



Inter-Center Collaboration at the ICRISAT Sahelian Center



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Abstract

Sustainable agriculture to feed the growing populations in West Africa has become an issue of major concern. Improved management of natural resources is necessary to effect long-term gains in productivity. This requires the adoption of more integrated approaches to agricultural production that consider the coexistence and dependence of man, trees, crops, and livestock. Various aspects of the strategic, applied, and adaptive research of six international agricultural research centers (IARCs) and the International Fertilizer Development Center (IFDC) at the ICRISAT Sahelian Center (ISC) in Niger that aim to improve the productivity of the millet-based cropping systems are described. ICRISAT coordinates this ecoregional activity in effective partnership with the appropriate national agricultural research systems (NARS) established through network mechanisms already operational within each IARC. Results of the past decade's cooperative activities are presented.

Résumé

Collaboration inter-centres au Centre sahélien de l'ICRISAT. L'agriculture durable pour soutenir les démographies croissantes de Afrique de l'Ouest est devenue aujourd'hui une question inquiétante. Ainsi est-il nécessaire de mettre l'accent sur la gestion améliorée des ressources naturelles pour des gains de productivité à long terme. Cela demande l'adoption des approches plus intégrées à la production agricole qui prennent en compte la coexistence et la dépendance de l'homme, des arbres, des cultures, et du bétail. Cet ouvrage décrit les divers aspects de la recherche stratégique, appliquée et adaptative au Centre sahélien de l'ICRISAT, au Niger, entre six centres internationaux de recherche agricole et le Centre international pour le développement des engrais (IFDC), visant l'amélioration de la productivité des systèmes de culture à base de mil. L'ICRISAT assure la coordination de cette activité éco-régionale en association efficace avec les systèmes nationaux de recherche agricole (SNRA) appropriés, établie à travers les mécanismes de réseau déjà opérationnels au sein de chaque Centre. Les résultats des activités coopératives réalisés au cours de la dernière décennie sont également présentés.

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ICRISAT

**International Crops Research Institute for the Semi-Arid Tropics
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Introduction

West Africa is one of the poorest regions of the world, and subsistence agriculture is the way of life for many of its inhabitants. Over 90% of the population lives in villages. Decades ago, with fewer people to feed, farmers could maintain the fragile natural resource base by practicing pastoral and shifting agriculture. However, growing population pressures, combined with shortened fallow cycles, continuous cultivation, extended droughts since 1969, and successive crop failures, resulted in a decline in the per capita food production. The following phenomena have created an urgent need to address the problems of inadequate food production.

- As population density increases beyond 30-50 km², fallowing (the traditional practice of leaving the fields idle for a season to restore soil fertility) will be eventually abandoned.
- The amount of wood cut for fuel currently exceeds the rate of its regeneration by 30%, and is expected to increase.
- Overexploitation of natural resources leads to erosion: currently, 2000 tons of soil km² are being eroded each year.
- Monocropping and deforestation aggravate the problem of wind erosion.

Recent data from the World Bank (Table 1) show that at least a quarter of the population in West Africa faces food insecurity. Imports of cereals are still high, specially in Nigeria and Senegal. Such countries as Niger and Chad are producing less food today than they did 12 years ago.

Table 1. Food insecurity and imports in West Africa.

Country	Population facing food insecurity (%)	Average annual cereal import (in thousand tons) in 1990	Index of per capita food production in 1980-90 (1979-81 = 100)
Burkina Faso	32	145	114
Chad	54	36	85
Gambia	19	-	-
Mali	35	61	97
Mauritania	25	85	86
Niger	28	86	71
Nigeria	17	502	106
Senegal	21	534	102

Source World Bank 1992

A recent analysis by the World Bank of the Green Revolution in Asia versus agriculture in West Africa showed clearly that the strategies adopted in West Africa to combat increased population pressure were different from those in Asia. In West Africa, serious problems relating to water management, erosion control, and soil amelioration (acidity, alkalinity, toxicity, etc.) have to be overcome before improved varieties could be effective. The Green Revolution approach can not therefore be transferred to West African ecosystems whose rainfall patterns, soils, and land forms differ unfavorably from those of Asia.

Sustainable agriculture to feed growing populations has become an issue of major concern, to which the Consultative Group on International Agricultural Research (CGIAR) has responded by emphasizing resource management research. The CGIAR's Technical Advisory Committee (TAC) recognized the need

to change the focus of research from agro-ecologically favorable areas to more marginal ones, primarily in sub-Saharan Africa (TAC 1987).

***CGIAR and resource
management research
in West Africa***

The focus in West Africa must obviously shift to improved management of natural resources for long-term gains in productivity, instead of merely increasing productivity per se. In line with this increased emphasis on sustainability, TAC considers it essential that research on resource management should focus on issues that have a direct bearing on the productivity and sustainability of agriculture, forestry, and fisheries. The task of resource management research is to demonstrate the potential and develop pathways for incremental improvements that meet the increasing demands in a way that the farmers and the countries of the region can afford.

Six of the nine goals of the CGIAR are pertinent to resource management research in West Africa.

- Effective management and conservation of natural resources for sustainable production.
- Improved productivity of high-priority livestock and their integration into sustainable production systems.
- Improved productivity of high-priority trees and their integration into sustainable production systems.
- Progress towards equity (including gender equity) as well as improved diets, nutrition, and family welfare through better understanding of the human linkages between production and consumption.
- Appropriate policies for the increased productivity of crops, livestock, trees, and fish, and for the sustainable use of natural resources.
- Strengthened human resources and institutions for greater research capacity in developing countries' research systems.

The first three goals refer to management of natural resources and the integration of improved commodities into sustainable production systems. The next two goals relate to socioeconomic and policy environment. The last goal focuses on development of human resources and on institution-building at national or regional level.

***ICRISAT Sahelian
Center and resource
management research***

The ICRISAT Sahelian Center (ISC) is ICRISAT's principal research base in the Sahelian region of West Africa. The objectives of ISC are an extension of ICRISAT's mandate:

- To serve as a world center for the improvement of grain yield and quality of sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut and to act as a world repository for the genetic resources of these crops.
- To develop improved farming systems that will help to increase and stabilize agricultural production through more effective use of natural and human resources in the seasonally dry semi-arid tropics (SAT).
- To identify constraints to agricultural development in the SAT and evaluate means of alleviating them through technological and institutional changes.
- To assist in the development and transfer of technology to the farmer through cooperation with national and regional research programs; by sponsoring workshops, conferences, and training programs; and by assisting in extension activities.

ICRISAT's Medium Term Plan (MTP) for 1994-98 was formulated in the light of the system-wide issues affecting the CGIAR. The methodology used in the development of the MTP was innovative and highly analytical, with the entire Institute contributing to the data and judgements on which the Plan was founded. Based on detailed analysis of the economic consequences of the various constraints affecting ICRISAT mandate crops and the SAT environment and following considerable discussion, 92 potential research themes were identified as components of ICRISAT's core-funded research portfolio.

Six priority themes in the MTP directly address the issues that concern resource management research at ISC:

- Soil fertility
- Water deficit
- Characterization of production environments
- Agroforestry
- Assessment of technology adoption and impact evaluation
- Consumption and demand studies

The first four themes are related to the first mandate statement and the last two themes to the second mandate statement.

In order to achieve closer integration of the crop improvement and resource management research activities across the Institute, and among the activities of ICRISAT, national agricultural research systems (NARS), other international agricultural research centers (IARCs) and mentor institutions, a new structure for the organization of research within ICRISAT was implemented on 1 Nov 1993. This new structure evolved from the concept of identifying target production systems through which to provide a common focus for the various regional commodity- and disciplinary-based research activities of the Institute and its collaborators. Emphasis is placed on 29 production systems, allowing a focus on ICRISAT mandate commodities in realistic situations, and the identification of specific researchable problems and the areas in which to assess their impact. Production systems are defined by four descriptors:

- Geography
- Environmental resources
- Key elements in the major farming systems (including commodity production trends and key socioeconomic variables)
- Important issues or constraints to improving productivity and sustainability.

Out of the 29 target production systems, six (numbers 13 to 16) were identified for the Western and Central Africa Region.

13. Transition zone from arid rangeland to short-season (less than 100 days), rainfed, millet/cowpea/livestock. *Sahelian Zone.*
14. Intermediate season (100-125 days), rainfed, millet/sorghum/cowpea/groundnut-based. *Northern Sudanian Zone.*
15. Intermediate season (125-150 days), rainfed, mixed, sorghum-based. *Southern Sudanian Zone.*
16. Long-season (150-180 days), rainfed, mixed, maize-based. *Northern Guinean Zone.*
17. Humid, bimodal rainfall, mixed root-crop based. *Southern Guinean and Forest Zones.*

18. Low-lying areas prone to inundation, postrainy season, sorghum/millet/groundnut-based. *Sahelian and Sudanian Zones.*

In the context of the emphasis on resource management research, there are clear advantages to using production systems:

- Interdisciplinary teams can be provided with identifiable objectives to focus on real problems, exploiting the synergism of genetic, management, and socioeconomic research.
- A concrete basis for collaboration can be established with our partners in the national programs, *all* of whom have mandates that focus primarily on applied research for their nationally or regionally important production systems.
- Ecoregional initiatives or research consortia that embrace NARS and IARCs and also focus on conservation and management of natural resources that interest donors are clearly delineated.
- The direct impact of research on the target production system, and spillover effects in related production systems or geographic areas, can be more easily assessed.
- Scientifically and geographically diverse research work can be described in a logical, cogent way, thus presenting a coherent picture to stakeholders.

Under the new structure, ICRISAT's research is packaged with the project as the basic unit of operation and management. Twenty-three global research projects were defined in relation to the priority needs and research opportunities identified in the four major regions of the SAT—Asia, Southern and Eastern Africa, Western and Central Africa, and Latin America and the Caribbean. Of these, four multiple commodity systems projects (MCSPs) directly address issues of resource management:

MCSP 1 Rainfed short season millet/legume systems in desert margins.

MCSP 2 Short to intermediate season millet/sorghum/legume production systems.

MCSP 3 Intermediate season maize/sorghum/legume mixed cropping systems.

MCSP 4 Rice/wheat/legume production systems.

In addition, a suite of 18 single commodity systems projects (SCSPs) and cross commodity systems projects (CCSPs) has identified outputs with specific linkages to the four MCSPs. These projects also include outputs that have implications for resource management research.

Each of the above projects will have a designated team and clearly defined objectives and milestones. The team will be accountable for the development, conduct, management, resource utilization, reporting, and impact assessment of the project.

To facilitate the definition, development, management, and conduct of projects, an organizational framework employing a tandem matrix was developed. There are two dimensions to the matrix. The horizontal axis of the matrix includes the four geographic regions of the SAT. These geographic regions are complemented by seven disciplinary Research Divisions on the vertical axis of the matrix. These Divisions have global responsibilities.

The axes of the matrix are designed to emphasize shared responsibilities, goals, and outcomes through development and delivery of a relevant global research project portfolio.

Cereal-based production systems in the Western and Central Africa region are complex and their improvement includes such aspects as

- better use of natural resources (land, crop residues, trees, water, light, nutrients),
- alleviation of crucial environmental constraints (poor nutritive status of soil, wind erosion, etc.),
- cowpea and forages (a vital component in the millet production system),
- consideration of the animal component (livestock, animal traction, and manures),
- diversification and intensification of production systems, and
- socioeconomic constraints to the use of improved technologies.

To effectively address all the above aspects, the research approach requires the efforts of a multidisciplinary team as each component of the production system is linked to the others. It was recognized in the early phases of research at ISC that the Sahelian Zone (SZ) is unique among all the climatic zones in the world because of the coexistence and mutual dependence of man, trees, crops, and livestock in this region for centuries. No discussion on crop production systems in this zone can be complete without an appropriate consideration of trees and livestock.

Importance of trees

In the traditional agro-silvi-pastoral systems of West Africa, multipurpose trees (MPTs) are predominant. They increase soil fertility by recycling nutrients from deep soil layers and are sources of fuelwood and timber, edible fruits, medicines, and forage. Multipurpose trees also control runoff and wind erosion; lower soil temperatures; and facilitate water infiltration. The major products of trees—their foliage and fruit—constitute important sources of livestock feed, particularly at the end of the dry season when stocks of crop residues are exhausted.

Importance of livestock

As integrated production systems have become more permanent, the earlier specialization in cropping or livestock rearing has become less common. Intercropping millet, sorghum, cowpeas, and groundnuts, and raising cattle, sheep, and/or goats stabilize food availability in a climatically risky environment. A variety of economic and biological interactions between livestock rearing and crop production make mixed systems attractive to producers. Some of these interactions have both beneficial and potentially detrimental consequences, as shown by the following examples.

- Mixed farming is a risk diversification strategy. Ruminant livestock provide an important investment opportunity, and stabilize food availability during poor crop production years. However, the individual productivity of crops and livestock in mixed farming systems is often lower than that in specialized separate production systems.
- Crop production becomes more intensive as demographic pressures increase. This requires in greater inputs of manual labor per unit of land and results in occasional labor shortages. The use of animal traction can alleviate labor shortages and increase crop yields. The adoption of animal traction in

many parts of semi-arid Africa has been slow, however, and tillage of some soils may increase the risk of wind and water erosion.

- Cropland forages and fodder (crop residues, weeds, browse, and fallow land forages) are important livestock feeds during the 6- to 8-month dry season. However, the depletion of the vegetative cover through grazing and/or harvesting of residues for feed, and the trampling of the soil surface by animals, may adversely affect soil properties and decrease the production potential of both crops and livestock.
- The application of animal manures sustains the yields of many cultivated areas. However, there is the risk of that nutrients will be removed from rangeland in order to support crop production, with deleterious results. Reductions in range:cropland ratios jeopardize the sustainability of nutrient transfers and could cause feed shortages and overgrazing during the wet season.

International centers at ISC

It is clear that the economic and ecological stability and sustainability of semi-arid mixed farming systems depend upon technologies of common benefit to crop, tree, and livestock production. Hence, the primary goal at ISC was to create an integrated research program in collaboration with other international centers. Two major considerations in defining the terms of partnerships were the comparative advantage offered by each center as defined by its specific mandate and the complementarity of these mandates. Based on these two considerations, collaborative agreements were established with the International Livestock Centre for Africa (ILCA), the International Fertilizer Development Center (IFDC), the International Institute of Tropical Agriculture (IITA), the International Centre for Research in Agro-Forestry (ICRAF), the International Food Policy Research Institute (IFPRI), and the International Board for Plant Genetic Resources (IBPGR) [now the International Plant Genetic Resources Institute (IPGRI)].

In order to address the issue of plant nutrient needs, IFDC stationed a soil scientist at ISC in 1982. ICRISAT signed a cooperative agreement with ILCA in 1983 to conduct research on crop-livestock interactions at ISC. In 1987, IFDC created an Africa Division to launch an integrated program of plant nutrient research, training, and development to address the special needs of countries in sub-Saharan Africa with an early focus on West Africa. In view of the importance of cowpea in the millet production systems in the SZ, IITA has stationed an agronomist at ISC since 1984 to study the place of short-duration grain types of cowpea in sole and intercropping systems. ICRAF recognizes that the Southern Sahelian and Sudanian Zones are important regions for its research and has already established SALWA, a network for the semi-arid lowlands of West Africa. A tree geneticist from ICRAF was assigned to ISC in 1991. IFPRI initiated a program of food policy research in West Africa by appointing a policy economist at ISC from 1987 to 1991. IPGRI placed a field officer at ISC in 1986 to strengthen its activities in genetic resource management in West Africa.

ISC provides good field and laboratory facilities including approximately 220 ha of experimental plots, pasture, and cultivated areas for grazing trials, and facilities for in-pen and group feeding of animals. The Center has plant and soil laboratories and crop drying facilities for assessing the feeding values of forages and conducting in-depth investigations on nutrient cycling. Short- and long-term seed storage and a tree nursery are also available.

Mandates of different centers and commonality of objectives

International Livestock Centre for Africa (ILCA)

Theme 1: Economics of livestock production in mixed farming systems in semi-arid West Africa

ILCA initially focussed its research on defining the role of livestock in mixed farming systems, monitoring the management and productivity of village herds, preliminary evaluations of feed supplements, and animal traction. The program was expanded in 1989 to include more strategic research aimed at devising and evaluating improved resource management technologies that increase the sustainability and stability of livestock production in mixed farming systems. ILCA's research is organized into four major themes.

Typology of livestock producers in mixed farming systems. Previous ILCA research has shown that producers keep different types and classes of livestock and practice different management and production strategies depending on the level of resources at their command. The degree of integration of livestock into the farming systems also varies.

The objective of this study is to develop a typology of crop-livestock production systems and producers in order to assess the constraints and opportunities that exist within the farming systems (Williams 1994). This study will help to identify the key research issues that are likely to have a maximum positive impact on the crop and livestock production activities of different categories of producers.

Whole-farm modeling. Modeling is a continuous exercise requiring the input of all ILCA, ICRISAT and other scientists working at ISC. The interdisciplinary approach to modeling will target key economic and biological interactions of the mixed farming system and identify important research issues that improve the sustainability of the system. Objectives of economic modeling are; (1) to develop a comprehensive whole-farm model that incorporates the essential interactions between components of mixed farming systems, (2) to investigate the extent to which interactions between components of mixed-farming systems influence the choice of crop-livestock enterprises and farmers' incomes, (3) to analyze the impact of relevant stochastic events on mixed-farming systems (e.g., the effect of drought on grain and biomass production and subsequent animal productivity) and what further adjustments can be made to increase the stability and sustainability of livestock production over the long term.

Theme 2: Agro-ecology of livestock production in mixed farming systems

Cropland forage and fodder resource use. The objectives of ILCA's research on cropland forages are; (1) to define a typology of cropland forage and fodder resources in terms of their types, amounts, annual and seasonal availability, management practices, and nutritive value, and (2) to identify constraints to, and management strategies for, efficient use of crop residues that satisfy nutritional demands of animals and requirements for soil management.

Nutrient cycling by ruminants. The objectives of nutrient cycling research are; (1) to assess the direction and magnitude of nutrient transfers between rangelands and crop lands, and (2) to identify and overcome constraints to more efficient use of animal manure in cropping systems while conserving the natural resource base (Fernandez-Rivera et al. 1993, Somda et al. 1993, Williams et al. 1993).

Integration of legumes into mixed farming systems. The objectives of the forage legume research are; (1) to identify dual-purpose (grain and forage)

legumes and browse species suitable to the production system, and (2) to develop management systems that fully exploit the agronomic benefits and feed value of legumes, and lead to the enhanced productivity of both crops and livestock. Appropriate mixtures of legumes and cereals may present possibilities to select feeds that satisfy animal nutritional demands, and produce animal excreta that is less susceptible to nutrient losses when applied to cropland.

Theme 3; Livestock nutrition in mixed farming systems

Feed shortages due to periodic droughts, long dry seasons, and the diminution of grazing areas as cropping expands severely limit the productivity of ruminant livestock. Seasonal differences in quantity and quality of feeds require that livestock diets be supplemented at certain times of the year. However, since supplements are both scarce and expensive, their use is very limited.

The objectives of the ruminant nutrition research are; (1) to determine and improve the availability and nutritive value of local and introduced feeds (Fernandez-Rivera et al. 1994) and to search for alternative feeds, and (2) to develop appropriate feeding systems for different animal categories that enhance nutrient cycling while improving survival, growth, reproductive performance, and offtake (Powell et al. 1994, Powell and Williams 1993).

The feeding value of, and economic returns from utilizing new, agronomically promising cereal and grain legume varieties, forages, and browse need to be determined in order to assess their impact on livestock production.

Theme 4: Animal traction

The adoption of animal traction for farm operations has been limited in semi-arid west Africa. Although its use has been promoted as a way to increase cultivated areas and yields, and alleviate labor shortages, sustained adoption has only occurred in such limited locations as low-lying valleys where cash crops like cotton and/or groundnuts are grown, and on irrigated rice schemes. Not only have adoption rates been low, but some farmers have abandoned animal traction after 3-5 years, or continue to use it only for transportation. Given the potential importance of animal traction, particularly as a labor-saving technique in production systems where seasonal labor shortage is a major production constraint, it is important to understand the reasons for this sparse and incomplete adoption pattern.

The objectives of animal traction research, which will be initially limited to Niger, are (1) to conduct systematic field investigations into the reasons for the utilization, non-utilization, and abandonment of animal traction, and (2) to test hypotheses on the effects of length of growing season, soil structure, rental markets, animal and equipment costs, farmers' experience, alternative combinations of traction technologies (e.g. cart only, cart and plow, cart, plow and weeder, etc.), and feed supplies on the adoption or non-adoption of animal traction.

International Institute of Tropical Agriculture (IITA)

The IITA mandate that covers collaborative work at ISC is; *"To improve the performance of selected food crops which can be integrated into improved and sustainable production systems."* In 1984 started to work at ISC on cowpea, and on maintenance of soil fertility and soil condition in the rainfed African SAT. Cowpea is traditionally grown as a subsistence crop. It is drought-tolerant and thrives on poor soils. In the millet/sorghum based cropping systems of the Sahelian region, cowpea is the main legume and a major source of human food

and livestock fodder. The principal objectives of the cooperative program at ISC are to develop superior cowpea cultivars that have such desirable attributes as resistance to diseases and pests (including *Striga*), greater ability to withstand drought and high temperatures, that retain their leaves at pod maturity, and that are less competitive with pearl millet when intercropped with limited inputs.

A cowpea breeder/agronomist was posted at ISC from 1984 to 1990. Since 1991, IITA has operated this program from its base in Kano, and continues these activities at ISC.

***International Fertilizer
Development Center
(IFDC)***

The new mandate of IFDC approved in October 1992 is; *"To undertake research and provide assistance, advisory services, and training in response to the global needs, with special reference to tropics and subtropics, for the transfer and use of improved fertilizer and related technology, and for the implementation of economic policies that promote open, competitive markets and market-led associated institutions for increased agricultural productivity and economic development, while conserving the natural resource base and the environment, and enhancing the efficient use of plant nutrients."*

Since 1982, IFDC, in collaboration with ICRISAT, has adopted a research program that aims to restore and maintain soil fertility as a means of increasing productivity through the development of sustainable soil fertility management technologies in the West African Semi-Arid Tropics (WASAT).

The immediate objective of this program is promote greater and more efficient use of plant nutrients to increase food production by supplying information on the fertility status of soils, the amounts of plant nutrients needed by the crops, and the economic sources of plant nutrients with emphasis on fertilizers produced from indigenous materials, and the best management practices that can ensure a healthy environment for sustainable agricultural production.

In 1987, IFDC-AFRICA Division was created to conduct research and training leading to a systematic buildup of soil fertility as the basis for increased agricultural productivity in sub-Saharan Africa in general, and in West Africa in particular.

Two programs have been designed to carry out this agenda. These are the Watershed Management and Environment Program and the Policy Reform, Market Research and Development Program. The IFDC Program at ISC is a part of the farmer.

***The objectives of the program
at ISC***

- To develop a regional database on the resource base, including a preliminary assessment of the characteristics of the agro-mineral deposits.
- To identify, within each agro-ecological zone of West Africa, the nutrient needs of the soils and the most important crops, and to evaluate alternative fertilizer sources such as indigenous agro-minerals and organic sources of plant nutrients.
- To develop and extend, through working with national agricultural systems and with farmer participation, improved and sustainable soil-, water-, and nutrient-management practices.
- To study the impact of fertilizer use on the farm population, and on the long-term productivity of the soil.
- To promote the development of national systems capable of establishing soil management, fertilizer research, and extension programs.

***International Centre for
Research in Agro-Forestry
(ICRAF)***

ICRAF's mission, as stated in its charter, is; *"To increase the social, economic and nutritional well-being of peoples of developing countries through the use of research and related activities to integrate the woody perennial in farming and related land-use systems in order to increase productivity, profitability, sustainability, diversity of output, and the conservation of natural resources."*

ICRAF defines agroforestry as a collective name for land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in a spatial mixture or in a temporal sequence. There are normally both ecological and economic interactions between the woody and non-woody components in agroforestry.

In order to fulfill its mission, ICRAF's goal is; *"To initiate and assist in the generation and dissemination of appropriate agroforestry technologies for resource-poor farmers and other land users."*

Multipurpose Tree (MPT) Improvement and Management is one of four programs in ICRAF's Research Division. ICRAF has established several Agroforestry Research Networks for Africa (AFRENAs) in collaboration with international and national research centers. The youngest AFRENA is in the SALWA. SALWA members and other international, regional, and national organizations in West Africa underscored the need for tree improvement research on MPT species with agroforestry potential in SALWA. This research could provide basic information for the development of national and regional MPT improvement programs, and would take advantage of the agroforestry research in progress in the SALWA AFRENAs. An ICRAF geneticist was posted at ISC in October 1991 in response to these research needs, and in recognition of the comparative advantage of ISC as the center for ecoregional research in SALWA, in particular for research in agroforestry.

***International Plant
Genetic Resources
Institute (IPGRI)***

IPGRI's current mandate is; *"To advance the conservation and use of plant genetic-resources for the benefit of present and future generations."* The International Plant Genetic Resources Institute was formed in 1993 from the former International Board for Plant Genetic Resources (IBPGR). Objectives of IPGRI are to:

- Assist countries, particularly developing nations, to assess and meet their needs for plant genetic resources conservation, and to strengthen links to users.
- Strengthen and contribute to international collaboration in the conservation and use of plant genetic resources.
- Develop and promote improved strategies and technologies for plant genetic resource conservation.
- Provide an international information service on plant genetic resources.

IPGRI has a Regional Group in Sub-Saharan Africa with its main office in Nairobi, and an officer in West Africa located at ISC. Activities of the Sub-Saharan Africa Group concentrate on providing technical and professional support to the development of national programs in the region. IPGRI activities at ISC started in 1987 with the appointment of a field officer, who left in 1992. A germplasm conservation scientist responsible for conservation strategies and technologies was appointed in the same year.

Integration of research of different centers

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

In strategic terms, ICRISAT's goal is; *"To improve farming systems by efficient use of human and natural resources."*

Under the new structure of ICRISAT, the following global research projects address the research needs and opportunities of the six production systems in Western and Central Africa.

- PM 1 Improving the productivity and stability of pearl millet in arid to semi-arid tropical transition environments
- PM 2 Improving the productivity and stability of pearl millet in semi-arid tropical environments
- SG 1 Improving the productivity and stability of sorghum in low rainfall areas
- SG 2 Improving the productivity and stability of sorghum in medium rainfall areas
- SG 3 Improving the productivity and stability of sorghum in high rainfall areas
- GN 1 Improvement in the productivity and stability of groundnut in medium- to long-duration rainfed environments
- GN 2 Improvement in the productivity and stability of groundnut in short-duration environments
- MCSP 1 Rainfed short season millet/legume systems in desert margins
- MCSP 2 Short to intermediate season millet/sorghum/legume production systems
- MCSP 3 Intermediate season maize/sorghum/legume mixed cropping systems
- ECON 1 Research evaluation and impact assessment
- ECON 2 Market and policy analysis
- GR Assembly and management for conservation and utilization of genetic resources

ICRISAT has seven Research Divisions

- Agronomy
- Cellular and Molecular Biology
- Crop Protection
- Genetic Enhancement
- Genetic Resources
- Socioeconomics and Policy
- Soils and Agroclimatology

Scientists for all Divisions are actively involved in the global research projects.

International Livestock Centre for Africa (ILCA)

ILCA's research at ISC mainly addresses its MTP themes on soil fertility, agroforestry, and assessment of technology adoption and impact evaluation. The on-station research conducted at ISC focuses on issues identified on-farm and requires expertise in both livestock and crop production. The collaborative on-station research program at ISC brings together researchers in animal, plant, and soil science and economics providing a unique format for interdisciplinary research (Table 2). For example, issues pertaining to crop (food) production are of principle concern to ICRISAT, whereas ILCA focuses on using crop residues

for animal feed. IFDC focuses on issues pertaining to crop residues and soil management, with all three institutes participating in nutrient cycling research and other issues that mitigate the competition between cropping and livestock in mixed farming systems.

Table 2. Research issues, institutions, and disciplines in research on millet production at ISC (for Sahelian and Sudanian Zone production systems).

MTP themes	Research issue	Institutions	Disciplines
Characterization of production environments, Assessment of technology adoption and impact evaluation, Consumption and demand studies	Identification of main production systems, constraints, and parameters for technology transfer and assessment	ICRISAT/ILCA	Economics, Cropping systems, Agroclimatology, Animal nutrition
Soil fertility, Water deficit, Agroforestry, Assessment of technology adoption and impact evaluation	Food production	ICRISAT	Breeding and physiology, Plant protection, Cropping systems
Soil fertility, Water deficit	Fodder/forage production and use	ILCA/ICRISAT	Animal nutrition, Soil and water management
Soil fertility, Water deficit	Crop residues and soil conservation	IFDC/ICRISAT	Soil fertility, Soil and water management
Soil fertility, Water deficit, Assessment of technology adoption and impact evaluation	Nutrient cycling in plants/animals/soils	ILCA/IFDC/ICRISAT	Agroecology, Animal nutrition, Soil and water management, Agroforestry

Interaction among ILCA and ISC scientists

Scientists from ICRISAT and ILCA have developed strong partnerships to accomplish the mandates of both centers, through jointly implemented cooperative research. Recent examples of interactions between them and other centers working at ISC include the following.

Pearl millet-stylo intercrop. ILCA and ISC scientists examined the possibilities of intercropping pearl millet with a local line of *Stylosanthes fruticosa* and an Australian cultivar (Verano) of *S. hamata*. Millet grown in association with stylo gave much lower grain yields than millet alone (Kouame et al. 1993). However, millet-stylo intercrops gave biomass yields similar to those from sole-cropped

millet, and crude protein yields up to four times greater than those obtained from millet alone. A positive residual effect of stylo on subsequent millet yields was also observed. Sole millet grown on plots that had been previously cropped with stylo yielded about 0.5 t more grain than millet that followed millet. Further trials demonstrated the beneficial effects of stylo on the growth rate of livestock. Sheep fed solely on millet stover gained less than 1 kg live weight in 70 days, whereas those whose diets were supplemented with 500 g of stylo day¹ gained nearly 3.5 kg.



Alternating strips of pearl millet and stylo (Stylosanthes hamata) at ISC.



Cattle grazing pearl millet stover

Crop residues and manure. In a series of long-term experiments scientists from ILCA, IFDC, and the University of Wageningen initially investigated the effects of crop residues, manure, and urine on the chemical and physical properties of the soil, and on millet grain and stover yields. They showed that crop residues had a very positive effect when used as a soil amendment. However,

farmers of the region continue to use crop residues as feed for livestock and/or to trade this resource for manure. Similarly, the manuring trials showed a highly positive impact of manure and urine on crop productivity, but, since only small amounts of manure could be produced from feeding crop residues, most manure nutrients need to be transferred from rangelands by grazing animals. Recently, the decision was made to continue these crop residue studies in a large multi- and inter-disciplinary experiment.



Sheep corralled to manure sorghum fields

Decomposition of plant material and manure in the soil. The role of soil microorganisms and termites in decomposing crop residues and livestock manure is under investigation. Initially, the leaching of nutrients from plant material and faeces, and the decomposition of these materials in the soil as a result of the activity of microorganisms and termites were studied by scientists from ILCA and the University of Hohenheim. Identification of termites found in the field indicated the predominance of the *Odontotermes* spp. Their populations were higher in animal-manured plots than in millet straw plots. Adjacent field plots are being established to investigate the relative response of millet to sources of manure, time of application, and biocide amendments. Urea-N¹⁵ will be applied to assess organic N uptake using an A-value method.

Pearl millet growth pattern, nutrient partitioning, and early grazing. Initial experiments evaluated the effects of fertilizer on dry matter yield and the N, P, and structural carbohydrate distribution in pearl millet (Powell and Fussell 1993). Fertilizer-N increased total millet yield by 13%, N uptake by 63%, and P uptake by 29%, whereas fertilizer-P increased total millet yield by 100%, N uptake by 80%, and P uptake by 140%. Results showed the importance of N and especially P in increasing grain and forage yield and quality, and that fertilizer and stover can be effectively managed so that both crops and livestock can be raised in a sustainable manner. This work is being expanded into a

study on growth patterns, the partitioning of nutrients and cyanide during growth, and the response of millet to early grazing.

Genetic influences on the feeding value of crop residues. The proportion of morphological components, the chemical composition, and digestibility of millet stover from several genotypes is being investigated in an ICRISAT-ILCA collaborative project. The results show that due to the high concentration of its structural components, millet stover is poorly digested. The genotypes differed little, if at all, in the digestibility of their leaves. However, preliminary evaluations suggested that the feeding value of millet stover can be genetically improved. Leaves that had brown midribs contained 42% less lignin and were 5% more digestible than normal leaves. The feed value of stover from varieties with trichomeless leaves is also being investigated. Although this effort has focused on millet stover, work has been initiated on determining the effect of genotype on the feed value of cowpea and groundnut hays.

Feeding value of multi-purpose trees. The multi-purpose trees established as windbreaks in the agroforestry program of ISC were evaluated for their dietary selectivity by small ruminants. Although only about 3% of the tree biomass was browse leaves, goats predominantly fed on trees, whereas sheep preferred millet leaves and weeds. Dietary preferences changed during the dry season. Goats showed initial preferences for *Ziziphus Mauritania*, *Acacia Senegal*, and *A. nilotica*, with *Bauhinia rufescens* being highly selected during the later part of the 5-month study. This study is being continued as an ISC-ICRAF-ILCA collaboration, in which the genetic variation in feed value of several MPT species is to be evaluated.



Goats browsing among shrubs that serve as windbreaks

Potential feeding value of herbage from *Striga hermontheca*. In an exploratory trial, the chemical composition, intake, and digestion of *Striga* herbage by sheep was investigated. *Striga* was found to have a highly atypical chemical composition (more than 20% inorganic matter, more than 3% N, more than 50% structural components, and relatively high levels of potential anti-nutritional factors). Although about 60 % of the organic matter was digestible, its high-ash content makes *Striga* a low-energy feed. The amount of *Striga* eaten by sheep was comparable to the amount of crop residues they ate. Results suggested that this weed is a low-quality feed, but that it could be a source of supplementary protein.

International Institute of Tropical Agriculture (IITA)

Since 1984, a large number of introduced and local cowpea germplasm accessions from Niger, Burkina Faso, Mali, and Senegal, have been evaluated. The local germplasm accessions, which are largely of a spreading habit, indeterminate, and photoperiod-sensitive, varied widely. The program has focused on dual-purpose (grain/fodder) cowpea resistant to insect pests and diseases. Lines resistant to bacterial blight have been identified and used to incorporate the resistance into susceptible but well-adapted local varieties and dual-purpose cultivars.



Improved cowpea cultivar (TVX 3236) sown after harvesting pearl millet

Striga resistance was identified in 11 cultivars, and genetic studies of Niger and Mali biotypes were undertaken by a Malian scientist.

Research was conducted on many factors that affect the productivity of the millet/cowpea intercropping system. These included the choice of cowpea cultivars (Ntare and Williams 1991), sowing date of cowpea in relation to millet (Ntare and Williams 1991), density and fertilizer responses (Ntare and Bationo 1992). The results showed that cowpea cultivars suitable for intercropping with millet should not compete strongly with the cereal, but should be able to produce acceptable yields of both grain and fodder when intercropped. The

genotypes suitable for intercropping were identified. The interaction between cowpea cultivars and sowing date was highly significant. Early-maturing cowpea cultivars sown in closely spaced hills had less effect on millet yields than a late-maturing cultivar sown in widely spaced hills. The optimum time to sow an intercrop of cowpea is 7 to 14 days after the millet has been sown. A compensation ratio was derived, and was found to be a useful index for selecting cultivars of cowpea suitable for use as intercrops.

Since 1991 IITA has continued to conduct experiments at ISC but on a reduced scale. Joint meetings are held regularly to coordinate cowpea research. Recently it has been agreed to coordinate research efforts on *Striga* resistance in the region, and collaborative programs have been designed to implement this strategy.

**International
Development**

**Fertilizer
Center
(IFDC)**

IFDC research at ISC is integrated into the MTP themes of soil fertility, water deficit, assessment of technology adoption, and impact evaluation. IFDC agronomic research consisting of benchmark and satellite experiments, has been established at ISC and at Tara, and supplemented with on-farm trials. In its MTP, ICRISAT calls for intensification of these efforts to understand and provide solutions to the fertility constraints to crop production in the WASAT. Both IFDC and ICRISAT are committed to these efforts, and under this revitalized program, additional benchmark trials will be established at the ICRISAT locations in Mali and Nigeria, and in Farako-Ba, Burkina Faso, in collaboration with the national research programs of the respective countries.

Activities on research stations involved the development of technologies based on farmers' practices, and the testing of innovations related to nutrient inputs, organic matter inputs, cropping systems, and land management. On-farm researcher-managed trials validate and adapt the methods that worked on the research station to the conditions that apply to farmers' fields within each agroclimatic zone.

Highlights of IFDC-ICRISAT collaborative research include:

- The assessment and characterization the soil resource base indicated that the soils in WASAT are inherently low in fertility, indicated by low levels of organic matter, total nitrogen, and effective cation exchange capacity (Bationo et al. 1989, Manu et al. 1991).
- Lack of moisture limits crop production in the WASAT but poor soil fertility is a more serious constraint in the long run.
- The main causes of the infertility of acid soils in the WASAT are aluminum and manganese toxicity, and deficiency or reduced availability of phosphorus, nitrogen, calcium, magnesium, and molybdenum (Bationo et al. 1991).
- Results of a study to examine the long-term effects of different soil fertility management processes showed that the sandy Sahelian soils in the WASAT are extremely fragile, and that poor management leads to serious soil degradation. Unless organic amendments such as crop residues or manure and lime are applied, continuous cultivation leads to a decrease in organic matter (5% a year), leaching of bases, soil acidification, and a decline in crop yields (Geiger et al. 1992).
- Several phosphate rock (PR) deposits in WASAT including Tahoua PR (Niger), Parc-W PR (Niger), Kodjari PR (Burkina Faso), Tilemsi PR (Mali), Hahotoe PR (Togo), and Matam PR (Senegal) have been characterized and their

agronomic potential has been determined (McClellan and Notholt 1986). Results indicated that direct application of Tahoua PR and Tilemsi PR is both agronomically and economically feasible. Partial acidulation of the more insoluble rocks (Roy and McClellan 1986) has effectively improved their agronomic potential (Table 3) (Bationo et al. 1986, 1989, 1990, 1991, and 1992).

Table 3. Agronomic effectiveness of sulfuric acid-based 50% partially acidulated phosphate rocks (PAPR) in different ecosystems of West Africa.

Phosphate rock source (50% PAPR)	Soil order	Crop	Relative agronomic effectiveness ¹
Togo	Alfisol	Maize	90.0
Togo	Ultisol	Maize	66.7
Togo	Oxisol	Maize	108.9
Kodjari	Alfisol	Maize	84.1
Kodjari	Alfisol	Sorghum	81.3
Kodjari	Alfisol	Millet	108.9
Parc-W 50%	Entisol	Millet	93.4

1. Single super-phosphate = 100%

- The results have contributed to significant changes in some government policies. For instance, the Government of Mali is currently planning to replace imported P with Tilemsi PR. The Governments of Niger and Burkina Faso, have assessed the feasibility of establishing local fertilizer industries through the transformation of Parc-W PR and Kodjari PR.
- N¹⁵ studies have shown that the efficiency of N uptake in the WASAT is low and that losses of applied fertilizer-N up to 58% are common. These losses can be higher (75%) in farmers' fields (Christianson et al. 1990, Bationo and Mokwunye 1991).
- The use of legumes in a millet-based cropping system has been found to be an efficient way to apply N, especially to cereals that follows legumes (Figure 1).
- Using isotopic dilution N¹⁵ technique, it was found that up to 80 kg N ha⁻¹ could be fixed by cowpea under good soil management. Therefore, rotating a cereal with a legume is of great benefit in maintaining soil fertility in the WASAT (Bationo et al. 1991, 1994).
- Measures to correct negative nutrient balances have led to active research on integrated plant nutrient management, including efficient use of such natural resources as locally available agro-minerals combined with recycling plant nutrients from organic residues.
- The use of crop residues and manure are prerequisites to sustainable agriculture in the Sahelian Zone. Continuous cultivation without organic amendments usually results in serious soil degradation over time. The addition of organic materials either in the form of crop residues or as manure improves soil chemical and physical properties (Figures 2 and 3).

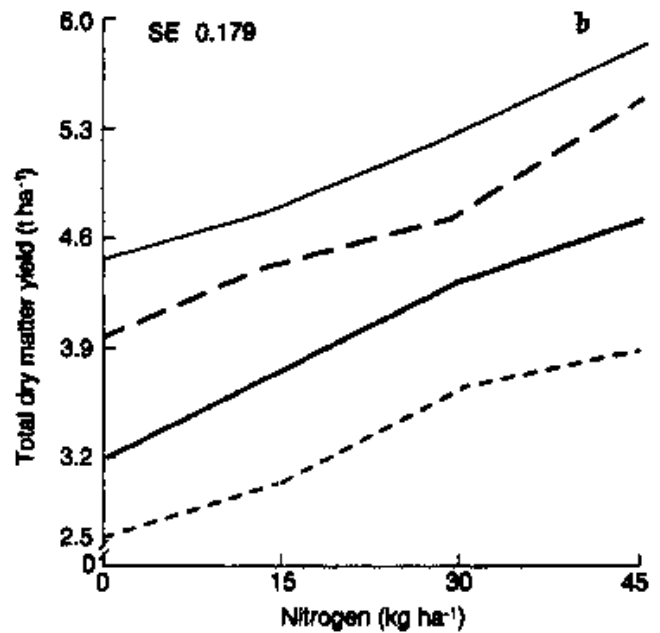
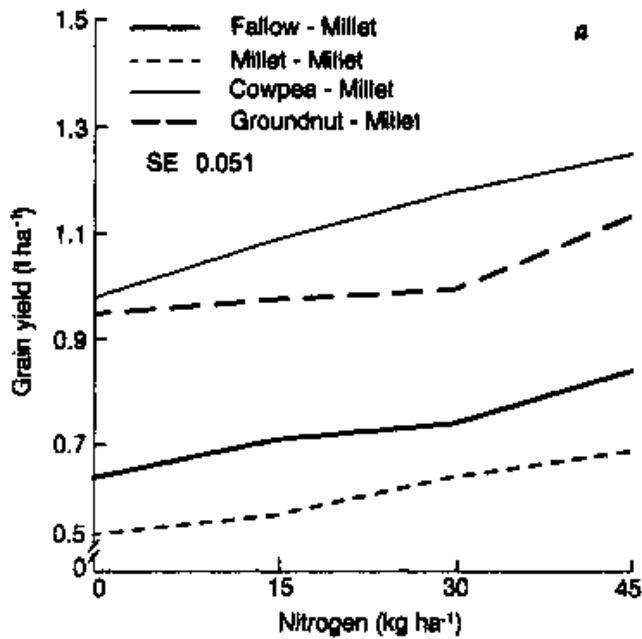


Figure 1. Increased yields of pearl millet as a result nitrogen and the cropping system at Tara, Niger 1989-92. (a) Grain yield ($t\ ha^{-1}$). (b) Dry matter ($t\ ha^{-1}$).

- Maximum sustainable crop production can be achieved by using both fertilizers and organic materials (Bationo and Mokwunye 1991b, Hafner et al. 1993, Bationo et al. 1993a and 1993b).
- As a rule, it would appear that sustainability is assured by applying manure or crop residues, and fertilizers, in combination with crop rotation.

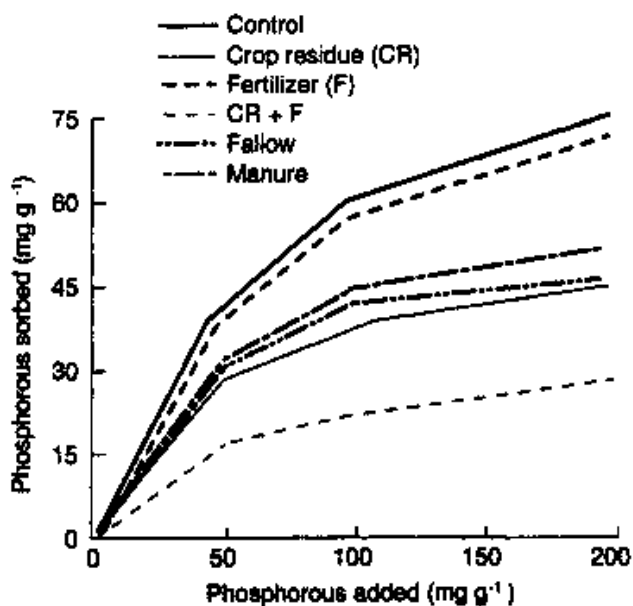


Figure 2. Increase in the sorbed phosphorus (at 0-10 cm depth) due to different management practices at Sadore, Niger rainy season 1991.

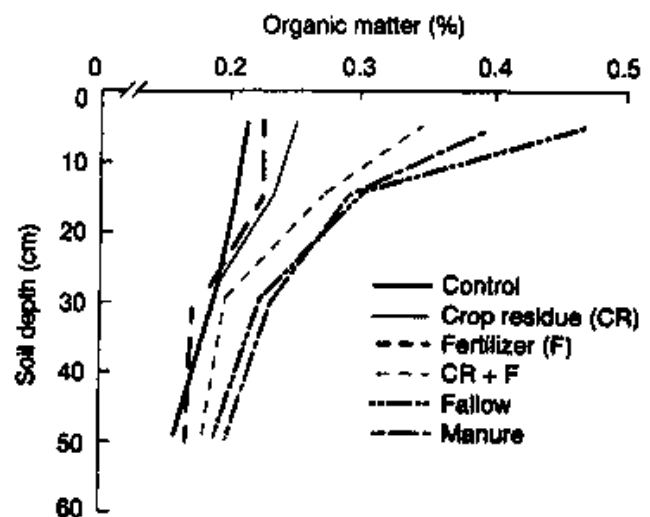


Figure 3. Effect of different management practices on soil organic matter content at Sadore, Niger rainy season 1991.

**International Centre for
Research in Agro-Forestry
(ICRAF)**

Most ICRAF research projects fit into ICRISAT's MCSP 1 and are carried out in collaboration with ICRISAT, ILCA, and the SALWA national programs. Such collaboration is particularly necessary if we are to; (1) identify traits that are adaptively and/or economically important in the appropriate agroforestry systems, (2) develop suitable methods to evaluate genetic variation in these traits, and (3) establish long-term trials of genetic variation.

The following species were selected for the initial phase of the ICRAF-ICRISAT MPT improvement project in SALWA: *Faidherbia albida*, *Prosopis africana*, *Combretum aculeatum*, and *Balanites aegyptiaca*. The species, which are indigenous to SALWA and other African regions, are valued for their fodder production and other species-specific proposes. The following projects were in progress, during 1993.

Genetic variation in growth, form, phenology, and fodder characteristics among open-pollinated families of *Faidherbia albida* and *Combretum aculeatum* in SALWA parklands

Objectives are to; (1) evaluate genetic variation in several MPT traits (e.g. growth, form, foliage phenology, foliage fodder value, and foliage decomposition rate) among open-pollinated families of *F. albida* and *C. aculeatum* in the parkland agroforestry systems of SALWA, (2) estimate genetic parameters for these traits, (3) evaluate index-selection methods for these traits, and (4) evaluate the level of genetic variation and the stability of traits with age, and in relation to the soils and meteorological conditions at the test site.



***Faidherbia albida*, showing its effect on pearl millet.**

Genetic variation within and among provenances of *Prosopis africana* and *Balanites aegyptiaca* in SALWA

Objectives are to; (1) evaluate genetic variation in several MPT traits (e.g., growth, form, foliage phenology, foliage fodder value, foliage decomposition rate, and drought tolerance) among open-pollinated families of *P. africana* and *B. aegyptiaca*, (2) estimate genetic parameters for these traits, (3) evaluate index-selection methods for these traits, and (4) investigate patterns of geographic variation in the traits.



***Prosopis africana* growing near local grain stores**

Variation in the breeding system and structure of genetic diversity in *Faidherbia albida* in SALWA parklands

Objectives are to; (1) develop laboratory methods for resolving isoenzyme variation in such vegetative tissues as leaves, buds, and root tips on rooted cuttings, (2) modify laboratory methods for cotyledon tissue culture to increase the number of resolvable enzyme systems as much as possible, and (3) investigate breeding system variation, genetic diversity, and genetic relatedness in SALWA parklands.

International Plant Genetic Resources Institute (IPGRI)

As a regional office, IPGRI at ISC provides technical and professional support to the development of germplasm activities in the region. These has been limited collaboration with ICRISAT agronomists in the characterization and evaluation of germplasm accessions, with agroforestry/ICRAF programs in the use of trees and forest reserve management, and with ILCA for handling the forage species. The cold storage facilities available at ISC are used to support IPGRI's germplasm conservation studies.

Contributions to ICRISAT's mission

As mentioned earlier, research on cereal-based production systems in the Western and Central Africa Region requires a strong multi-disciplinary approach. Collaborative efforts with other IARCs not only reinforced ICRISAT's core research on natural resource management, which was limited, but also helped to achieve synergisms that would not have otherwise materialized. For example, the livestock research agenda of ILCA perfectly complemented the millet cropping systems and agroforestry research carried out by the ICRISAT core group. Through collaborative trials and sharing of resources, the livestock component was integrated into ICRISAT's mission and both the centers achieved economies of scale that are so desirable under the prevailing funding constraints.

Similarly, collaboration with IFDC enabled integration of research on locally available agro-minerals and nutrient dynamics into ICRISAT core research on cropping systems and soil and water management. In operational scale research conducted on-station and on-farm, IFDC and ICRISAT scientists worked together to achieve the common objective of increased and sustained productivity of millet-based cropping systems.

Integration of inter-center research with national agricultural research systems (NARS)

Collaboration with IITA's cowpea program helped advance ICRISAT's cropping systems work on relay cropping and intercropping to the stage of operational-scale research, through contributing very useful information about suitable cowpea varieties.

These are only a few examples that illustrate the benefits of working together. Inter-center collaboration at ISC provides a good example to NARS in the region of how research on crop/tree/livestock interactions can be integrated in an operational framework.

The research programs of different international centers at ISC is closely integrated, mostly through existing networks, with ongoing work in different NARS, to improve zonal research coordination, and to identify research issues of mutual interest. The on-farm economic research of ILCA that involves typology of livestock production and animal traction is conducted in cooperation with the national department of rural economic research [Departement national de la recherche economique rurale (DECOR)] and the animal resource services [Services agricole de ressources animales (SARA)] of Niger. Agro-ecological research involving cropland forage and fodder resources and nutrient cycling, and research on animal nutrition, have been initiated with the Departments of Animal and Ecological Research of the Institut national de recherches agronomiques du Niger (INRAN), the University of Abdou Moumouni, and the Ministry of Agriculture and Animal Resources.

Collaborative networks in which ILCA actively participates include the Pan African Small Ruminant Meat and Milk Network, African Research Network for Agricultural By-Products (ARNAB), Sahelian Pastoral Monitoring Network, and Animal Traction Research Network (all ILCA-coordinated networks), and the West African Farming Systems Network.

Since the initiation of an IFDC-ISC Program in 1982, ISC has helped to establish the West African Fertilizer Management and Evaluation Network (WAFMEN). The initial meeting to establish WAFMEN was held in Niger in 1983. It began with collaborators from six national research institutions. Today, 19 national institutions in 14 countries are part of the network. Many WAFMEN collaborators are conducting more and more trials at different locations and are working with their extension colleagues to conduct on-farm trials—a measure of the confidence they have gained over the years.

IFDC-ICRISAT farmer-managed trials are designed to be managed entirely by farmers as a means of testing a particular technology and its interaction with farm management practices. National research and extension workers assist farmers and IFDC scientists in developing technology packages adapted to the means and circumstances of the farmers. The data generated are analyzed and maintained in an interactive database accessible to national collaborators. Such agronomic data, combined with socioeconomic data will form a base that can be used to formulate effective policies in different countries in the region.

Current members of the SALWA AFRENA include ICRAF, ICRISAT, and national agricultural research centers in Burkina Faso (IRBET), Mali (IER), Niger (INRAN), and Senegal (ISRA). SALWA is coordinated by an ICRAF scientist in Burkina Faso. Research, training, and other activities of ICRAF scientists are regional in scope and integrated with activities of all SALWA members. Researchers at ISC and most national programs in SALWA conduct considerable research on the agroforestry potential of *Faidherbia albida*. Researchers at ISC and/or some national programs have also worked on *Combretum aculeatum*, *Prosopis africana*,

and *Balanites aegyptiaca*. However, relatively little research has been carried out on the genetics of these four species.

Inter-center collaboration in training activities

Training national technicians and scientists through short- and long-term courses is of prime importance to all IARCs. At present, the programs of the different centers working at ISC provide financial assistance, and technical guidance and facilities for graduate students. These encompass a variety of subjects including soil and plant nutrient research, animal nutrition, forage agronomy, agro-ecology, tree genetics, and animal traction. A number of students from the University of Abdou Moumouni and other universities in the region together with students from universities in developed countries participate in these training programs. All the centers collaborate closely in organizing training courses at ISC. Future collaboration in this area is expected to increase with the increasing recognition that such courses bring together experts from different centers and are highly cost effective.

Although ILCA scientists consult an ILCA statistician who visits ISC regularly, they also interact frequently with ICRISAT senior statistician and their peers in the process of reviewing experimental protocols, research papers, and research reports.

Inter-center collaboration in information dissemination

ILCA-ICRISAT co-sponsored the International Conference on Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa (22-26 Nov 1993, Addis Ababa). The conference brought together national and international experts in livestock (cattle, sheep, and goat) nutrition and management, crop and forage production, soil science, and socio-economics, and addressed fundamental issues of nutrient balances, agricultural productivity, and the well-being of people, livestock, and the environment in the SZ.

Scientists from different centers collaborate actively in the preparation of journal articles and conference papers. The large number of papers published every year is an adequate testimony to the effectiveness of inter-center collaboration at ISC.

Conclusions

Future increases in productivity in the Sahelian region require the adoption of more integrated approaches to agricultural production. In recognition of the urgent need for knowledge to bring about sustainable increases in agricultural production, TAC proposed an ecoregional approach to focus and coordinate the research skills of the CGIAR in pursuit of this goal (TAC 1991). Three aspects of this research were recognized.

- Applied and strategic research on the foundations of sustainable production systems in the ecoregion
- The improvement of productivity in the ecoregion by drawing on appropriate global research activities
- Strengthening of cooperation with national partners and the development of transnational mechanisms of collaboration.

Research of different international centers at ISC embraces all these approaches and focuses on both applied and strategic research to improve the productivity of millet-based cropping the predominant production system in the Sahelian region. The global activities of the centers involved contribute to this aspect of research in the region. Effective partnerships with the appropriate NARS in the region are well established through the network mechanisms already operational within each center.

ICRISAT recognizes the advantages offered by inter-center collaboration in problem-solving and plans to further strengthen this approach in its medium term plan. Results of the past decade's cooperative activities provide ample evidence of the effectiveness of this approach to the benefit of all the participating centers.

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<i>Acronyms</i>	AFRENA	Agroforestry Research Networks for Africa (ICRAF)
	ARNAB	African Research Network for Agricultural By-products (ILCA)
	CGIAR	Consultative Group on International Agricultural Research
	DECOR	Departement national de la recherche economique rurale (Mali)
	IARC	International agricultural research center
	IBPGR	International Board for Plant Genetic Resources (Italy)
	ICRAF	International Centre for Research in Agro-Forestry (Kenya)
	ICRISAT	International Crops Research Institute for the Semi-Arid (India)
	IER	Institut d'economie rurale (Mali)
	IFDC	International Fertilizer Development Center (USA)
	IFPRI	International Food Policy Research Institute (USA)
	IITA	International Institute of Tropical Agriculture (Nigeria)
	ILCA	International Livestock Centre for Africa (Ethiopia)
	INRAN	Institut national de recherches agronomiques du Niger (Niger)
	IPGRI	International Plant Genetic Resources Institute (Italy)
	IRBET	Institut de recherche en biologie et ecologie tropicale (Burkina Faso)
	ISC	ICRISAT Sahelian Center (Niger)
	ISRA	Institut senegalais de recherches agricoles (Senegal)
	MPT	Multi-purpose tree
	MTP	Medium Term Plan
	NARS	National agricultural research systems
	PAPR	Partially acidulated phosphate rock
	PR	Phosphate rock
	SALWA	Semi-Arid Lowlands of West Africa (ICRAF)
	SARA	Services agricoles de ressources animales (Mali)
	SZ	Sahelian Zone
	TAC	Technical Advisory Committee of the CGIAR (Italy)
	WAFMEN	West African Fertilizer Management and Evaluation Network (IFDC)
	WASAT	West African Semi-Arid Tropics

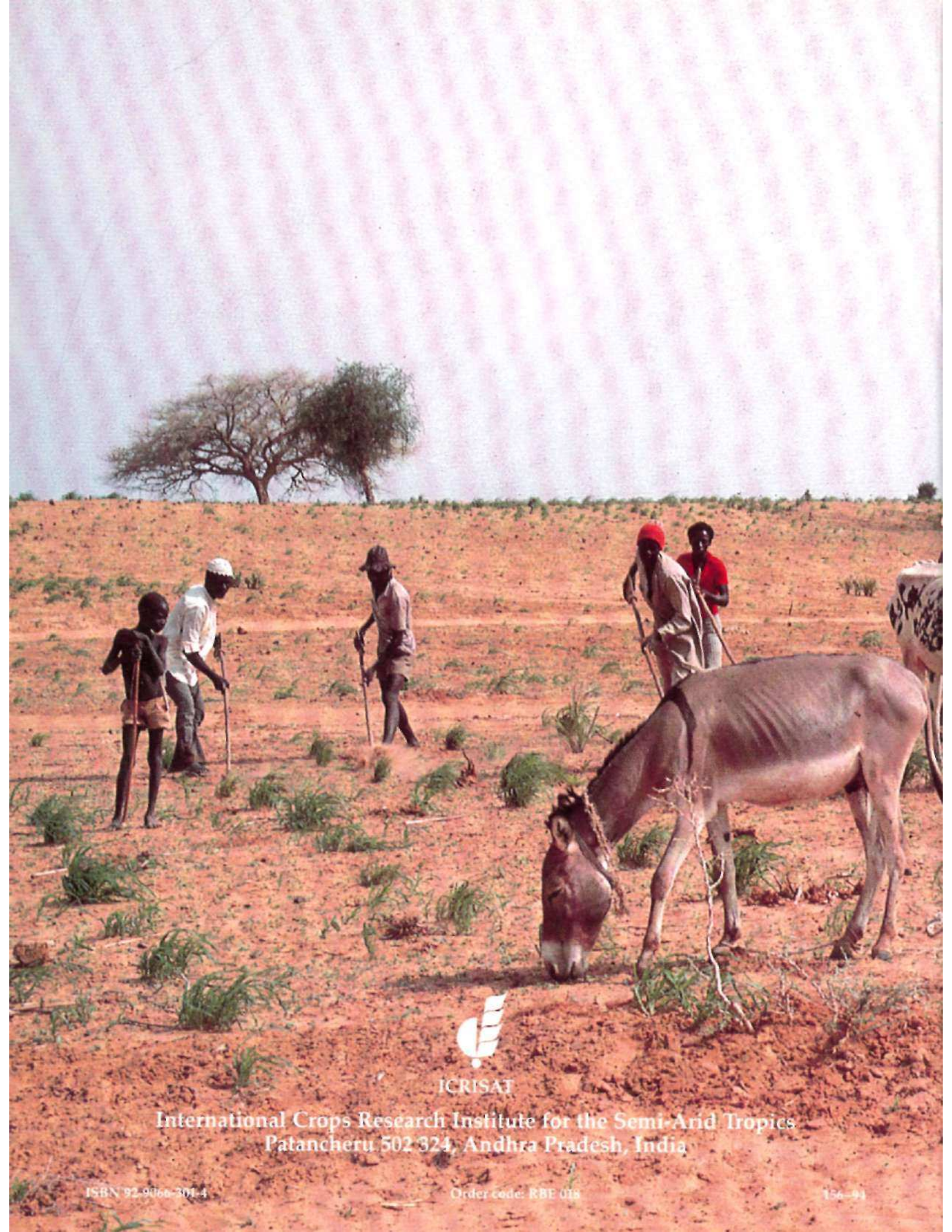
About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 17 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the World Bank, and the United Nations Development Programme (UNDP).

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