in inland valley swamps, (d) they are mixed with organic matter, for example in microbiologically active compost pits (*Fr: fosses fumières*), and (e) they are applied to leguminous species, which are able to acidify their own rhizosphere by taking up N_2 instead of NO_3^- (Aguilar and Van Diest, 1981). The high residual effect of PRs has an important bearing on the agronomic and economic evaluation of PR use in West Africa. This is an area that has often been neglected since calculations are made on the basis of one season's production. Although PRs are most effective in wet soils, they have proved effective also in the drier zones of West Africa (Bationo et al., 1986). They may be especially useful for perennial crops and in reforestation efforts.

6.3.2 Lime and Dolomite

Lime and dolomite deposits are found in many West African countries and are indispensable for correcting Al and Mn toxicity in acid soils, as was shown, among others, by Brams (1971) for Sierra Leone, IITA (1985) for Nigeria, and Jallah et al. (1991) for Liberia. In addition, they improve the Ca- and Mg-status of soils. Convincing examples of the dual effects of dolomite in continuous cultivation in Burkina Faso were given by Lompo (1993). Nonetheless, the use of lime at the farmers' level is negligible, whereas the extent of acidity problems in West Africa is worrisome. Liming materials are bulky and costly and involve extra labor for application. Usually, the effect of liming is rather short-lived (2-4 years). One encouraging phenomenon is the use of granulated dolomite as filler in some bulk blends in Nigeria. The amount of dolomite is supposed to be sufficient to neutralize the acidity produced by the fertilizer.

6.4 Organic Inputs

Organic sources of plant nutrients (so-called organic fertilizers) may originate from the farm itself (crop residues, farm livestock manure) and, thus, provide a basis for a nutrient-saving technology, or they can be obtained from other sectors or from products manufactured elsewhere, and as such they provide a basis for a nutrient-adding technology. The major constraint regarding the use of organic inputs is their bulkiness since large quantities are often required to provide even a fraction of what would be needed to maintain agricultural production at a desirable level. Besides, there is a common misunderstanding that adding organic inputs to tropical soils will easily raise soil organic matter levels. This is only true if large quantities are continuously applied (De Ridder and Van Keulen, 1990). On the other hand, the role of organic materials in maintaining the physical and biological characteristics of the soil is often undervalued.

6.4.1 Crop Residues: To Burn, to Incorporate, or to Use as Mulch?

The direct or indirect return of crop residues to the soil aids in maintaining the nutrient balance. This holds true, especially for K, which is relatively abundant in the residues of most crops. The impact of crop residues on soil fertility depends on the way they are managed (e.g., burning, mulching, incorporation), and their quality (C/N and C/P ratios, content of lignin and polyphenols; Tian et al., 1995). It is important to realize that the quality and nutritive value of residues is, in the first place, a reflection of the nutrient stocks of the soil that produced them! Incorporating crop residues with a high C/N and C/P ratio such as maize or rice stover causes initial immobilization of N and P. Smith et al. (1990) estimate 1.2% N as a threshold value below which N immobilization takes place as a result of the addition of residues. Nguu (1987) found, on an Acrisol in Cameroon, that burning of crop residues (4 t ha^{-1}) and weeds outyielded treatments in which crop residues were used as a mulch (2.7 vs. 2.3 t ha^{-1}). The practice of burning, however, can lead to invasion by *Imperata cylindrica*, which is hard to eradicate (Kang et al., 1990). Other field trials in the EFZ have shown that crop residues applied as a surface mulch protect the soil and improve crop yields (Kamara, 1988). Application of an N budget model in southern Ghana has shown that annual surface application of maize crop residues (one crop per year) significantly reduced degradation of labile soil organic nitrogen (Rhodes, 1995). A farm survey conducted by IFDC (Baanante et al., 1992) showed that as much as 70% of crop residues produced by farmers in a village in the Ashanti region of Ghana served no useful agricultural purpose. Substantial amounts of residues are merely discarded or burned in the traditional system of land preparation. Systems based on no-tillage and residue mulches are effective in soil fertility restoration but have not been widely adopted because of weed control needs (Greenland et al., 1994).

Crop residues in the traditional systems in the SSZ are first used to meet the needs for fuel, animal feed, housing and fencing. Whatever remains on the surface is used as mulch or burned on the field as a source of nutrient. Materials that are used for cooking, fencing and roofing eventually return to the compound farm (Bationo et al., 1993). Annual burning of fields and fallow in the dry season is a common practice in the SSZ. In the absence of farm power, burning is the only way to clear the land for cultivation by hoe (Balasubramanian and Nnadi, 1980). Different negative effects of burning are (a) the considerable loss of carbon and nutrients; Charreau and Poulain (1964) estimated losses in the order of 20-40 kg/ha of N and 5-10 kg/ha of S annually; (b) the physical and biochemical deterioration of the soil; and (c) considerable contribution of the practice (in the form of CO_2) to the so-called greenhouse effect. Positive though short-lived effects of burning are the increase in pH and the immediate release of nutrients such as K and Ca to crops from the ashes.

6.4.2 Animal Manure From the Farm

In EFZ farming systems, livestock is not very common, and animal manure is not generally valued as a source of nutrients. Stocking rates in the GSZ are higher, as animal diseases become less menacing. In the SSZ, however, use of animal manure is an integral component of soil fertility management. Low rural income, low use of mineral fertilizers, and the relatively high numbers of livestock in the region turn animal manure into a principal source of nutrients (Penning de Vries and Djiteye, 1982; Breman and Niangado, 1994). A survey by McIntire et al. (1992) revealed that in on-station research applied quantities of manure were of the order of 2.5 to 20 tonnes/ha, whereas farmers' actual application levels ranged from 175 to 700 kg/ha. There is simply not enough manure to sustain crop yields at even the current levels found in farmers' fields, a problem that is particularly pronounced in post-drought years (Williams et al., 1995). The only crops receiving high levels of manure are those grown in the *champs de case* (Pouzet, 1991; Prudencio, 1993).

Manure application to cropland takes several forms. Farmers can corral their animals overnight on fields during the dry season, or they can gather manure from stalls, transport, and handspread it on fields. Corralling returns both manure and urine to soils and results in greater crop yields than when only manure is applied. Corralling also requires no labor for manure handling, storage, and spreading. Since 40%-60% of the N excreted by ruminants is in the form of urine, the potential for nutrient loss is greater when animals are kept in stalls since only manure can be collected and spread on cropland (Powell and Williams, 1994). Urine can however be "harvested" if crop residues with a high C/N ratio are used as bedding in stalls and kraals. Microbes will rapidly fix the nitrogen and, thus, enrich the bedding as a future organic manure.

6.4.3 Organic Inputs Obtained From Outside the Farm

In general, in West Africa, the use of organic wastes and agro-industrial byproducts has slowly increased over the last few years. An IFDC study in Ghana (Owusu-Bennoah and Visker, 1993) and a study by INERA in Burkina Faso (Sédogo et al., unpublished) reported a range of products from municipal wastes, breweries, timber industry, juice factory, cocoa company, and slaughterhouses, which were potentially available as organic inputs in agriculture. At the time of the Ghana study, these products were primarily sold as animal feed. A preliminary estimate indicated that the nutrient contents are low (5.0%-8.1% N, 0.1%-0.9% P, 0.3%-2.0 % K), and that they are more costly per kilogram of nutrient than imported commercial fertilizers. There is limited information on the response of crops to the agro-industrial byproducts and wastes in field trials. The use of off-farm organic inputs is governed by three major factors; a discussion of these follows.

- Transport and labor costs. The shorter the distance between source and the field, the more profitable the enterprise will be (Matlon and Fafchamps, 1988; Owusu-Bennoah and Visker, 1993), which largely restricts their economic use to the peri-urban agricultural sector. Organic materials are not only more bulky but are also less concentrated than mineral fertilizers. Composting of organic materials in town may alleviate this constraint because the volume is reduced with a relative increase in the hygienic and nutritive value.

- Competitive uses. In the IFDC Ghana study, agro-industrial byproducts (fishmeal, wheat bran, spent grain, cocoa shells, copra and groundnut cake) were sold as animal feed on the national and international markets (Owusu-Bennoah and Visker, 1993).
- Difficulties in collection. Failure to corral animals in the dry AEZs results in the droppings not effectively being used in arable farms (Bationo and Mokwunye, 1991). Alternatives in the Sahel, such as paying herders to corral their cattle on given fields during the dry season, markedly increased the efficiency of the manure use (Geiger et al., 1992). Exchanges in benefits between sedentary farmers and pastoralists involving crop residue for the animals and manure for the fields are common throughout West Africa, with the exception of the EFZ (Bernus, 1974; Bernardet, 1984; McIntire et al., 1992). These practices, however, appear to be declining in many areas due to sedentarization of pastoralists, shift of cattle ownership to nonpastoralists, and increasing conflicts between pastoralists and farmers over land rights.

6.5 Improved Land Use Systems

6.5.1 Rotating and Intercropping

Intercropping of cereals and grain legumes is often mentioned as having many advantages over monocultures. It should be pointed out, however, that the N input by biological fixation from most tropical intercropping systems is low. Ofori and Stern (1987) reviewed numerous experiments in which sole cropping and intercropping were compared. The leguminous crops (mainly *Phaseolus* beans, cowpea, soybean, groundnut), grown in association with maize and sorghum, had yields of 1000-2500 kg ha^{-1} when sole cropped, but this decreased by 50% (80% in the case of soybean) when grown in association. Cereal crop yields declined to a much lesser extent. In Kenya, maize (long rains) grown in sequence with beans (short rains) outyielded intercropping systems (Nadar and Faught, 1984). The traditional advantages of intercropping can definitely be improved by the use of fertilizers and other inputs. One obvious drawback to intercropping is that one crop always seems to benefit more from the particular season's conditions. For example, in maize/bean association, beans are smothered during good rainfall years, while maize performs poorly during low rainfall years. In other words, intensification of agriculture requires new systems rather than adjustment of existing systems.

Groundnut and cowpea are the most widely grown grain legumes in the Sahel and the SSZ. These legumes are often intercropped with pearl millet in the Sahel and with sorghum in the SSZ. Rotating cereals with legumes, however, is not practiced. Bationo et al. (1994) showed the beneficial effects of cereal-legume rotations in Niger (Figure 6.1). In these fragile ecosystems, continuous

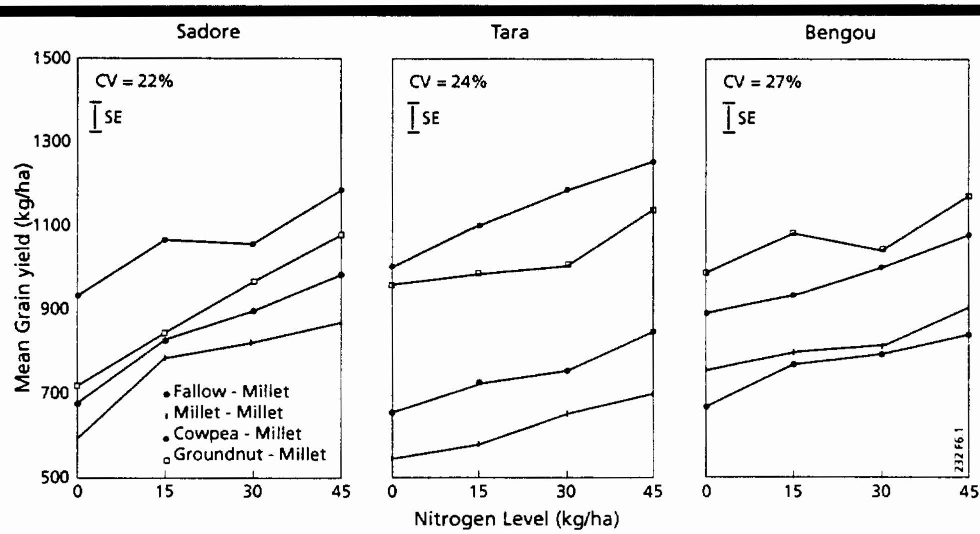

Figure 6.1 Effect of N and Cropping Systems on Pearl Millet Grain Yield at Sadore, Tara and Bengou, Niger, Rainy Seasons of 1989-92 (Source: Bationo et al., 1994).

cropping of pearl millet resulted in lower yields across all N rates, whereas millet-cowpea and millet-groundnut associations performed markedly better. In northern Nigeria, Lombin (1986) reported similar beneficial effects of cereal-legume rotations (Figure 6.2). The positive effect of rotating on cereal yields has been attributed to both the biologically fixed N from the legumes, improvements in soil biological and physical properties (Hooshikawa, 1990), and the ability of some legumes to produce exudates that can solubilize occluded P and highly insoluble calcium-bound phosphorus (Gardner et al., 1981; Ae et al., 1989). Other advantages of crop rotation include soil erosion control (Stracy and Jones, 1985), organic matter restoration (Surgeon and Grisson, 1985), and pest and disease control (Curl, 1963; Sinnadurai, 1973). Benefits of associations involving cotton-maize, groundnut-sorghum, and cowpea-millet rotations have been discussed by Cattan and Schilling (1990).

6.5.2 Green Manures, Cover Crops

In contrast to the economic role of grain legumes, a green manure legume is grown wholly for use as a source of organic manure for a subsequent crop.

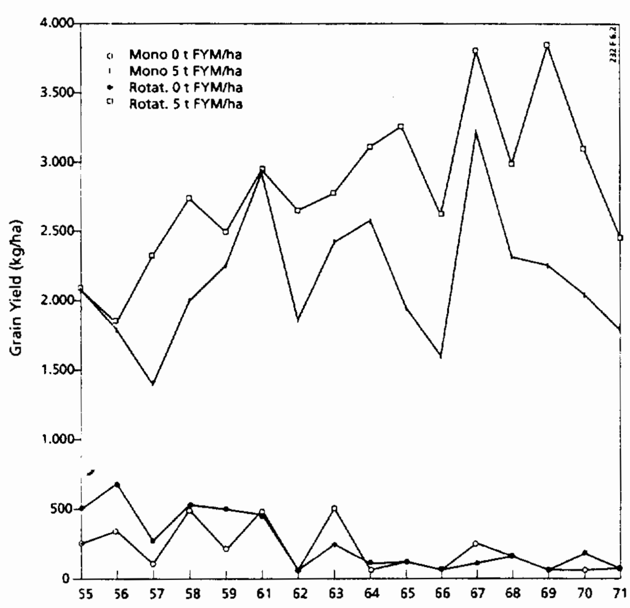

Figure 6.2 The Long-Term Impact of Crop Residues and Farmyard Manure on Sorghum Grain Yields in Northern Nigeria, 1955-71 (Source: Lombin, 1986).

This obviously maximizes the amount of N from the legume available for the next crop. Green manure legumes usually contain adequate N to promote mineralization shortly after soil incorporation. Examples are *Crotolaria*, *Mucuna* and *Sesbania* species, where research has indicated that over 100 kg N ha^{-1} was accumulated in the above-ground plant parts under favorable soil and climatic conditions (Giller and Wilson, 1991). It is unusual for farmers to adopt green manures solely for their beneficial effects on soil fertility. However, where other benefits such as suppression of weeds, reduction of the incidence of pests, and erosion control can be identified, farmers have enthusiastically adopted the practice of planting green manures. Juo and Kang (1989) assessed the performance of *Mucuna utilis* and *Pueraria phaseoloides* (kudzu) as green manures in rotation with maize and found that maize yields were maintained at 2-3 t ha^{-1} over at least 10 years without fertilizer application. *Mucuna* grew faster and produced better ground cover than *Pueraria*, which, however, had the best nodulation in acid soils. *Pueraria*'s annual biomass contained 62 kg N/ha at IITA's high rainfall station at Onne (Hairiah and Van Noordwijk, 1989). Van der Heide (1988) showed that inclusion of *Mucuna* or *Stylosanthes* in cropping systems involving cassava or maize in the EFZ increased organic matter content and the soil N stocks.

6.5.3 Azolla

Good responses by wetland rice to the incorporation of *Azolla* have been reported in several West African countries (Esiobu and Van Hove, 1992). WARDA (1981) showed in Sierra Leone that incorporation of *Azolla* applied at fairly sizable rates (up to 34 t/ha) gave rice yields comparable to those obtained by application of urea at 40 kg N/ha. Problems associated with the use of *Azolla* in small farms in West Africa include poor water control and cultural practices that are not ideal to support the use of *Azolla*, e.g., direct sowing of seeds, prevention of P deficiency, and insect attacks. Moreover, there is a labor constraint, given the vast amounts needed. Of equal importance is the fact that many farmers are not even aware of the value of *Azolla*.

6.5.4 Agroforestry and Related Systems

Agroforestry is a collective name for land use systems in which woody perennials are grown in association with crops or pasture in a spatial arrangement, a rotation or both, and in which there are both ecological and economic interactions between the tree and non-tree components of the system. Interest has grown in the development and use of more productive land use technologies involving agroforestry systems (Steppler and Nair, 1987). In addition to numerous NGOs that deal with tree growing, three centers belonging to the Consultative Group on International Agricultural Research (CGIAR) located in sub-Saharan Africa – IITA (Nigeria), ICRAF (Kenya), and ILRI (Ethiopia) – work on agroforestry. Two agroforestry technologies are alley cropping for food production and alley farming for both food and animal production (Kang et al., 1990). Alley cropping was considered a promising technology in the EFZ and parts of the GSZ. Fedden (1988) promoted the system as "forest farm husbandry" for Ghana. There is substantial evidence from on-station trials at IITA in southern Nigeria that alley cropping can be beneficial to soils and crops (Kang et al., 1990). As much as 30% of the N required by the crop can come from the leguminous hedgerow trees (Kang and Mulongoy, 1992). The applicability of this technology to the acidic Ultisols and Oxisols of the EFZ requires further investigation.

Agroforestry systems perform best on nonacid soils in the EFZ, and appropriate species are being selected for specific locations. Initial data suggest that under acid conditions, species such as *Acioa barterii*, *Cassia siamea*, *Fleminga congesta*, and *Gliricidia sepium* are suitable for alley cropping (Karim, 1987; Kang et al., 1990). Amara and Mansaray (1989) selected fast-growing leguminous and nonleguminous shrubs/trees that reached heights of 2 - 4 m, produced 7 - 42 t/ha of biomass, and yielded 4 - 24 t/ha of fodder in Sierra Leone. *Enterolobum cyclocarpum*, *Albizia lebbek*, and *Gliricidia sepium* combined fast growth with nodulation and high N_2 fixation. Reports on voluntary adoption of planted fallows of *Acioa barteri*, *Anthonotha macrophylla*, and *Alchornea cordifolia* in eastern Nigeria attest to the potential for adoption of this technology (Benneh, 1972; Okigbo and Lal, 1979). This potential, however, has yet to be realized (Francis and Atta-Krah, 1989; Kerkhof, 1990).

In the nonacid Alfisols of the Guinea Savannas, *Leucaena leucocephala* reportedly fixes 75-200 kg N ha^{-1} and produces up to 40 t ha^{-1} of fresh green manure, depending on interrow spacing and number of cuttings (Sanginga et al., 1989; Juo and Kang, 1989; Kang et al., 1990). Kang et al. (1981) showed that *Leucaena* prunings, when incorporated, increased maize yield more than when applied as a mulch. Annual N yield from five prunings of *Gliricidia* and *Leucaena* hedgerows in Nigeria was 170-250 kg ha^{-1}, as opposed to 40-85 kg ha^{-1} in the nonleguminous species *Acioa barterii* and *Alchornea cordifolia* (Kang et al., 1990). Large yields of biomass from *Gliricidia* prunings (7.6 t/ha to 24 t/ha) and N yields (285 kg/ha to 879 kg/ha) were also reported in Sierra Leone; the range depends on alley width and within-row spacing (Karim et al., 1993). Applications of prunings of *Gliricidia* as a surface mulch (20 t/ha) to an Oxisol in Sierra Leone resulted in significant increases in total soil N and soil moisture conservation (Karim, 1987).

Research on agroforestry in the drier zones (preferably referred to these days as agro-silvo-pastoralism) has shown less promising results. Recently, Breman and Kessler (1995) undertook the quantification of N and P balances for agroforestry-based systems in the Sahel and the SSZ. They conclude that competition for water and light is highly constraining. The success of the system largely depends on soil and climatic conditions and farm management. A viable option seems to be the combination of trees with increased use of fertilizer. Valet (1985) reported that barrier hedges in Sine Saloum, Senegal, sharply reduced water and wind erosion. In the Maggia valley of Niger, windbreaks have been shown to improve pearl millet yield by 15% by diminishing wind erosion and shading plants from winds (Dennison, 1986). In the Integrated Rural Development Project of Keita, Niger, Grall (1986) and Carucci and Cupers (1986) reported significant positive effects of windbreaks on crop yield although the sustainability was doubtful (Pretty, 1995). Michels (1994) reported a significant sand flux reduction by different types of windbreaks within a 10-m distance from the windbreaks and an increase of organic carbon and total N in the topsoil at a distance of 1 m from the windbreak as compared with the control plot.

Initial high expectations from integrating N-fixing trees into agro-silvo-pastoral systems and in particular alley cropping systems have recently been tempered by the result from several different researchers (Lal, 1991; Breman and Kessler, 1995; Sanchez, 1995). Although trees can potentially provide building poles, fuelwood, fodder, fruits, shade, etc., competition for light, water and nutrients with other system components can be stiff. Nonetheless, agroforestry can really be of economic interest to a farmer. As to the nutrient budget, agroforestry systems may increase biological N fixation (*IN 4*), reduce leaching (*OUT 3*), and add nutrients to the topsoil from layers not accessible to the roots of annual crops (*IN 6*). The main advantage of agroforestry and related systems and the only one that has continuously passed every test is the role in curbing runoff and water and wind erosion (*OUT 5*; Young, 1989; Kiepe, 1995; Sanchez, 1995).

6.5.5 Fodderbanks and Improved Pastures/Fallows

In the Northern GSZ, the introduction of forage legumes (e.g. *Stylosanthes spp.*) into the traditional farming and livestock husbandry systems has been investigated by ILRI staff. The initial idea was to provide supplementary feed for ruminants. Fodderbanks, if adequately supplied with phosphorus, also accumulate nitrogen that becomes gradually available to subsequent crops (Maina, 1994). In on-farm trials conducted inside and outside pastoralist-owned and managed *Stylosanthes* fodderbanks, Tarawali et al. (1992) reported that yield of maize planted in the fodderbanks nearly doubled that on natural fallow at different N fertilizer levels (0, 60, 120 kg N/ha).

Penning de Vries and Djiteye (1982) have studied the possibilities of improving the productivity of pastures in the Sahel and SSZ. Recently, Coulibaly (1995) compared improved pastures and fodderbanks and concluded that fodderbanks can do well even in the northern parts of the Sahel, whereas the scope for improved grazing grounds did not reach further than the southern SSZ.

The beneficial effects of fallow systems are closely linked to their effects on soil organic matter levels. Fallows can sustain a level of soil organic matter, relative to that of a virgin forest, ranging from 60% in the SSZ (Hoefsloot et al., 1993) to 75% in the EFZ (Nye and Greenland, 1960; Aweto, 1981). The accumulation of the organic matter in fallow systems greatly depends on the root biomass. Young (1989) estimated that a land use system in the humid tropics must add biomass in the order of 8 tonnes of dry matter per hectare per year to maintain soil organic matter. If improved fallows are to have a chance on degraded land, they may have to be fenced off from animals. This, however, does not appear to be a very feasible option. Under controlled (project) conditions, however, regrowth on virtually bare, overstocked land in the southern SSZ near Koutiala, Mali, was spectacular (Vlaar, pers. comm.). Ohler (1985) described improved fallow systems in Mali and concluded that with good management 30%-50% of farmers' fuelwood consumption can be supplied by their fallows. He underscored the need to replicate the functions of fallows in modernized farming systems.

Hermann et al. (1995) studied eolian activity and dust transport processes in West Africa. The nutrients deposited by dust and rain are likely to remain in the fallow areas, whereas in cropland, they are more likely to be retranslocated by wind and water erosion.

6.6 Soil Conservation

Deforestation and burning, permanent cropping and overstocking are all important contributors to the high runoff and erosion problems in West Africa. Oldeman et al. (1990) estimated that 72% of the African arable soils and 31% of pasturelands have been degraded as a result of soil erosion.

Roose (1989) reviewed the results of 30 years of research at ORSTOM and CIRAD on water and soil conservation in the SSZ of West Africa and concluded that the major factors involved in curbing erosion are slope management, cultural practices, and vegetative cover. Unfortunately, quantitative data on runoff and erosion were largely obtained from miniplot research. Only occasionally (Breman and De Ridder, 1991) have such results been properly extrapolated to entire catchment areas and river basins. Moreover, the erosion factor in the continental nutrient balance study (*OUT 5* in Figure 3.3; Stoorvogel et al., 1993) proved to be both high and highly sensitive in terms of the output of the balance model. Unraveling the real impact of erosion and soil conservation measures on the nutrient budget in different land use/catchment area combinations is crucial. Such an attempt was made for southern Mali by Bah (1992). Table 6.4 provides a glance at other researchers' findings on runoff and erosion rates in the region as a function of rainfall, slope gradient, and land use.

In the SSZ of West Africa the prominent soil and water conservation techniques include the making of stone bunds on slopes, contour stone bunds, stone terraces, stone lines, earth bunds, and planting pits (Savonnet, 1976; Reij, 1983; Roose, 1990). Currently, in parts of Burkina Faso, Mali, and Niger traditional stone lines and planting pits are increasingly used to rehabilitate degraded land; technologies derived from indigenous knowledge are used. Impressive results have been obtained in the Yatenga area in Burkina Faso where Vlaar and Wesselink (1990) reported a sorghum yield increase of up to 1,500 kg/ha because of the use of permeable rock dams. Biological means of reducing erosion are contour-planted trees and fodder grasses and the application of trash lines of surface mulch and weeds. Research results with respect to tillage as a means of enhancing water infiltration show large differences. Whereas minimum tillage is advocated in the EFZ (Lal, 1991), it seems that soil tillage does reduce erosion in the drier zones as it enhances water infiltration into the soil profile (Nicou and Charreau, 1985). The effect of tillage is greater in soils with surface sealing or crusting, such as those at the Kamboinse research station near Ouagadougou (SAFGRAD, Annual Reports). Using all tillage methods at Saria and Kamboinse research stations (Rodriguez, 1987), researchers received high responses to tied ridges. Figure 6.3 shows that high maize grain yield

Table 6.4 Runoff and Soil Loss Data for Selected Locations in West Africa (Collated by E. R. Rhodes)

Country	Location	Mean Annual Rainfall (mm)	Slope (%)	Treatments	Runoff (%)	Soil Loss (tonnes/ha/year)
Benin	Boukombe	875	3.7	Millet Conventional Village	11.7	1
Niger	Allokoto	452	3	Sorghum, Cotton	16.3	8
Nigeria	Samaru	1,062	0.3	Bare Soil	25.2	3
	Ibadan	1,197	15	Bare Soil	41.9	229
				Maize-Maize	13.5	40
				Maize-Cowpea	2.6	0
				Cowpea-Maize	1.7	4
Senegal	Sefa	1,300	1.2	Bare Soil	39.5	21
		1,241	1.2	Groundnut	22.8	69
		1,113	1.2	Sorghum	34.1	83
Burkina Faso	Ouagadougou	850	0.5	Bare Soil	40.6	10.2
				Crop	2.32	0.6
				Forest	2.5	0.1
Côte d'Ivoire	Bouake	1,200	0.3	Bare Soil	15.3	18.3
	Abidjan	2,100	7.0	Bare Soil	38.0	108.2
Mali	Niono		1.3	Millet	25.0	NA
Niger	Sadore	560		Millet	1.5	NA
				Bare Soil	0.2	NA
Sierra Leone	Mebai	2,000		Unfertilized Maize		11
Sierra Leone	Mabai	2,000		Fertilized Maize		8

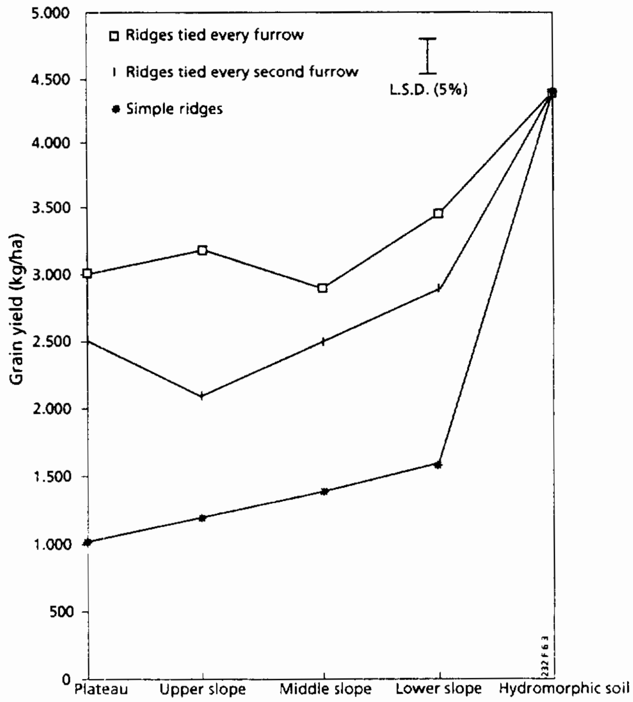

Figure 6.3 The Effect of Crop Position Along the Toposequence and of Tied Ridges on the Grain Yield of Maize on the Mossi Plateau of Burkina Faso, 1981 (Source: Rodriguez, 1987).

responses to tied ridges were found in all positions along the toposequence at the Kamboinse station, except for the bottomlands. Klaij and Hoogmoed (1989), in Niger, found that ridging increased seedling survival rates for pearl millet. Ridging effectively reduced wind erosion.

6.7 Integrated Nutrient Management (INM)

6.7.1 Combining Technologies Means Creating a Win-Win Situation

So far, different technologies have been discussed in isolation. Experience has shown, however, that the most rewarding experiences occur when different technologies are combined. Such is the case for instance, when mineral fertilizers (*IN 1*) are combined with manure (*IN 2*). Because the nutrients in manure are released slowly, it is possible to avoid losses by synchronizing the release of nutrients with momentary crop nutrient demand by manipulating the rate, quality, timing, and placement of organic inputs. Moreover, addition of the organic inputs can increase fertilizer use efficiency because fertilizer nutrients can complement nutrients released from organic sources (Mokwunye, 1980; Sanginga et al., 1989; Lompo, 1993; Woomer and Swift, 1994; Dudal and Roy, 1995). Moreover, acidification risk is reduced, and nutrients not present in the fertilizer are supplemented by those present in the manure (De Ridder and Van Keulen, 1990). Also, applying fertilizers to crops on the lower parts of terraced fields that have good water management, combines inputs (*IN 1*) with relatively good water and organic matter conditions that control erosion (*OUT 5*; Van Driel and Vlaar, 1991). In other words, integrated nutrient management (INM) is not the sheer combination of techniques; it is a quest for win-win situations that involve both low and higher-external capital and labor input technologies. It should be borne in mind that each tract of land has its own "niche," i.e., its own agroecological potentials and limitations; consequently, the number of INM options needed to build productive and sustainable farming systems is highly location-specific. Some examples of INM systems in West Africa are given by Reijntjes et al. (1992).

Many authors have indicated that the application of high amounts of mineral fertilizers alone cannot redress nutrient depletion. Perhaps the most striking beneficial effects of fertilizers, lime, and organic manure on maize yield were those demonstrated by Fore and Okigbo (1974) on an Acrisol in southeastern Nigeria. With 0.8% organic carbon and a pH of 4.6, control yield was a mere 116 kg/ha. Application of N, P, K, and Mg in fertilizers increased yields to 2,214 kg/ha; adding lime raised yields to 4,037 kg/ha; and again adding manure gave a bumper harvest of 7,086 kg/ha. Jones (1971) in Samaru, Nigeria, found that, in the absence of fertilizers, it required at least the application of 7.5 tonnes/ha of manure to measure an increase in soil C and N. When fertilizers were added, the manure rate dropped to 5 tonnes/ha. In the EFZ conditions of Sierra Leone, Rhodes (unpublished data) demonstrated on recently cleared land that with minimum tillage and with annual applications of N, P, K, Ca, and Zn in the form of fertilizers and restitution of crop residue, maize yields were initially high but dropped from 3.9 tonnes/ha to 3.4 tonnes/ha in 7 consecutive seasons over 4 years. Soil organic matter was maintained, available soil P was increased, but soil acidity also increased. Similar results were reported by Mahapatra et al. (1980) at the Rice Research Station Rokupr. With the use of fertilizers and lime, Ultisols and Oxisols at Kwadaso, Ghana, have been shown to produce good crop yields at least for several seasons without irreparable damage to the soils in research station trials (Greenland, 1992). Yields of 2 tonnes/ha were obtained after 27 years of annual application of 30 kg P/ha as SSP and 25 kg K/ha as KCl. Okafor and Fernandes (1987) have described the "compound farm" found in southeastern Nigeria and characterized by multipurpose woody species in multistoried associations with annual crops and small ruminants. The soil is almost completely covered by plant canopies and is thereby conserved; its fertility is maintained by the addition of household refuse, crop residues, and animal manures. The system is a potentially sustainable form of land use with potential application for the entire EFZ. For Senegal, Diop and Sands (1995) described sustainable farming systems in the *Basin Arachide* in cases where farmers used both phosphate rocks and off-farm organic inputs in cereal-legume rotations.

6.7.2 Long-Term Experimentation Shows That INM Can Succeed

In the United Kingdom, the famous Rothamsted long-term experiments showed that grain yields can be sustained (and even increased) for almost 150 years in monocultures of wheat and barley with annual applications of organic and inorganic fertilizer. One of the most useful features of the Rothamsted trials (and of long-term trials in general) is that they enable us to follow the effects of soil and crop management on soil organic matter level over long spans of time. It was, for example, found that long-continued use of inorganic fertilizer containing N, P, K, and Mg increased soil organic matter level, but the increase was much less than that caused by farmyard manure (Jenkinson, 1991; Leigh and Johnston, 1994).

In West Africa, only few long-term data sets are available. At IITA, Kang and Balasubramanian (1990) reported that yield of maize that was fertilized dropped over 12 years of continuous cropping but never fell below 4 tonnes/ha. In the absence of fertilizers, however, yields dropped to 2 tonnes/ha. Pichot et al. (1981) reported on 20 years of continuous trials on sorghum near Saria, Burkina Faso, and found that manure in combination with small fertilizer applications improved the soil as opposed to heavy fertilizer doses alone or the mere application of crop residues. Chabalier (1986) at Bouake, Côte d'Ivoire, found that even high levels of compost, applied during 11 years, were not enough to maintain long-term fertility. Many results of relatively long-term soil fertility experiments in West Africa have been summarized by Pieri (1989).

Table 6.5 summarizes results of medium-term soil fertility management trials at IFDC's benchmark sites in Togo. Davié is situated in the coastal savanna region, and Koukombo is in the northern Guinea Savanna zone. The other sites are located in between these two extremes. Both N and P effects are very marked at all sites. Response to K was only observed in the coastal zone, which has the poorest soils. Response to S was only observed in the northern zone. Neither crop residues alone nor the application of 10 tonnes/ha of manure every 3 years could promote optimum maize growth. The highest yields were obtained where fertilizers were used in combination with organic inputs and lime.

Figures 6.4-6.6 summarize results of relatively long-term trials in different agroecological zones. Figure 6.4 shows response of pearl millet to different treatments in the northern SSZ of southwestern Niger (Bationo et al., 1994); Figure 6.5 presents the results of long-term sorghum trials in the southern SSZ of central Burkina Faso (Sédogo, 1993); and the results of the effect of nutrient inputs on maize in the EFZ of southwestern Nigeria (Juo and Kang, 1989) are presented in Figure 6.6. All examples show that although application of mineral fertilizers is an effective means of increasing yields in arable farming systems, mineral fertilizers alone cannot sustain crop yields in the long run. When mineral fertilizers are combined with other technologies, such as manure application and return of crop residues, productive and sustainable production systems can be developed.

Table 6.5 Average Maize Grain Yield After 3-6 Years of Soil Fertility Management Trials at Different Sites in Togo

	Davié	Amoutchou	Tchitchao	Kaboli	Koukombo	Mean
1. Control	1,842	2,129	1,009	1,414	1,656	1,510
2. TSP + N + K	3,272	3,815	1,712	3,204	3,857	3,172
3. N + K	2,529	2,696	1,353	2,095	2,823	2,319
4. SSP + K	3,024	2,523	1,344	2,703	2,535	2,426
5. Treatment 2 + Mg + Zn	3,432	3,844	2,327	3,535	3,515	3,331
6. SSP + N	2,340	3,631	2,150	4,418	4,062	3,320
7. SSP + N + K	3,514	3,971	2,576	4,015	4,748	3,765
8. Treatment 7 + lime (500 kg every 3 years)	3,255	4,096	2,400	4,022	5,195	3,794
9. Treatment 7 + Mg + Zn	3,502	4,207	2,251	4,329	5,159	3,880
10. Crop residue (CR)	1,830	2,610	1,482	1,648	2,426	1,999
11. ½ Treatment 7 + CR	3,042	3,547	1,997	3,348	4,162	3,139
12. Manure (10 t/ha) every 3 years	2,375	3,497	1,475	2,493	2,645	2,497
13. Treatment 9 + Lime	NA	4,377	2,513	4,651	4,483	4,006
14. Treatment 9 + CR	3,491	4,544	2,735	4,582	5,061	4,083
15. Treatment 14 + Manure + Lime	4,090	4,550	3,085	4,697	5,025	4,289

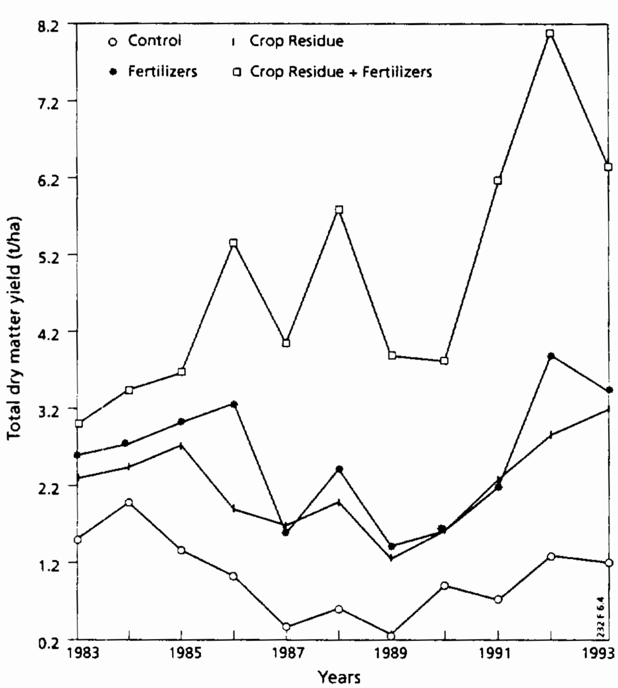

Figure 6.4 Pearl Millet Total Dry-Matter Yield as Affected by Different Management Practices Over Time (Source: Bationo et al., 1993).

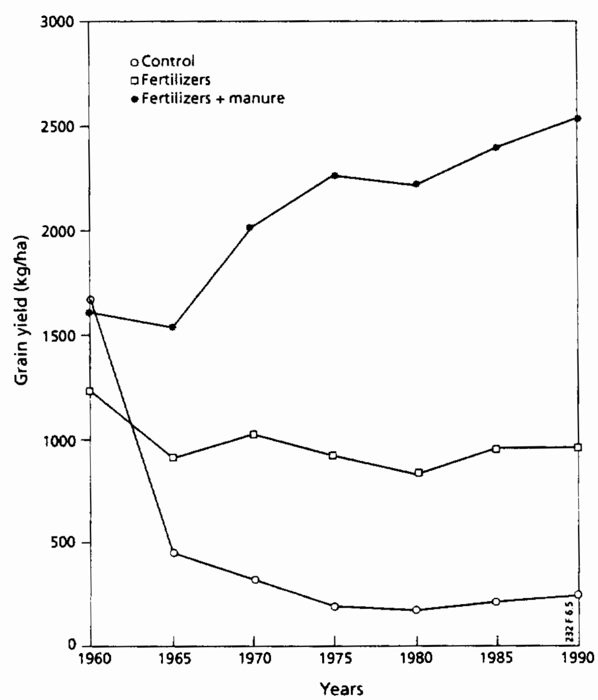

Figure 6.5 Sorghum Grain Yield as Affected by Mineral and Organic Fertilizers Over Time (Source: Sédogo, 1993).

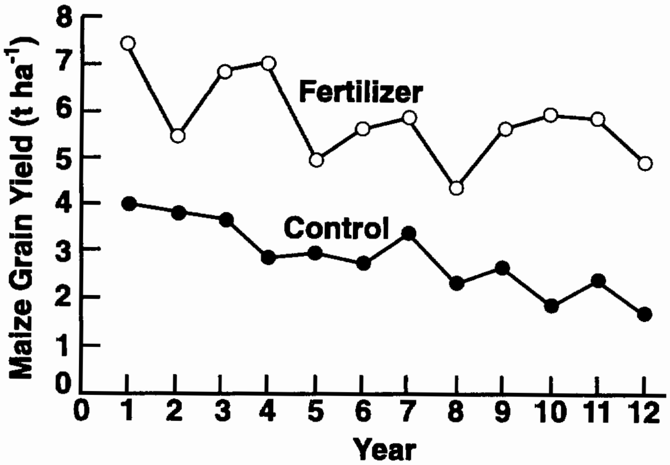

Figure 6.6 Effect of Nutrient Inputs on Maize Yield in a Maize-Cowpea Rotation on a Nigerian Alfisol. Relatively High Rates of N, P, K, S and Zn Were Applied to Each Maize Crop. Cowpea Received No Fertilizer (Source: Juo and Kang, 1989).

Technologies for Restoring Soil Fertility

To restore soil fertility, technologies that save nutrients from being lost from the agroecosystem are not sufficient; they need to be supplemented by technologies that add new nutrients to the agroecosystem.

When used judiciously, i.e., proper type, amount, and timing of application for the specific crop, soil, and climatic conditions, use of mineral fertilizers can result in considerable production increases without harming the environment.

The two major environmental risks of continuous fertilizer use in Africa are soil acidification and the accelerated depletion of nutrients that are not included in the fertilizer.

Farmers buy mineral fertilizers to achieve immediate production increases rather than to increase soil fertility.

In some West African countries, the use of local phosphate rock is a viable alternative to the use of expensive soluble imported P fertilizers. In general, PRs can serve both a production objective (increased P availability) and a sustainability objective (recapitalization of P stocks).

The use of phosphate rock is particularly attractive in P-deficient areas with relatively high rainfall and rather acid soils, for wetland rice and on leguminous species, and in areas where tree crops are common or where afforestation is envisaged.

Organic materials serve as indispensable sources of plant nutrients. In addition, organic materials enhance soil chemical and physical properties and biological life.

Maximum use of organic inputs includes maximum recycling of both on-farm and off-farm supplies. Reported major constraints are labor, transport, and low nutrient concentration.

Technologies that involve low-capital inputs such as crop rotations, green manures, fodderbanks, improved fallows, and agroforestry systems have a role to play in the restoration of soil fertility. The extent to which this can be successful is largely determined by soil, climate, farmers' willingness to invest scarce labor into improving their land and crop management practices, and the degree to which the policy environment is "enabling."

Erosion is a very important cause of nutrient depletion. Therefore, soil and water conservation is of paramount importance in restoring soil fertility through nutrient-saving rather than nutrient-adding mechanisms.

Major constraints to soil and water conservation practices are the labor requirements and the fact that farmers see no immediate economic gain for their efforts. This highlights the need to combine soil and water conservation efforts with soil fertility improvement technologies such as fertilizer addition.

This philosophy behind INM implies that a combination of technologies is better able to redress nutrient imbalance in West African agroecosystems. Under an INM philosophy, the farmer can optimize the allocation of the different production factors to different parts of his/her land. This may involve both low- and high-external input practices.

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Part IV – Interventions

7. Turning the Tide

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Part IV – Interventions

7. Turning the Tide

7.1 Farm-Level Constraints to Technology Adoption

Within the context of existing physical and macroeconomic conditions, rural farm households primarily determine the prevailing features of farming systems and therefore play a key role in the food security equation. To develop more sustainable agricultural systems to meet the food demands and improve the food security situation in West Africa, governments, NGOs and donor-sponsored development projects directly or indirectly attempt to influence decisionmaking processes at the farm household level.

Farm household decisions regarding such varied activities as production, food stocks consumption, and marketing are made at various levels (village, household, individual). A set of these types of decisions constitutes a strategy. Studies in SSA reveal that strategies comprise a mixture of decisions affecting food self-sufficiency, profit or cash maximization, risk aversion, and long-term security of livelihood (de Haen and Runge-Metzger, 1990; Maatman and Schweigman, 1994; Hunt, 1991). Depending on the prevailing conditions, one or more strategies are dominant. For instance, in agricultural marginal areas, strategies that are based on "economy of survival," comprised of only decisions with a short-term planning horizon, predominate. The fact that a farm household is at the same time a production and a consumption unit has impacts on the decisionmaking processes (Low, 1986). For instance, it is argued that low-income farm households maximize utility with partial disregard to market prices (basic consumption need), whereas the choice of production method usually is very cost-sensitive (Hunt, 1991).

Conditions in West Africa have changed considerably in the past decades because of increasing population density, increased resource degradation, greater integration in the market economy, and increased urbanization (Okai, 1994; Turner et al., 1993; Snrech, 1994). Given the observed increase in rural poverty (World Bank, 1992; Jazairy et al., 1992) and deteriorating natural resources, it is apparent that farm households have not sufficiently prepared themselves for these changing conditions. At first sight, this seems to contradict observations revealing the rich basket of existing indigenous knowledge at the farm household level (Brouwers, 1993) and the fact that farm households tend to behave rationally regarding profit maximization, risk aversion, and/or allocation of resources given prevailing technological, social, and economic conditions (Norman, 1977; Low, 1986). However, the pace and the proportions of the changes that occur require similar dramatic changes in the farming systems and farm management practices (Traoré and Breman, 1993).

In the preceding section, a wide range of available technologies to maintain or restore soil fertility was presented. However, adoption of these technologies at the farm household level has been very limited and, thus, result in very slow progress in terms of technical change in West African agriculture.

Several factors influence the adoption of new technologies by farmers. These include:

- Characteristics of the household (education level, social status, attitude, social influence, estimated skills, resource endowments).
- Objectives or strategies of the household.
- Characteristics of the technology (its profitability, its appropriateness, complexity, friability and observability) (Rogers, 1983).

To these factors may be added existing external factors such as infrastructure and geographical conditions. It is unfortunate that in the process of technology development and dissemination, relatively limited attention has so far been paid to processes that affect attitude towards innovation, adoption-decision behavior, and adaptation of technologies to fit local circumstances.

The Value/Cost Ratio (VCR) is often used as a simple economic indicator to assess the suitability for adoption of a new technology at the farm household level. To account for risk, opportunity costs, additional labor costs, possible high fluctuations in values in time and place, depending on external circumstances like output prices, yields, weather conditions, and functioning of delivery systems, a VCR of 2 is often considered as the minimum value below which it would not pay farm households to adopt a given new technology. Recent studies by IFDC-Africa confirmed previous knowledge that the primary effect of the withdrawal of fertilizer subsidies and the devaluation of local currencies has been to reduce the VCRs of fertilizer use on rainfed foodcrops to well below 2 (Gerner et al., 1995). In general, the added value on investments is rather low for rainfed agriculture in West Africa (Van der Pol, 1993). There are two contrasting views on the influence of higher output agricultural prices on the implementation of soil conservation measures. (Lipton, 1987; Barret, 1991). It is argued that with increasing returns farmers are better able to invest in soil fertility improvement; others argue that higher prices will stimulate the process of soil mining by promoting the production of "quick, big money-earning" crops. However, with respect to soil fertility restoration technologies, factors other than the generic ones already mentioned or those that are characterized by short-term economic profitability also influence decisions to adopt technology. These factors are as follows:

- The technologies are not appropriate for the specific situation of farm households.
- Difference in time horizon: farm households often adopt short-term strategies; restoring soil fertility requires adoption of a long-term strategy.
- Farm households are not accustomed to investing money on the land and in most cases do not have the resources to invest.
- Land tenure arrangements prevent long-term investments in the soil (Bâ, 1992).
- Perception of the problem is not always very clear at the farm household level (Hailu and Runge-Metzger, 1993; Naipier, 1994). If, for instance, the irregular rainfall pattern is considered as the major cause of declining yields instead of soil degradation, it will be extremely difficult to involve farm households in activities concerning soil fertility restoration.
- Biophysical conditions are so fragile in certain areas that chances of total crop failure are very high; thus, it is difficult to justify investments in tools, equipment, or fertilizers.
- Knowledge of technology at the farm household level may be insufficient because of limited access to research results because of weak extension services and the virtual absence of effective research-extension-farmer linkages.
- Limited possibilities of regional economic development outside agriculture.
- Insufficient supportive infrastructure (credit, technical support).
- Limited marketing possibilities and market access.
- The technology conflicts with existing local knowledge, social events, or community structures.

In addition, a step-by-step intensification of agricultural production is not feasible in many areas since either labor or profitability is a constraining factor to implementation of most intensification technologies (Breman, personal communication). Interventions characterized by an integrated approach (comprehensive technology package) may be an option in such areas. Unfortunately, concrete examples of such interventions are very scarce.

In Table 7.1, the available technologies are listed, and an attempt is made to identify the degree to which each technology is affected by selected constraints. An integrated nutrient management approach seeks to combine technologies to optimize the efficiency of nutrient use. In this way, the approach combines the low-external- input technologies and the high-external-input technologies.

7.2 Farm Household Strategies Versus Government Strategies

Government strategies (or the absence of any strategies) and resulting policy instruments directly influence decisionmaking at the farm household level. Goals set by governments often differ from goals set by the different households. This fact has a decisive impact on adoption and implementation of practices at the farm household level.

The attainment of food security and, if possible, food self-sufficiency, has been the primary objective of the agricultural policies of West African governments. In the 60s and 70s, policies were biased in favor of urban centers. Such policies

Table 7.1 Major Constraints to Adoption of Groups of Technological Interventions

Constraints to Adoption	Mineral Fertilizers	Mineral Soil Amendments	Organic Inputs	Improvement Land Use Systems	Soil Conservation	Integrated Nutrient Management
Awareness of technology		high constraint		high constraint		high constraint
Adaptation to farming system		low/medium constraint				
Research-extension-farmers' linkage	low/medium constraint	low/medium constraint		high constraint	low/medium constraint	high constraint
Land tenure				low/medium constraint	low/medium constraint	low/medium constraint
Labor			high constraint		high constraint	low/medium constraint
Capital	high constraint	low/medium constraint			low/medium constraint	low/medium constraint
Institutional support	low/medium constraint	low/medium constraint		low/medium constraint	low/medium constraint	low/medium constraint
Gender	low/medium constraint		low/medium constraint	low/medium constraint	low/medium constraint	
Agronomic performance						high constraint
Output/input prices (profitability)	low/medium constraint	low/medium constraint	low/medium constraint		low/medium constraint	
National policies	high constraint					
Regional policies						
International policies	low/medium constraint					
Payback period		high constraint			high constraint	
Riskiness	low/medium constraint					
Perception		high constraint		low/medium constraint		low/medium constraint
Availability		low/medium constraint	high constraint			low/medium constraint
Market development agricultural products	high constraint	low/medium constraint				low/medium constraint

- high constraint
- low/medium constraint
- no constraint

emphasized low, fixed food prices and compensation for shortfalls in local production by importation either on a commercial basis or through food aid. The overriding goal was to stabilize the urban markets (Makken, 1993). More recently, West African governments have been persuaded by the international community to adopt structural adjustment programs that attempt to link the economies with the realities that exist in the international marketplace. The new objectives and instruments should focus on an increase in agricultural productivity while promoting overall economic growth through strengthening marketing systems for agricultural inputs and outputs, improving agricultural research and extension services, and improving the functioning of credit systems (Sijm, 1993). At the farm level, the effects of long-term declines in soil fertility have been felt. West African farmers are very aware of the effects of nutrient mining, deforestation, and erosion on the resource base for agriculture. Unfortunately, there has been no conscious effort by any government to develop an explicit and coherent strategy to maintain and enhance soil productivity.

Both at the level of the government and farm household, short-term planning horizons have tended to prevail. Thus, government strategies have focused on short-term concern for large productivity gains in food and export crops and in livestock husbandry. Such "survival" strategy results in failure to give high priority to long-term concerns over the conservation of the natural resource base and the maintenance of future production capacity. More often than not, limited-resource farmers were expected to develop and fund strategies to maintain land productivity (Reardon and Vosti, 1992).

The present situation in West Africa calls for partnerships between governments and farm households in the formulation and implementation of long-term strategies to conserve the soil. Once a strategy is in place, governments have different types of instruments to effectively ensure implementation. These instruments include:

- Laws and regulations (prohibition of a type of pesticide);
- Financial incentives or other transactions (subsidies, levies);
- Social regulations or persuasion (extension, research, information, infrastructure).

The last instrument ensures that there is a limit on interference in economic activities while relying mainly on social regulation and persuasion. It is arguable whether persuasion instruments alone will be sufficient to address effectively the problems of declining soil fertility. In addition to improvements in the research and extension system, credit system, and marketing infrastructure that would generate increased off-farm employment opportunities, direct financial support to facilitate various individual and communal investments in soil fertility in specific fragile production systems is also required.

In carrying out activities, it is important that an attempt be made to create a general awareness concerning environmental issues among all sectors of society. Participation of the communities in the formulation, design, execution and further development of strategies and policies is therefore essential (Turnham et al., 1992). The recently observed institutional developments at the government level, including a trend towards decentralization and increasing involvement of economic operators like Chambers of Agriculture and others, indicate positive developments in that direction.

7.3 The Need for Reorientation of Valuation: Discounting Externalities

In every day cost:benefit analyses, rapid returns on investments are more highly valued than returns that take a long time to be realized. Soil fertility restoration and maintenance measures are effective over the long term. To properly evaluate them requires a clear understanding of how externalities can be accounted for. The absence of accounting for externalities hinders an appropriate economic analysis since discounting practices result in a lower economic valuation of long-term soil conservation investments.. What are these externalities? When agricultural production leads to soil fertility decline through nutrient mining, deforestation, and soil erosion and the agricultural producers are not charged the full costs of the effects of their actions on the production base, this is considered an externality. Externalities can be beneficial or nonbeneficial to society. Failure to account for environmental costs at the society level implies costs that are transferred to or imposed on consumers, the environment, and the society at large. On the other hand, failure to account for the beneficial externalities implies unpriced benefits to society. Accounting for these externalities (or so-called internalizing externalities) is accomplished when either consumers pay for the environmental costs that are not traditionally included in the market prices of agricultural produce, or agricultural producers pay directly for restoring the fertility of the soil. The basic problem, however, has been the failure of the market to price externalities and of policymakers to 'internalize' them through regulation. This causes externalities to remain hidden, unpriced, and ignored until consequences of inaction lead to grave crises (Gerner et al., 1995).

A number of relevant methodologies such as the cost-effectiveness analysis (Bojö, 1990) and valuation methods such as the productivity method (benefits of doing something versus foregone costs of doing nothing; Bishop and Allen, 1989) and the replacement cost model (Stocking, 1986) have been developed to account for externalities. The productivity method, for example, permits the estimation of the effect of yields on, for instance, soil loss due to specific management practices. One drawback is that the variability in the data generated by these studies is very large and highly dependent on price levels for the products. For example, the results of various studies on valuation of soil degradation showed a variation between 1,000 to 25,000 FCFA per ha in the same research area of Southern Mali (Keddeman, 1991).

The productivity method has been used to valuate some soil conservation measures in Kenya. The data showed that none of the soil conservation measures could be considered to be most profitable during the first 3 years. Measures involving moderate level of conservation were most profitable during the following 6-8 years, whereas those requiring intensive physical and biological conservation were profitable only after 8 years (Ekbom, 1995). If Net Present Values (NPV) are estimated for productivity declines because of loss of topsoil, it would become obvious that the application of a discount rate is of crucial importance in arriving at the above results (Ekbom, 1995). High discount rates invariably lead to preference for no or only very limited long-term soil conservation measures. Determination of the discount rate at the farm level is difficult and depends on many factors among which are the alternative investment opportunities, tenure system, and commercial bank rates.

In the replacement cost method, the costs incurred to replace damaged productive assets such as depleted soil nutrients are estimated. The depleted nutrients are considered to have an economic value equal to the market value of an equivalent amount of fertilizer. In the study of southern Mali, for example, (Van der Pol, 1993), the use of the replacement costs approach and economic indicators as the Economic Nutrient Depletion Income Ratio (part of the economic return based on soil nutrient depletion) showed that soil mining costs were considerable.

7.4 The Way Forward: Interventions to Restore Soil Fertility

Sustainable development in West Africa depends on a healthy growth of the agricultural sector. Today, this engine of growth for the economies is sputtering. Locally produced cash crops, the main revenue earner for most governments, face increased competition from other producing regions where there have been substantial productivity increases and greater production efficiency. In some instances, consumer nations have found substitutes. Yields of food crops have steadily declined. At the same time, the number of mouths to feed is increasing more rapidly than at any other time in recorded history. Cheap imports of rice, wheat, and meat, the new staples for the urban wage earners, have displaced local staples. Subsidy removal and currency devaluation, two of the key items of structural adjustment programs, have resulted in much higher prices for external inputs such as fertilizers. Such high prices have discouraged farmers from using inorganic fertilizers. Because of increased demographic pressure and decreasing yields, established practices for the restoration and maintenance of soil fertility as is typical of shifting cultivation have given way to exploitative continuous cropping. As farmers' yields decrease, area expansion is the only means available to them to increase the absolute amounts of food produced. Marginal lands are thus brought under cultivation. Deforestation, uncontrolled erosion, loss of biodiversity, and overstocking continue to destroy an already fragile ecosystem while investments to maintain the productive capacity of the soil, i.e., its nutrient stocks, are virtually nonexistent. The net result is that more and more of the rural population is being drawn into the heart of the poverty spiral. For these people, the nexus of population growth, poverty, and environmental degradation is all too real.

The above scenario has to be viewed in the context of a region where the inherent fertility of the soils is very low. Increased cropping intensity without replacing the nutrients that the crops remove annually has resulted in the mining of the small quantities of native nutrients. Meanwhile, soil degradation, both physically and chemically, has become irreversible in many ecosystems because the soil resilience is very limited. For the next 10-20 years, West African governments and the international community cannot afford a "business-as-usual" attitude. Sustained growth and sustainable development call for a number of interventions to be rapidly implemented.

This review has demonstrated that:

- A wide range of technologies is available. However, adoption of these technologies has been hampered by socioeconomic/economic conditions.
- A comprehensive, integrated rural development agenda, at the system level, is absent. Rural development efforts are fragmented and ad-hoc in nature.
- Existing policies favor attainment of short-term goals and are not geared toward long-term sustainable agricultural development.

In Table 7.2, recommended actions at different intervention levels are presented. The implementation of these interventions must be led by national governments using the ingenuity of a properly sensitized farming community. The implementation also, inevitably, requires considerable institutional, scientific, and financial support from the international banking and donor community.

Apart from specific interventions geared toward implementation of technologies, interventions of a more general nature affecting the agricultural sector more directly or cutting across all technology interventions can be identified.

Supranational and Regional Level

- Revisiting impacts of Structural Adjustment Programs (SAP) and the General Agreement on Tariffs and Trade (GATT) in view of the need to introduce incentives to promote fertilizer use and agricultural production. A compromise between fiscally unsustainable government outlays and complete withdrawal of agricultural sector support is required.
- Developing and promoting economic valuation of externalities in international economic indicators, statistics, and cost/benefit analysis. Based on such figures government investments and interventions can be justified for cases where externalities largely influence the benefits of interventions.
- Raising awareness and arriving at a general consensus regarding the use of phosphate rock as a capital investment to enrich the phosphorus pool in West African soils (The World Bank Initiative in this respect is to be lauded).
- Raising awareness of the threat of gross migration and the necessity for urgent action to promote survival through, for example, a worldwide funding of a "Marshall Plan" for West Africa. This has to imply a long-term strategy and donor commitment with participation by all sectors in program formulation, design, execution, review and evaluation.
- Promoting effective interdisciplinarity and systems approaches in research and development through broad-based ecoregional consortia.
- Developing a regional West African agricultural policy aimed at supporting the agricultural production sector and increasing food security in the region. This should include mild forms of market protection at the regional border for most vulnerable food crops, minimum price guarantees for essential food products, facilitating and promoting internal trade, joint procurement of inputs (fertilizers) and coordinated production/ distribution of phosphate rocks.

National and District Level

- Establishing, at a high political level, Natural Resource or Soil Fertility Management and Development Units (such as the IFDC-assisted Soil Fertility Management Unit in Burkina Faso) to design and implement strategies for soil fertility restoration and maintenance.
- Establishing formal bodies that enhance linkages between national agricultural research systems (with adjusted research agenda signifying a shift from commodities and factors to systems), extension services, nongovernmental organizations, and the farming community.
- Creating an "enabling" environment that promotes agricultural growth: action on credit schemes, clear-cut land tenure arrangements, support to institutional and physical infrastructure, fine tuning of fertilizer recommendations for specific crop-soil combinations, and other nonfinancial incentives.
- Developing an inventory of natural resources available in the country for the purpose of increasing the soil fertility.
- Developing policies that reward maximum use of organic inputs and that optimize the use of external inputs in the rural and peri-urban sector.
- Formulating and implementing coherent policies that link increased productivity directly with conservation interventions.
- Developing and implementing agricultural market development policies, including promotion of crop diversification, improvement of domestic and export market structures and market information.
- Formulating and implementing policy directed at creating economically viable off-farm employment in rural areas (e.g., processing units for oil and karité, small-scale manufacturing).

Table 7.2 Recommended Actions at Different Intervention Levels to Facilitate Implementation of Technology Options to Restore Soil Fertility

Technology / Level	Mineral Fertilizers	Mineral Soil Amendments (P&Lime)	Organic inputs (crop residues & manure)
Major constraints -->	- Capital - National policies - Market development agricultural products/ input-output prices	- Awareness/R-E-F-linkages - Perception - Payback period	- Labor - Availability
Supranational and regional (West Africa)	- Review of SAPs - Replacement of food aid with fertilizer aid - Common regional agricultural policy (increased market protection) - Joint fertilizer procurement	- Perception of phosphate rock (PR) as capital investment - Support World Bank PR initiative - Valuation of unaccounted costs and benefits (internalize externalities) - Regional coordination of exploitation of deposits	- Valuation unaccounted costs and benefits - Awareness/quantification of international flows of organic matter and nutrients
National and regional	- Government support to private fertilizer sector (physical/institutional) - Forms of fertilizer subsidies - Policy support to agricultural sector - Finetune fertilizer recommendations for various crops to soil and AEZs - Gender-specific extension activities (e.g., more women extension staff)	- Formalization/implementation of NARS - Extension/NGO-Farmers linkages - Facilitation of exploitation and distribution - Establishment of national resource management unit - National P/lime investment policy - Extension message and methodology development	- Energy conservation policies - Waste management policies (recycling of agroindustrial and city waste)
Village/ farm household	- Financial support services to farmers (selective rates, credit) - Development of group-banking systems (Grameen) - Development of women's banking groups - Cash crop development (diversification) - Local processing of agricultural products - Participatory fertilizer trials with farmers and women's groups	- Participatory on-farm trials - Extension message and methodology development	- Improved animal husbandry management - Measures to reduce/avoid bush burning - Maximization of biomass production - Increasing quality of organic matter (composting) - Improvement of transport facilities and techniques - Training in use of green manures

Table 7.2 Recommended Actions at Different Intervention Levels to Facilitate Implementation of Technology Options to Restore Soil Fertility (Continued)

Technology	Improved Land Use Systems (LEISA)	Soil conservation	Integrated Nutrient Management (LEISA+HEIA)
Major constraints –>	- Awareness of technology - R-E-F-linkages	- Labor - Payback period	- Awareness of technology - R-E-F-linkages - Agronomic performance
Level			
Supranational and regional (West Africa)	- Foster international initiative for greening the region - Policies to integrate pastoralism and sedentary agriculture - Valuation of unaccounted costs and benefits	- Valuation of unaccounted costs of soil erosion and offsite effects	- Awareness/support international approach - Shift in paradigm to ecoregional research and development approach
National and provincial	- Formalization/implementation of NARS-Extension/NGO-Farmers' linkages - NARS research policy shifting from commodity to systems approach - Policies to secure land tenure systems - Policies addressing gender-sensitive issues in land use	- Facilitate maximum use of indigenous knowledge and materials - Development of national soil conservation development scheme (incentives to farmers) - Policies to secure land tenure systems	- Formalization/implementation of NARS-Extension/ NGO-Farmers' linkages - Shift from commodity to ecoregional approach - Strategy to maximize internal input and optimize external input use - Integration of indigenous knowledge with scientific knowledge systems - Niche differentiation
Village/ farm household	- Participatory technology development and demonstration on technical components of improved LUS (AEZ-specific)	- Promoting community conservation programs - Development of labor-saving soil conservation technologies - Participatory technology development and demonstration	- Participatory technology development and demonstration - Exploitation of farm heterogeneity

- Implementing and coordinating large-scale soil conservation investment schemes that integrate erection of structures with systems to improve soil fertility (e.g., use of phosphate rock in districts where stone lines have been erected).

Village and Farm Household Level

- Promoting participatory approaches to technology development and adoption.
- Promoting financial, technical, and moral support specifically to women's groups
- Promoting "nutrient-saving" and "nutrient-adding" technologies where appropriate, while sensitizing farmers to the advantages (e.g., use of energy-saving stoves, corraling in fields rather than in stables, N-fixing fodder species to be mixed with phosphate rocks, composting, planted stone bunds, periodic fencing off of fallows).
- Promoting fertility buildup and intensified production on land that is of high potential (land that combines advantages like water, labor, proximity to homestead and compost pit, relatively high fertility) to give land without such advantages a recuperation break.
- Promoting and supporting farmers' organizations and NGOs to increase empowerment of farm households in general and their influence on policy, development programs, research and project formulation in particular.
- Implementing voluntary or mandatory group savings and credit schemes.

Turning the Tide

Adoption levels of production technologies that promote sustainable agriculture, although currently limited, can be raised through increased participation of farm households in the process of technology development and through a better understanding of the decision-making processes at the farm household level.

All actors on the national agricultural scene – farmers, research and extension personnel, NGOs, public and private sector activists – should participate in problem identification, analysis, and prioritization of constraints. They should also participate in the development of strategies to overcome the constraints. In these activities, support from the donor community would strengthen national efforts.

Compatibility of policies and strategies of national governments and individual farm households should become a national goal to arrive at effective implementation measures to improve soil fertility.

Government strategies should focus on providing incentives to enable farmers to be better stewards of the land.

The quantification of externalities and the development of reliable methodologies for discounting externalities are necessary for promoting agricultural policies that involve long-term investments in soil fertility maintenance.

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