APPROPRIATE TECHNOLOGIES FOR SUSTAINABLE AGRICULTURAL PRODUCTION IN SUB-SAHARAN AFRICA

Proceedings of a Workshop on Appropriate Technologies for Developing Sustainable Food Production Systems in the Semi-Arid Regions of Sub-Saharan Africa, held at Ouagadougou, Burkina Faso. 11 - 14 April, 1989.

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Published by
OAU/STRC-SAFGRAD
Semi-Arid Food Grain Research and Development
Ouagadougou, Burkina Faso.
BP 1783

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This publication has been partially supported by the International Funds for Agricultural Development (IFAD)

An OAU/STRC-SAFGRAD Publication.

ISBN 978-2022-59-4

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PREFACE

The importance of appropriate technologies for the sustainability of crop, livestock and agroforestry production cannot be overemphasized. This realization led to the idea of bringing together experts in various disciplines to address this issue. This book is a collection of papers contributed during the "Workshop on Appropriate Technologies for Developing Sustainable food production systems in the Semi-Arid Regions of Sub-Saharan Africa ". The workshop which was funded by SAFGRAD was held April 11 - 14, 1989 in Ougadougou, Burkina Faso.

This book is divided into three parts. Part I "Farming Systems Research Development and Implementation" consists of four articles which highlight the role farming systems research can play in shaping the food and agricultural policies in sub-Saharan Africa. The food and agricultural production has to grow at a rate of 4 per cent per year in order to meet the needs of the growing population. The rapid growth in food production must come from a sustainable production system. Given the resource constraints, organizational complexities and vulnerability of the economics of the sub-region, it is necessary to develop a comprehensive agricultural system that is not only technologically sound, but economically, socially and ecologically stable. The methodology of Farming Systems Research (FSR) is capable of meeting this challenge if it can go beyond its present narrow focus and begin to address fundamental policy reforms in addition to generating technologies.

The need for each sub-Saharan African country to develop and implement FSR programmes is highlighted in this book. Attempts are being made by some countries to establish FSR programmes. The case of Nigeria is given in detail and the effort of SAFGRAD in establishing FSR programmes in Benin, Cameroon, Burkina Faso and Mali are cited. The activities of the West African Farming Systems Research Network (WAFSRN) in the propagation of FSR approach, serving as a medium of information exchange and provision of training avenues for member countries are also enumerated.

Varietal development and agronomic practices for increased production constitute the focus of part II. The development of early-maturing varieties is an ecological way of opening the short rainfall climate areas of the sub-regions to maize production. Regional and international research institutions like SAFGRAD, IITA and CIMMYT have, in collaboration with national programmes in the region, developed varieties that combine early-maturity with good grain yield. Improvement effort on other grains like millet, sorghum and cowpeas have begun to yield promising results.

The improved varieties are being tested under the harsh climatic and soil conditions of the semi-arid sub-Saharan africa. Agronomic practices to minimize drought stress and improving productivity of millet and sorghum-based systems by judicious use of fertilizers, tillage techniques and improved cultivation methods like tied-ridging are documented in detail. Soil and water conservation studies carried out in the sub-regions as well as crop and soil management practices needed to enhance productivity are the preoccupation of some contributors. Technology options for crop rotations with inclusion of legumes and alley cropping have been shown to be superior to farmers' traditional practices. A lot of technologies developed have been tested on farmers' fields to assess their technical, social and economic feasibility.

Part III concentrates on the role of livestock and agricultural production in sub-Saharan Africa. The relatively poor soils in the sub-regions inadventantly leads to the poor livestock feed quality which is a major constraint to ruminant productivity. For the purpose of removing this constraint, ILCA has, in collaboration with national research and development agencies, introduced forage legumes into the traditional and livestock husbandry systems. This introduction is meant to improve the quality of the feed available to ruminants and to promote sustainable improvements in crop yield.

Integration of the soil-crop-animal systems to achieve sustainability of production is inevitably burdened by many problems bordering on soil moisture, soil nutrients and feed nutrients. The use of forage or dual purpose legumes could go a long way in strengthening the integration of the three systems.

The role of trees and improved agroforestry systems in alleviating numerous agricultural constraints and improving food production is becoming more recognized. The book also discusses the interactions and integration of crops, livestock and trees and the research needs for efficient integration, management and utilization for sustained food and energy production. There is no doubt that the facts and figures contained in this book have been generated through several years of research endeavour. The purpose of this book is to sensitize policy makers into supporting and scientists into conducting more research to generate appropriate technologies that are technically feasible, economically viable, socially acceptable and ecologically adapted to achieve sustainability in food and agricultural production in the Semi-Arid Sub-Sahara African countries in not too distant a future.

PART I

FARMING SYSTEMS RESEARCH DEVELOPMENT AND IMPLEMENTATION

THE ROLE OF FARMING SYSTEMS RESEARCH IN SHAPING FOOD AND AGRICULTURAL POLICIES IN THE SEMI-ARID TROPICS OF SUB-SAHARAN AFRICA

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ABSTRACT

This paper highlights the debt and food crisis facing the sub-saharan region and proposes sustainable solutions to these problems. An important precondition for a lasting solution to these problems is the creation of sustainable food production systems. The agricultural research effort needed to accomplish this task will need to be characterized by imperatives that conform to the requirements of stable and sustainable agriculture. Farming Systems Research (FSR), because of its comprehensive and responsive nature, is appropriately equipped to achieve this goal. However, FSR must go beyond its present narrowly defined preoccupation of improving upon single commodity and single processes into examining fundamental and long-term policy issues.

I. INTRODUCTION

The boundaries of the Semi-Arid Tropics of Sub-Saharan Africa (SATSA) are quite imprecise in that their definition depends on a number of assumptions. While there is some consensus as to the drier limits of the zone, the definition of the wetter limits varies considerably. In this report, SATSA is defined as comprising all those countries in Sub-Saharan Africa with areas where the average precipitation equals or exceeds potential evapotranspiration for at least 70 days but not more than 210 days in a year. On the basis of this definition, SATSA encompasses: all of Burkina Faso, Gambia, Guinea, Guinea Bissau, Kenya, Senegal, Zambia, and Zimbabwe; at least half of Angola, Botswana, Ethiopia, Malawi, Mali, Mozambique, Namibia, Nigeria, Somalia and Tanzania; and smaller areas of Benin, Cameroon, Central African Republic, Cote d'Ivoire, Ghana, Mauritania, Niger and Togo.

Available statistics from the Economic Commission for Africa (ECA) show that the population of countries that fall into the SATSA is over 400 million and is growing at an average rate of over three per cent per annum with most of the population depending on agriculture and the rural areas for their livelihood and survival. Cereals occupy about 43.0 per cent of the total arable land of the SATSA. Twenty one per cent of this arable land is devoted to sorghum and millet production and about 10.0 per cent to maize. Between 1980 and 1987, the SATSA produced a total of 156 million tonnes of millet and sorghum and 117 million tonnes of maize. During the same period 53 million tonnes of rice and 650 million tonnes of root crops were produced in the SATSA. Between 1980 and 1987, agricultural and food production increased at an average annual rate of 1.2 and 1.5 per cent, respectively in the SATSA, much below the average rate of population growth. Cereal production only increased at an average annual rate of about 1.0 per cent during the same period.

These figures suggest that the food and agricultural crisis in Sub-Saharan Africa is still with us and will exacerbate if present trends continue. Furthermore, since the SATSA forms an important component of Africa, it must therefore, by implication, contribute significantly towards liberating the continent from the throes of its present poverty and economic stagnation.

II. FARMING SYSTEMS OF SATSA

It is difficult to generalize about the farming systems of the SATSA as these change not only as one moves from the drier tropical climates to the wetter ones but also as one moves from the western parts of the continent to the eastern parts. In the West African Semi-Arid Tropics (WASAT), millet predominates in areas with rainfall of 250 to 650mm while sorghum production is concentrated in areas having rainfall of between 650 to 1000 mm. Maize production is limited to the heavily fertilized soils adjacent to compounds and around swamps in the northern most regions of the WASAT but increasingly replaces sorghum in the cropping system as one moves progressively southwards. The major grain legume in WASAT is cowpea and is usually grown in mixtures with millet or sorghum (Matlon, 1987). The traditional system of crop cultivation is prevalent in the WASAT with most farmers growing their crops in mixtures in small and fragmented family farms, keeping some livestock including chicken, guinea fowl, ducks, small ruminants and in a few cases cattle. Matlon (1987) reports that support services to these farmers such as extension, credit, and input delivery are in most cases inadequate.

The most important crop in the Eastern and Southern African Semi-Arid Tropics (ESASAT) is maize occupying about 30 per cent of all areas under production. Collinson (1987) reports that in many areas, maize has replaced the traditional staples such as sorghum, finger millet, and bulrush millet. Small-scale farmers represent a large majority of the farm population in the ESASAT and produce the bulk of the food crops, although many countries in the subregion do operate an industrial farming sector producing mainly for export (ECA, 1988). The small-scale farms in the ESASAT are characterized by a heavy dependence on family labour; low level agricultural technologies; inadequate access to resources and government agricultural support services; poor access to markets; low levels of savings and investments; production decisions dominated by subsistence requirements; and a preponderance of women in agriculture (ECA, 1988).

Although one or two of the principal crops grown in the SATSA usually dominate in different zones, there exists considerable diversity in the cropping systems in the subregion brought about largely by considerable heterogeneity in the ecological conditions contained in it. The quantity and distribution of rainfall and the operating soil conditions usually determine the combinations of the major crops and the secondary crops which determine the important cropping systems in each zone. Most of the agricultural production in the SATSA is undertaken by small-scale resource-constrained farmers using primarily family members for labour and rudimentary hand tools as their primary farming equipment. In some areas, periods of peak labour and other input requirements necessitate cash expenditures for the hiring of labour and the purchase of inputs such as seed, fertilizers, and in some instances, chemicals.

In most cases, farmers in the SATSA continue to use the traditional practices their forefathers used and to grow their crops the same way as several generations before them. Several studies have, however, shown that there often exists good economic and social logic for the persistence of these farmers in growing their crops the way their forefathers did (Ryan *et al*, 1974; Norman *et al*, 1981a and 1981b).

III. THE PERFORMANCE OF SATSA AGRICULTURE

The production efficiencies for the principal crops grown in the SATSA are presented in Table 1. The ratings have been conducted using data supplied by the FAO. Giving the difficulties in collecting accurate agricultural data in Africa, it is suggested that these estimates be regarded simply as indicative of the general position. Of all the variables on which agricultural statistics are usually presented, the measures of yield is used here to gauge productivity. This is done since the efforts of many of the countries in the subregion have been directed towards improving the yield performance of the principal crops grown there. A useful exercise may therefore be achieved by comparing existing yield rates in individual SATSA countries with potential yield rates for the subregion. The potential yields for the principal SATSA crops are presented in Table 2. It should be pointed out that the assumptions that underlie the concept of potential yield as used here are largely biological in nature and we do know that there are logical, economic and social reasons why the established biological potentials cannot or have not been achieved. The estimates in Table 2, however, represent levels that have been achieved without much difficulty under controlled conditions in all the SATSA countries.

TABLE 1: Productivity ratings of principal crops in SATSA (1980 - 1987)

Country	Sorghum & millet	Maize	Rice	Roots & tubers
Angola	E	E	D	D
Benin	E	E	D	D
Burkina Faso	E	E	D	D
Cameroon	D	E	A	E
Central African Republic	D	E	D	E
Chad	E	E	E	E
Cote d'Ivoire	E	E	D	E
Ethiopia	D	D	–	E
Gambia	D	D	D	E
Ghana	E	E	D	D
Guinea	E	E	D	D
Guinea Bissau	E	E	D	E
Kenya	D	D	B	D
Madagascar	E	E	D	E
Malawi	D	E	D	E
Mali	D	D	D	D
Mauritania	E	E	B	E
Mozambique	D	E	D	D
Namibia	E	E	–	D
Niger	E	E	C	D
Nigeria	D	D	C	D
Senegal	E	E	D	E
Sierra Leone	D	E	D	E
Somalia	E	E	C	D
Sudan	E	E	D	E
Tanzania	D	D	D	D
Togo	D	E	D	D
Zaire	D	E	D	D
Zambia	D	D	D	E
Zimbabwe	E	D	–	E
Total SATSA	E	D	D	D

Source: FAO Production Yearbook Volume 41, 1988.

Notes:
A = Actual yield above 90% of potential yield.
B = Actual yield between 65% and 90% of potential yield.
C = Actual yield between 50% and 64% of potential yield.
D = Actual yield between 20% and 49% of potential yield.
E = Actual yield under 20% of potential yield.
– = Negligible production.

Table 2: Potential yield of principal SATSA crops

Crop	Yield (kg/ha)
Sorghum and millet	3,500.00
Maize	6,000.00
Rice (paddy)	4,000.00
Roots and tubers	30,000.00

The production efficiency for each crop is defined as the observed yield rate per hectare as a percentage of the potential yield rate. For purposes of comparison, the average yield for the period 1980 to 1987 is used to reduce the variation in the data that may be caused by other factors such as weather and to take into account the contribution to output brought about by increases in farmed area. The crude efficiency ratings presented in Table 1 suggest that all the SATSA countries are achieving yield performance that are far below potential levels for the principal SATSA countries. The simple fact is that, while agricultural research in almost all the SATSA may have resulted in the generation of new and improved crop and livestock technologies, in most cases, the farmers in the subregion have either been unable or unwilling to adopt these technologies on their farms in a widespread manner.

IV. THE ROLE OF FSR IN DEVELOPING SUSTAINABLE FOOD PRODUCTION SYSTEMS IN THE SATSA

The World Bank has estimated that to meet the needs of development during the next 20 years, food and agricultural production in Sub-Saharan Africa has to grow at a rate of at least 4 per cent a year. The productivity ratings in Table 1 suggest that, if present trends continue, the SATSA will not be able to achieve this minimum requirement for overall national and regional economic growth. However, to achieve this minimum growth rate target, national and subregional agricultural research will have to contribute significantly towards rapidly improving upon the existing food production systems, through technological change. This is particularly true for the SATSA where expansion in the cultivated area has ceased to be the major source of growth of output.

Experience has, however, shown that growth in food production *per se* will not by itself alleviate the food crisis facing the subregion. The rapid growth in food production must come from a sustainable food production system. Since SATSA food production systems are resource-constrained, organizationally complex, and ecologically vulnerable, the only way to improve upon them is through the development of a comprehensive agricultural system that is technologically, economically, socially and ecologically stable. The research effort needed to attain this sustainable food production system would need to be characterized by imperatives that conform to the principles of stable agriculture and, will, of necessity, have to be comprehensive and responsive in nature. Not only will it need to generate new and more appropriate technologies that are relevant to the conditions and circumstances in the farming system in which the majority of farmers operate, it will also need to focus on the interdependence and interrelationships that exist among the elements of the farming system and between these elements and the technical, economic, social and ecological environments.

Farming systems Research (FSR) is a philosophy and methodology that is capable of accomplishing this task because it is predicated on the assumption that radical changes of the farming systems currently preferred by the farmers, are not necessarily possible or desirable, at least, in the short term, but that the farming systems can be prompted to evolve over time as new and improved inputs are tested and introduced if found to be appropriate. The philosophy is amendable to the development of sustainable food production systems, because, if successfully pursued, it would result in a two-way interdependence of agricultural growth and sustainable flows of food and resources in meeting the basic needs of the farmers and producing a marketable surplus. FSR, viewed in this way, involves the interrelations of all the interacting components which make up the farming systems in the subregion: the land itself and the structure of farms and tenure systems imposed on it; the climatic, soil and soil fertility influences which operate; the labour resource and how it is used; the capital available for farm improvement; and the forces and conditions governing institutions and structures involved in the provision of marketing services, credit, extension, farm inputs, etc.

The usefulness of FSR in developing sustainable food production systems lies in its ability to permit planning backwards from a new and improved technology scenario which takes into account the implications of modifications of the existing system, as well as forward from the existing traditional farming system. The required sequence of events in this type of an FSR framework will include but not necessarily be limited to the following:

(1) Identify the constraints operating to limit sustainable food production in a given area.

(2) Evaluate on the basis of available information, possible technologies which might be used to overcome the most limiting of these constraints, not only from the viewpoint of their economic and social efficiency, but their ecological integrity.

(3) Test, usually on farmers' fields and in consultation with them, the technologies which appear to be appropriate and then either reject them or try something else, or modify them and try again, or accept them.

(4) Propose the necessary policy actions to facilitate their adoption.

(5) Monitor the adoption process and either;

- continue to modify the technology as necessary, and/or;

- propose additional policy options to ensure their sustainability, or;

- identify and propose solutions for the next most binding constraints,if any.

Figure 1 illustrates a schematic summary of the above sequence of possible FSR activities. This sequence of events is often broken down into a number of key research stages in which different types of agricultural research activities are carried out. These usually include: the design or planning stage, the testing stage, and the recommendation and transfer stage. It should be emphasized that the sequence of FSR events described above or their research stages often overlap and could be multi-directional.

V. FSR AND FOOD AND AGRICULTURAL POLICY CHOICES IN SATSA

In the preceding sections of this report we have described the important role that FSR can and should play in getting farmers to successfully move to higher levels of agricultural technology as a first step towards attaining sustainable food production systems in the SATSA. Others have, however, argued strongly that another equally important factor preventing the achievement of sustainable food production systems in Africa is the pursuit of inappropriate policies by African governments. Is the problem with the research strategy or with the bad policies being pursued by African governments? The answer is that the problem is more likely with both.

Farming Systems Research (FSR) can be used not only to generate new agricultural technologies that are relevant to the actual conditions and circumstances in which the majority of African farmers live and operate, but also to provide an understanding of how modifications in existing farming systems will result in changing patterns of resource allocation. Both of these understandings are useful in analyzing macro-economic processes and in shaping food and agricultural policies. The problem, however, is that FSR has traditionally been viewed as micro research. The preoccupation by donors and national agricultural administrators alike with quick and revolutionary results, has imposed a rather narrow definition of FSR on FSR practitioners in Africa. This narrow definition of FSR focusses on single-factor and single commodity revolutionary changes (green revolution) at the expense of the fundamental long-term changes that will ensure production stability and sustainability.

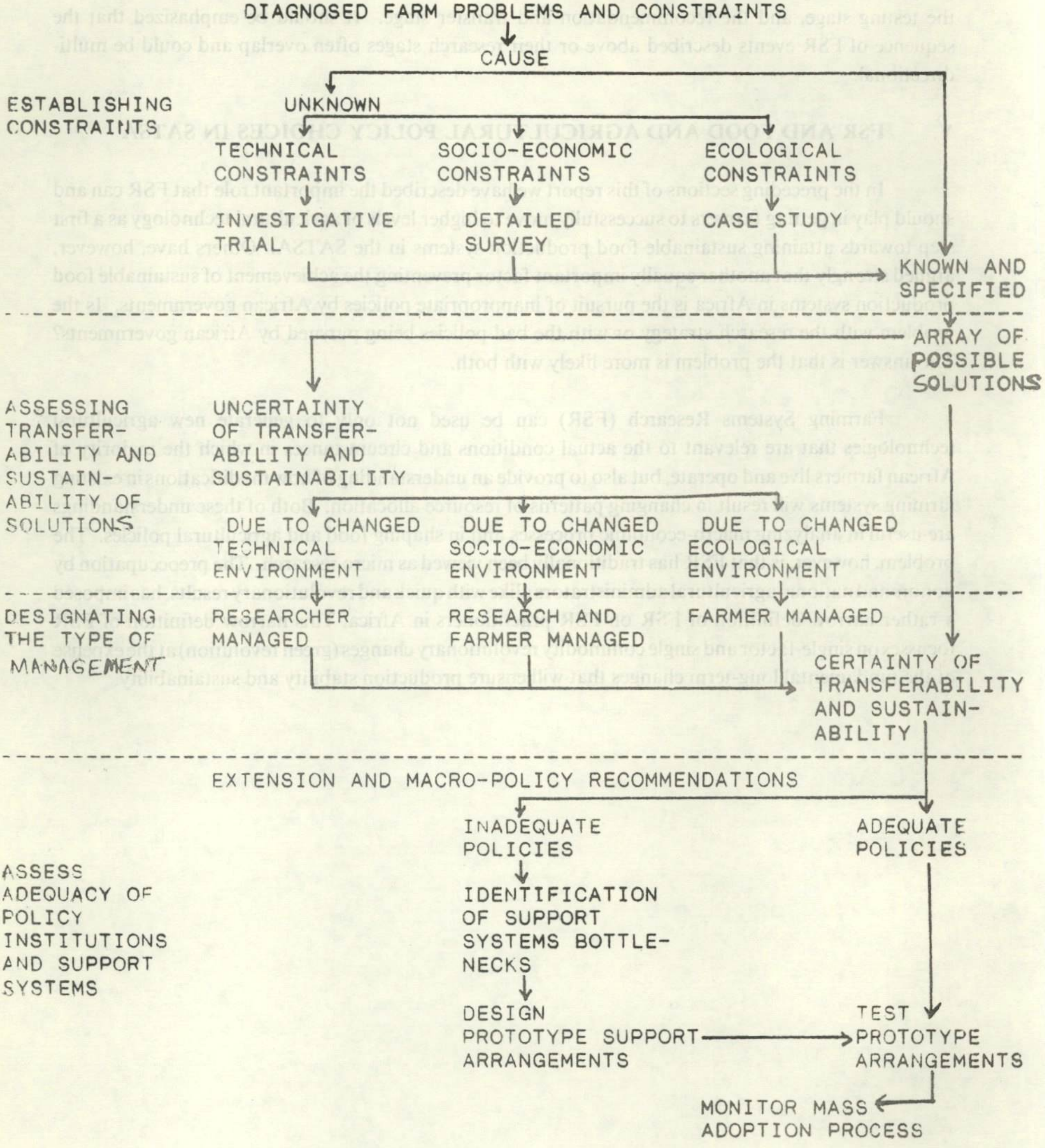

FIGURE 1: Schematic diagram of sequence of FSR activities.

It is my view that FSR will fail to make such impact in the SATSA unless it seeks ways of reforming existing *institutional and infrastructural support* services at the same time that it is promoting the generation and adoption of relevant and improved agricultural technologies. This is because, in most cases, without policy reforms, production stability and sustainability will not be possible. In other words, FSR can and should play the important role of providing informed parameters around which macro food and agricultural policies should be built.

However, in considering the role of FSR in shaping food and agricultural policies in the SATSA, a distinction has to be made between the short, medium, and long run. In the short-run endowment of resources would be fixed and institutional and infrastructural capabilities and the international environment to support them are likely to be inflexible. As such, the role of FSR would be largely restricted to the development and transfer of improved technologies whose adoption by farmers is not critically dependent on significant reforms of existing support systems. In this case, the principal contribution of FSR to policy formulation would be the identification and analysis of institutional and infrastructural constraints, appropriately packaging these in well written but simple reports and communicating them in a timely manner to the appropriate agricultural administrators. In the medium and long run, FSR would need to help shape policies aimed at explicit institutional and structural changes and reforms.

FSR can help shape policy choice in the SATSA in four different ways: technically, economically, socially and ecologically.

FSR and Technical Policy Choices

Many countries of the SATSA are presently not quite sure of how their existing low levels of agricultural technologies should be improved upon. This confusion has led to a proliferation of efforts to generate and transfer new technologies into the agriculture of the subregion. The problem, however, is that most of these efforts have aimed at transferring successful technologies and innovations by using, as building blocks, elements that made technological change successful in the developed countries. This strategy has not achieved much success in the past. Many countries are now trying to evolve a more coherent technology policy. FSR, with its systematic approach to technology generation, can assist these countries to evolve appropriate technology policies.

Furthermore, because the SATSA contains mostly sandy soils with poor water-holding and nutrient-retaining capabilities, variations in the distribution and amount of rainfall make the risk to crop failure due to the late arrival or early cessation of rains an important factor in any effort to create sustainable food production systems there. Macro-economic disequilibria are bound to arise as a result of exogenous shocks imposed on the economy by droughts resulting in harvest failures. Information flowing from FSR activities to government could assist in shaping the appropriate policy responses to these disequilibria. Such responses could take the form of the creation of an early warning system for crop failure, the formulation of a "second best' strategy with regards to cropping systems and input use, determination of the location, size and distribution of storage and transport facilities, etc.

FSR and Economic Policy Options

SATSA agriculture is organized around very small and scattered family or individual farms. In the past, production was maintained or even increased through extensive cultivation. However, increasing population pressures on land means that future increases in agricultural production in the SATSA would have to come either from hitherto unused land or from intensive cultivation using biological means to increase the productivity of land and labour. Policy choices are needed as regards the extent to which hitherto unused land can be committed to agricultural production *vis-a-vis* the feasibility of developing more intensive technical methods. FSR is in a position to provide the needed information to make these policy choices in the context of the existing resource base.

Another area in which FSR can be used to shape economic policy options is with respect to the interfacing of new technologies with the actual conditions under which different farmers operate. Since different farmers operate under different conditions, the profit maximizing incentives that are now increasingly being advocated and offered to all farmers may be entirely inappropriate for certain categories of farmers. For example, profit maximization is almost never the only objective of small farmers. Other goals that these category of farmers have include: meeting subsistence requirements, minimizing risks, and accumulating wealth. FSR can serve a useful purpose in predicting the responses of the different categories of farmers to different economic policy options and assessing their effects on agricultural performance, production patterns, resource use, etc. In addition, FSR can provide useful information that can be used to reformulate the conceptual basis of macro-economic analysis because it is capable of identifying how the different categories of farmers fit and interact within the wider economic and political systems.

FSR and Social Policy Options

One of the principal reasons for creating sustainable food production systems in the SATSA should be because agricultural administrators and planners want to use such systems to eradicate poverty in the subregion. If this premise is accepted, and because agriculture is a social subject, the primary focus of food and agricultural policy in the SATSA should be first and foremost on the farmer himself rather than on his crop or livestock as is presently the case. Changes in agriculture are at once influenced by social relations and themselves influence social relations within the society. Sound agricultural policies therefore require a good understanding of how agriculture is socially organized in the subregion and who gets what in the production process. A number of questions would need to be raised and answered. For example, who has control over new and/or improved agricultural resources? How has this control evolved over time and what form will it take in the future? Who is likely to benefit from the introduction of new technologies and what are the implications for overall economic development? FSR provides promising ways of thinking about these questions. This potential is clearly highlighted by Berry (1986) when he says:

> **"Policies designed to promote agricultural growth and/or extract agricultural surplus often change incentive structures and thereby affect the conditions of access to productive resources, patterns of resource allocation and division of labor, and the distribution of income and wealth, both within and among households and farms. By tracing these processes into patterns of exchange, conflict, cooperation, etc., between rural households (or communities) and other sectors of the economy, we can move towards the understanding of how intersectoral linkages actually operate, how they affect the level and direction of resource flows and how changes in agriculture actually shape - as well as reflect - developments in regional or national economies".**

The need for group participation in Sub-Saharan Africa has been widely recognized but not seriously pursued due largely to lack of understanding of the nature of group participation and co-operation in rural areas of Africa. FSR also provides promising ways of determining the scope for improving group participation and establishing effective community organization. Unfortunately, existing instructions in the subregion have not been effective in providing the necessary support for widespread adoption of new technologies. There is also considerable confusion as to how to set up new institutional support systems capable of effectively supporting new technologies. Experience would suggest that African agricultural administrators have tended to underestimate the contribution which so-called peasant farmers can, and should, be called upon to make to the agricultural development process. While there is no doubt that government should play a major role in bringing about technological change in agriculture, the number of people involved in agriculture and the responsibility involved in looking after them (and people in other sectors of the economy) are so large that government cannot do it alone. Farmers must be called upon to contribute in a major way. FSR can also play a major role here.

FSR and Environmental Policy Options

The net effect of introducing new technologies in the SATSA is to improve upon, albeit gradually, the farming systems in the region. This is particularly true for the SATSA where most of the new technologies on offer involve sole cropping. The ecological environment in sub-Saharan Africa is very fragile and more susceptible to degradation than most of the other continents in the world. This is even more true for the semi-arid areas of Sub-Saharan Africa which are prone to environmental degradation which depresses yields and, in some cases, eliminates hitherto usable land from production.

It is too early to know the eventual impact on the SATSA ecosystem of replacing or modifying the existing farming systems. One thing that is sure is that some of the classic advantages of the traditional ways of growing crops in the subregion would be lost. For example, the traditional methods of growing crops in mixtures not only maximizes the use of environmental factors such as light, water and nutrients, but can also result in supplementary or complementary symbiotic relationships between different crop species. Mixtures are also known to reduce the incidence and severity of pest attack and to control the incidence of weeds. Because many crops overlap in terms of the time they are in the ground, the growing of crops in mixtures is also said to extend the period of the year in which the soil is protected by leaf cover and root systems (Normal *et al.*, 1981a).

It is likely that changing the existing farming system in the SATSA would change the existing ecological balance in the subregion. For example, the present pest and disease situation is relatively low and has been kept so because inputs with built-in checks are being used and because over the years a balance between production and pest and disease resistance has been reached. Changing the existing farming systems is bound to disturb this balance. The balance would be affected in two ways. Firstly, since the new varieties being introduced do not have the advantage of having evolved over the years, they are more likely to be pest and disease prone. Secondly, since the new systems would also involve more sole and intensive cropping, their susceptibility to attack is greatly increased.

The advent of the green revolution in Asia has demonstrated the vulnerability of having genetically uniform species. The potential, however, of loss from disease, pest, and drought attack will vary from crop to crop and from area to area. The possibility of a breakdown of the existing ecological balance when the old system is modified or a new one introduced means that a protection umbrella involving increased use of crop production and protection chemicals must be provided if the new system is to be sustained. There are a number of critical issues here for SATSA agriculture as regards the possibilities of desert encroachment and the implications for increased application of chemicals.

Firstly, if current trends continue whereby the benefits of new technologies accrue mostly to large and more wealthy farmers, the tendency would be for farm sizes to increase rapidly. This in turn would lead to massive land clearing. The more widespread this tendency becomes, the more serious the problem of desert encroachment is bound to be.

Secondly, while the amount of chemicals currently being used on farms in the region is relatively low, the introduction of new sole crop varieties is likely to result in significant increases in the use of chemical inputs. Their use would conceivably become quite high as the preoccupation with sustaining increased levels of agricultural production continues. Their use could, however, prove to be quite dangerous as careless storage of the chemicals used could pose hazards to life. There is also the possibility of contamination of food and water through negligent use of chemicals. When one considers the fact that most farmers in the region are illiterates who can neither read nor write, the dangers involved become very real.

Finally, the normal ecological problems associated with intensive chemical application should also not be discounted. For example, the effect of long-term use of persistent chemicals cannot be overemphasized. The long dry season in SATSA makes this an area of concern. Another area of concern is the possibility of changing the ecological spectrum of the region. For example, the use of herbicides will change the spectrum of the weed population. New weeds not controllable by existing methods (hand cultivation and herbicides) could emerge. The same could be said of other chemicals as well. Furthermore, the dangers of massive use of wrong chemicals in the region cannot be discounted. For example, faced with the usual delays in the procurement of chemicals, large quantities of untested or even banned chemicals could find and have found their way into the subregion.

For sustainable food production systems to be created in the subregion, appropriate policies as regards conservation and the maintenance of the ecosystem must be evolved. FSR can provide the necessary information about environmental degradation in the subregion as well as about conservation efforts that have succeeded elsewhere in the subregion. Such information will be useful in carrying out macro-analyses and formulating macro-policies and processes. FSR could also play a useful role in providing the conceptual framework for creating the institutions and structures needed to protect the environment from degradation.

VI. CONCLUSION

Sub-Saharan Africa could be said to be faced with one of the greatest calamities of the century. Even the great depression of the early 1930's pales into insignificance when compared to the current crisis facing the subregion. During the last decade, the United Nations Economic Commission for Africa through such documents as the Lagos Plan of Action, the United Nations Programme of Action for Economic Recovery of Africa of 1986, the Abuja Declaration of 1987, the Khartoum Declaration of 1988 and Africa Alternative to Structural Adjustments: A Framework for Transformation and Recovery of 1989, has been in the forefront in highlighting the debt and food problems facing the subregion and proposing sustainable solutions to these problems.

The creation of sustainable food production systems in Africa is an important precondition for a lasting solution to the current crisis facing the region as most countries in the subregion are locked in the double-edged dilemma of either servicing their debt or feeding their people. The achievement of sustainable food production systems in the semi-arid tropics of sub-Saharan Africa is itself a precondition for the attainment of overall substainability in food production in Sub-Saharan Africa, not only because countries that have substantial areas that fall into the subregion contain about 75 per cent of the total population, but, more importantly, because the SATSA region produces a significant amount of the food staples of Sub-Saharan Africa but is most vulnerable to the vagaries of climatic, socio-economic, and environmental conditions.

In order to liberate Sub-Saharan Africa from the throes of hunger and malnutrition and to create a situation in which the subregion can feed itself in a suitable manner, ways must be found to ensure sustainable food supplies from SATSA. The agricultural research effort needed to accomplish this task will need to be characterized by imperatives that conform to the requirements of stable and sustainable agriculture.

Farming Systems Research, because of its comprehensive and responsive nature, is appropriately equipped to achieve sustainable food production systems for the SATSA. However, in order to be able to achieve this task, FSR in the SATSA must go beyond its present narrowly defined preoccupation with how to improve upon single commodity and single processes and begin to examine fundamental and long-term policy issues concerning production stability and sustainability associated with the management of the natural resource base of the subregion. In the short-run, the success of each nation in the SATSA in achieving a sustainable food production system will depend on how well it responds to its existing endowment of resources, available technologies, and environment within its institutional capability and policy structures. In the medium- and longer-run it will depend on the extent to which FSR can successfully contribute towards the promotion of institutional and structural policy reforms to promote the continuous adoption of improved technologies on offer, improve the resource endowment, reduce pressure on the environment, and further improve the levels of available technologies.

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OVERVIEW OF THE SAFGRAD FARMING SYSTEMS RESEARCH SUPPORT EXPERIENCE 1980 - 1989

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ABSTRACT

In this paper a short historical review of SAFGRAD's collabortive effort in the development of farming systems research in the National Agricultural Research Systems (NARS) is highlighted. The problems encountered by the NARS in attempting to institutionalize FSR is discussed. The advantages and disadvantages of four types of institutional arrangements are given as well as the conditions for improving national FSR capacity.

INTRODUCTION

Farming Systems Research (FSR) within the SAFGRAD Project was started a decade ago in collaboration with the National Agricultural Research Programme (INERA) of Burkina Faso and Purdue University. A major contribution of Farming Systems Unit (FSU) was the development of FSR methodology, proposal of technologies that could increase the production of food grains (i.e. soil fertility improvement, water retention techniques, and the use of improved varieties that exploit moderate levels of inputs). A number of other technological options were tried (i.e. tied ridging, chemical fertilizers, animal traction, crop associations, etc) one at a time and in combination, in order to determine the synergistic effects of agricultural inputs in increasing the yield of food grains.

Based on the experience of FSU/SAFGRAD three pilot projects within the national research programmes of Benin, Burkina Faso and Cameroon were established since 1985. The project through International Fund for Agricultural Development (IFAD) funding was structured not only to bring together on-station scientists and development planners in order to gain closer understanding of the total farm interaction, but also to enable each FSR team in the National Agricultural Research System (NARS) to carry out its rigorous testing of technological innovations. It was also to determine that research results are adaptable and profitable. The long-term objective of the programme has been to facilitate the "fitting of FSR" into the national agricultural research and extension structure.

Since 1970's some so-called FSR projects which were limited in scope, mushroomed in many countries of Africa. What has been lacking in most of these programmes was the integration of an agro-ecological conceptual framework of resource-based disciplines (i.e. characterization of the climate, ecology, socio-economics etc) into the agricultural production systems. The FSR programme that has been pursued by FSU/SAFGRAD during the last four years comprised of sub-systems of production (such as cropping, livestock, agroforestry etc) and management of available resources such as labour, land, capital and off-farm activities. Farming Systems Research philosopy places special emphasis on the systems approach in the generation and dissemination of improved agricultural technologies based on farmers' needs.

The purpose of this paper is to share some experiences on institutionalization of FSR. In most national research programmes, the FSR team is composed of professional researchers, and technicians on one hand, extension agents and farmers on the other. The functional linkage and interface activities of these entities are critical both for the adoption of technologies and viable development of national FSR. One of the most crucial aspects of FSR is to organize a cohesive and motivated interdisciplinary team. This can be partially attained through continuous dialogue in order to arrive at a common conceptual FSR framework. Definition and clarification of FSR is the starting point although there could be various perceptions of FSR by researchers, research administrators, donors etc.

Through interaction in the above mentioned FSR in Benin, Burkina Faso and Cameroon, an attempt was made to develop common understanding of FSR within the national research framework. From technical operation view point, FSR is an approach to research that is system-based and interdisciplinary in its research composition. Its holistic character attempts to understand the farm as a unit comprised of various sub-systems i.e cropping, livestock sub-systems, trees, shrubs and off-farm activities. The socio-economic consideration is an essential element of FSR.

What would be the expected output of FSR? This could depend on the set of predetermined objectives. From FSR institutionalization point of view, the transformation of particular national agricultural research programme towards interdisciplinary research approach is relevant. FSR could therefore influence a research output. The identification and evaluation of suitable technologies, and reorientation of research priorities and strategies are also expected achievements of FSR interaction. Furthermore, attempts to elucidate the rationale for adoption or rejection of technologies. From its clients (farmers and extension agents), FSR provides feedback information to reasearch and development organizations.

Modes of Organization of FSR

While signifcant attention was given to the development of FSR methodology, little effort was made in fully integrating this approach within NARS research process during the last two decades. The institutionalization challenge of FSR was underestimated. As a result, many NARS have encountered signifcant problems and confusion in integrating FSR into their research and extension activities. The recent study by Merryl-Sands and McAllister both of ISNAR (1988) provided a body of practical experience on the organization and management of FSR in different NARS.

Four types of FSR institutional arrangements have been documented in Sub-Saharan Africa (Heinrich *et al.*, 1989). The advantages and disadvantages of these arrangements are briefly described below:

i) **FSR could be structured as a department or as a programme of a particular national research institute** (e.g. INERA/FSR of Burkina, IER/FSR programme of Mali, etc). The FSR team could be based in a major Agricultural Experiment Station with local or regional research mandate. The team is usually responsible for the design and analysis of research, largely implemented in a number of research sites by the technicians whom the FSR team visits periodically.

Advantages

It could:

a. provide horizontal connections with other departments or programmes;

b. provide vertical links with policy and decision making groups;

c. provide strong and well defined operating procedures and operational set-up; and

d. attract more resources.

Disadvantages

It could:

a. get too big and become competitive with other research departments;

b. lead to overlapping of research mandates of different departments;

c. create frictions and interdepartmental communication problems; and.

d. tend to look inward rather than opening up, thus leading to "compartmentalisation".

ii) **Interdisciplinary or interdepartmental research arrangement.** The development and implementation of FSR programmes are monitored by an interdisciplinary committee. A typical example of such an institutional arrangement exists at Ahmadu Bello University in Nigeria (Faculty of Agriculture and Institute for Agricultural Research). Different programme leaders are requested to contribute their expertise to a common FSR programme. The basic idea is to have individual team members, provided by their respective departments, to work together on an FSR programme.

The advantages of such an arrangement are that it allows researchers to retain their departamental affiliation and identity; creates less friction between departments; has a better chance of transforming the methodology of agricultural research and of generating a long lasting programme. As a disadvantage, it may not attract funds because the programme could have diffused boundaries and departmental interests.

iii) **FSR is a separate programme often loosely tied to national research project, programme or development agency.** In such a situation, scientists of NARS are seconded for the life of the project.

Advantages

The FSR programme:

a. could be implemented according to schedule due to ease of availability of resources.

b. could be autonomous administratively and scientists could be based at project sites;

c. attempt to explain rationale for adoption and rejection of technologies and eventually provide feedback to research and development organizations.

d. scientists could be directly involved in all phases of research and could also be in constant contact with extension agents and farmers.

Disadvantages

The programme:

a. could have the least influence in the institutionalization of FSR within the national research structure;

b. team could be isolated from other researchers,

c. relatively more expensive since most of FSR scientists could be expatriate;

d. may not always be attuned to realistic situations and resources of the particular national research and extension system.

iv) **No separate FSR team or department.** This is slightly similar to "ii" mentioned above since the FSR programme goals are incorporated with other research programmes. Scientists of the station are responsible for both on-station and on-farm research.

Advantages

The programme could:

a. provide relatively strong linkage between on-station and on-farm research.

b. be considered as an interdisciplinary research approach by the entire research and research management staff of a particular Agricultural Experiment Station;

c. have more focused mandate and development target groups;

d. be least expensive.

Disadvantages

a. The experience would be highly localized;

b. The change of researchers could be a set-back to continue the FSR research concept;

c. It could be least attractive to obtain more research allocation from national and donor sources due to lack of clarity of programme objectives and schedule of implementation.

Conditions for Improving National FSR Capacity

Improvement of the national FSR capacity and its institutionalization is not an easy task and requires a long period of research experienc and resource support. An important aspect of this phenomenon is the perception of FSR which varies considerably among researchers, policy makers, development agencies, research administrators, extension workers etc. FSR is perceived in some countries in its narrow scope i.e. as pre-extension activities limited to multi-locational agronomic trials with socio-economics research support. In its fullest development, FSR includes various sub-systems of production. With regards to linkages of FSR to on-station research, one school of thought is that FSR as an approach to research should also conduct on-station research in order to motivate thematic researchers. This implies that researchers engage in interdisciplinary research activities since FSR and on-station research should be complementary sets of activities. The other prevailing view is that FSR activities should be limited to on-farm since station-based research focus should be to generate technologies (varieties, etc) to obtain optimum yield under specific conditions. Once technology is made available, the assumption is that FSR should work on the adaptive end of the spectrum by evaluating technologies to fit different socio-economic and environmental conditions.

The assumption is that relevant technologies could usually be made available from on-station research. The experience of several NARS seems to indicate that in practice integration between thematic on-station research and FSR is difficult to achieve. Conflicts and misunderstandings among thematic researchers and FSR have been observed in many cases. The conflict could be exacerbated when FSR activities are carried out in relative isolation. Conflicts arise from divergent perception of priority of research and strategies. Differences in research objectives, methods, and modes and basic approaches further exacerbate the area of conflict.

Thematic research and FSR differ in their strategy even though they should have common goals and clients, i.e., to improve the standard of living of the farmer. Other aspects of institutionalization of FSR are:

1. Institutionalization of FSR within a particular NARS is slow and could delay the evolution of relevant farming system.

2. FSR scope was limited to cropping system in many countries of Africa without concurrent integration of complementary sub-systems of production (i.e. livestock, agroforestry, etc...)

3. The efficiency of external technical FSR support is much influenced by particular NARS research capabilities such as institutional setting, linkages, defined research objectives, priorities, and perception of FSR. As a result, the pace for developing relevant farming system is much influenced not only by available resources, environmental and socio-economic factors but also by the interactions of the above mentioned research parameters.

As Heinrich *et. al.,* (1989) pointed out, "There are many methodological and implementation issues still to be resolved in the FSAR, which is not surprising perhaps, since the actual use of the FSAR is still relatively new in many countries of sub-Saharan Africa. But the consensus seems to be emerging that the FSAR, together with the establishment of good links between on-farm research and on-station component research groups, can help in improving the research product and thus, hopefully, the welfare of limited resource farmers in the semi-arid areas of sub-Saharan Africa".

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RESEAU D'ETUDE DES SYSTEMES DE PRODUCTION EN AFRIQUE DE L'OUEST (RESPAO) PRESENTATION ET PROGRAMME D'ACTIVITES

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ABSTRACT

The reason for the creation of the Farming Systems Research Network (FSRN) in West Africa, the objectives, statutes and activities are explicated in this write-up.

I. POURQUOI UN RESEAU RSP?

La forte croissance démographique et La pression qu'elle entraîne sur les terres cultivables est généralement admise comme une des causes profondes des problèmes de production alimentaire et de la crise économique auxquels font face la plupart des pays de l'Afrique au Sud du Sahara et de l'Afrique de l'Ouest en particulier. La sécheresse et d'autres facteurs ont sérieusement aggravés la situation. Bien que les paysans aient essayé d'adapter leurs systèmes traditionnels de production en adoptant quelques techniques ameliorées, l'accroissement de la production et de la productivité qui en résulte reste très en deça du rythme nécessaire pour faire face à la croissance démographique et à l'amélioration du bien-être des populations. Paradoxalement, les résultats des recherches sur les productions végétales, animales et forestières obtenus dans les stations de recherche ont été rarement adoptés par la majorité des paysans.

Aussi, dans les années dix-neuf cent, soixante dix, une tendance de plus en plus nette s'est dessinée pour conduire les recherches dans les champs des paysans de façon multidisciplinaire et avec la participation des paysans. Parmi ceux-ci, les petits paysans ont reçu une attention particuliere. Cela a permis d'identifier leurs contraintes reelles et d'oeurver a l'adaptation des résultats de la recherche à leurs conditions et à leurs besoins. Cela a aussi permis aux chercheurs de modifier et de redéfinir leurs programmes de recherche pour répondre aux priorités des producteurs. Vers la fin des années dix-neuf cent soixante dix, un nombre limité de pays de l'Afrique de l'ouest avait une expérience de la Recherche sur les Systèmes de Production (RSP) ce qui a amené les donateurs à soutenir un nombre croissant de projects visant à l'implanter dans les systèmes nationaux de recherche agricole.

Le consensus sur l'importance de la RSP pour améliorer l'agriculture paysanne en Afrique de l'Ouest n'empêchait pas les divergences entre instituts nationaux et internationaux de recherche, et entre les chercheurs concernant les buts, le domaine et la méthodologie de la RSP.

En Novembre 1982, un atelier fut tenu à l'IITA, à Ibadan (Nigeria) avec l'objectif général de création d'un Reseau d'Etude des Systèmes de Production en Afrique de l'Ouest afin de faciliter les échanges d'information, les communications, et les rencontres, avec comme résultat majeur une mailleur compréhension et une mise en commun des recherches, travaux et résultats entre scientifiques, techniciens et acteurs du développement, grace à un langage, des méthodologies, et des stratégies plus proches. Un comité de pilotage, un président et un coordonnateur furent élus et chargés de la définition de l'organisation et d'un programme d'activités pour le reseau, et de la recherche des moyens nécessaires à son execution.

L'absence de statut juridique, indispensable pour recevoir des subventions de donateurs, liée au caractère professionnel du reseau, et d'un coordonnateur à plein temps, n'ont pas permis d'atteindre les objectifs fixés.

Un symposium a été tenu en mars 1986 à Dakar (Senegal) sur la RSP en Afrique de l'Ouest. Des chercheurs des institutions internationales et de 16 pays sur 17 de l'Afrique de l'ouest y participerent alors que 7 pays seulement étaient presents en 1982 à Ibadan.

Objectifs

L'objectif général de RESPAO est de promouvoir et faciliter la coopération entre les chercheurs, les programmes et les institutions de recherche nationaux, internationaux et extérieurs travaillant en Afrique de l'Ouest dans le domaine des recherches sur les systemes de production. Cette collaboration devrait permettre de soutenir les chercheurs et de renforcer les programmes nationaux à travers la formation, les échanges d'expériences méthodologiques, les comparisons de résultats et un meilleur accès à l'information.

Les objectifs spécifiques sont:

-De stimuler la collaboration en matière de planification et d'évaluation des recherches sur les systèmes de production en Afrique de l'Ouest.

-D'améliorer les pratiques méthodologiques à travers les échanges d'expériences notamment en organisant des rencontres, des voyages d'étude de chercheurs et toute autre activité repondant aux besoins des membres.

-D'organiser, d'aider à organiser et institutionnaliser des activités de formation concernant l'approache RSP en direction des chercheurs et des autres acteurs de dévelopment rural.

-De collecter, traiter et diffuser les résultats pertinents de la RSP et notamment d'encourager les chercheurs à publier leurs résultats de façon à ce que ceux-ci soient largement disponibles à toutes les parties intéressées: chercheurs, institutions de recherche, agents et responsables de la vulgarisation, producteurs agricoles, organismes professionnels et responsables de la politique agricole.

-D'assister à leur demande, les chercheurs, les programmes et les institutions nationaux dans la planification, la mise en oeuvre et l'évaluation de recherches sur les systèmes de production et eventuellement l'élaboration de requêtes de financement.

Dans la réalisation de ses objectifs, le RESPAO tient à collaborer avec d'autres reseaux ayant un champ d'intérêt plus spécifique.

Le reseau entend s'appuyer sur les centres internationaux et les organismes extérieurs de recherche agricole.

Les premiers bénéficiaries de son programme seront les chercheurs et dans une certaine mesure les vulgarisateurs en contact avec les chercheurs. En dernier ressort, les paysans et surtout les petits paysans de la region seront les beneficiaries des technologies améliorées qu'ils auront contribuées à mettre au point.

Statut

Le RESPAO est une association professionnelle. Il est ouvert à tous les praticients s'intéressant à la recherche sur les systèmes de production en Afrique de l'Ouest, qu'ils travaillent ou non dans les organismes internationaux, étrangers, nationaux de recherche, d'enseignement supérieur et de vulgarisation. L'adhésion se fait à titre individuel et se limite à un enregistrement auprès du secretariat. Il n'y a pas de droit d'adhésion ni de cotisation annuelle à acquitter.

Conformément à la décision du Symposium de mars 1986, un protocole d'accord a été signé avec la Commission Scientifique, Technique et de la Recherche de l'Organisation de l'Unité Africaine (OUA/CSTR). Cet accord fait bénéficier le reseau du statut juridique de l'OUA. Ainsi tous les actes officiels du RESPAO sont effectués par le Secrétaire Exécutif de la CSTR. **Le Secrétariat du reseau est placé au sein du Projet de Recherche et Développement des Cultures Vivrières dans les Zones Semi-Arides (SAFGRAD) de l'OUA/CSTR à Ouagadougou, Burkina Faso.** Le SAFGRAD apporte son appui en matière de gestion en contrepartie de frais de gestion versés par le RESPAO.

Organisation

-**Le Symposium Bi-annuel** se réunit sur un thème qui permet aux chercheurs de présenter et de discuter de leurs expériences. Il est aussi l'assemblée générale du reseau: bilan des activités, définition des orientations et élection du Comité de Pilotage.

-**Le Comité de Pilotage** est élu pour deux ans. Il définit le programme d'activités et contrôle sa mise en oeuvre par le secrétariat. Il comprend 9 membres: 7 élus à titre personnel dont au moins 4 provenant des organismes nationaux de la region (1 seule personne élue par pays) et 2 des organismes non nationaux, plus un représentant du SAFGRAD et le coordonnateur. Il élit son président et sélectionne le coordonnateur. Il se réunit au moins une fois par an.

-**Le Secrétariat** est chargé de la préparation et de l'exécution des activités. Il est dirige par le coordonnateur qui est permanent depuis novembre 1987.

-**Les Correspondants Nationaux** sont les relais du secrétariat pour la circulation de l'information et la participation des chercheurs nationaux aux activites. Ils sont designes par les responsables de la recherche agricole parmi les praticiens de la RSP.

II. ACTIVITES

Le Comité de Pilotage a arreté un programme d'activités pour 1988 et 1989 en avril 1988. Ce programme a été discuté avec les responsables nationaux de la RSP réunis à Ouagadougou, Burkina Faso, en octobre 1988 et réajusté compte-tenu des priorités dégagées et des ressources disponibles. Ce programme comprend les volets suivants:

Information Scientifique et Technique:

L'objectif est de collecter, traiter et diffuser les informations utiles pour la RSP. Le système comprendra;

-une **Cellule de Documentation Informataisée** gérée par un documentaliste avec une base de données sur les organismes, les programmes et les chercheurs RSP en Afrique de l'Ouest et une base de données bibliographiques. L'accent sera mis sur la littérature non-conventionnelle produite au niveau national. Une collaboration négociée avec les organismes internationaux et étrangers permettra d'inclure dans la base de données les documents traités par ces agricole derniers. Les utilisateurs, professionnels et organismes du secteur, pourront recevoir les informations sur profil, et à la demande et des copies de documents. Un répertoire et une bibiographie de la RSP en Afrique de l'Ouest seront publies annuellement.

-le **Bulletin Trimestriel du RESPAO** publié depuis 1986 et qui donne des informations sur la vie du reseau, de courts articles methodologiques et de recherche, proposés par les adhérents, des annonces de séminaires, conférences, publications, etc...

-la **Revue Scientifique** qui sera publiée à partir de fin 1989 et sera semestrielle dans un premier temps. Un Comité Scientifique et un éditeur à plein temps en cours de recrutement auront la charge de la revue. Les articles publiés couvriront toutes les recherches menées en milieu rural et non exclusivement la RSP.

Formation:

Le reseau compte surtout identifier les besoins en formation des praticiens de la RSP et aider les institutions nationales dont c'est la vocation à y répondre.

- Un **Cours Annuel de Formation à la RSP** va être crée par le Centre Universitaire de Dscahng, Cameroun, en collaboration avec l'Institut de Recherche Agronomique, pour les chercheurs débutants de l'Afrique de l'Ouest et du Centre. Le premier cours aura lieu debut 1990. Un protocole d'accord a été signé entre l'IITA, l'Université de Floride, le Réseau Recherche/Développement français, le RESPAO et le CU Dschang pour assister ce dernier dans l'organisation et l'animation du cours ainsi que la recherche des ressources financières.

- Un **Atelier de Formation à la Rédaction Scientifique** a été retenu et devrait être organisé dans les mêmes conditions.

Ileme Symposium:

Le deuxième symposium du réseau se tiendra du 28 août au 1 septembre 1989. Le thème retenu est **"Contribution de la Recherche sur les Systèmes de Production au Développment de Technologies Améliorées pour les Zones Agro-Ecologiques de l'Afrique de l'Ouest"**. Le texte d'annonce a deja été diffusé et les inscriptions se font auprès du secretariat.

Appui aux Systèmes Nationaux de Recherche:

Le réseau se propose à la demande d'apporter un appui aux organismes, programmes et chercheurs nationaux. Ces appuis peuvent porter sur des aspects méthodologiques ou techniques, sur la formation, sur l'élaboration de programmes de recherche et sur la planification de la RSP. Les compétences et les ressources disponible ne permettent pas pour l'instant d'en faire une priorité.

Le réseau a déjà eu à appuyer la Direction de la Recherche Agronomique de Guinée-Conakry et le Centre Universitaire de Dschang pour la formation en RSP.

Ateliers, Séminaires, Voyages d'Etude:

Le réseau compte à partir des conclusions et recommandations du Iléme Symposium organiser des réunions scientifiques et des voyages d'études. Il est aussi ouvert à toute proposition de coorganisation et de parrainage de telles activités.

Recherche Collaborative

Le réseau compte initier et animer la recherche collaborative entre équipes de la région et en faire une activité prioritaire comme l'ont recommandée les responsables nationaux de la RSP réunis en octobre 1988 à Ouagadougou. Le RESPAO est en train d'examiner les thèmes d'intérêt commun et les possibilités de financement. Le IIème symposium devrait notamment permettre de dégager des thèmes de recherche collaborative qui seront ensuite soumis aux donateurs sous forme de projets régionaux.

PROGRAMME QUINQUENNAL 1990 - 1994.

Un programme de cinq ans doit être elaboré. Il devrait permettre de renforcer les activités en cours et de mieux repondre aux besoins des adhérents.

FARMING SYSTEMS RESEARCH DEVELOPMENT IN NIGERIA

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ABSTRACT

The need for Farming Systems Research (FSR) strategy in Nigeria has been prompted by the fact that the new technologies developed using the conventional research system did not make far reaching impact. This paper gives the historical evolution of FSR in Nigeria using the Institute for Agricultural Research (IAR) as a case study. The linkages existing between research and extension in Nigeria are described. The implementation of FSR at the national level and the establishment of the National Farming Systems Research Network are highlighted. The paper concludes that FSR practices in Nigeria had yielded a measure of success but warns that FSR is a relatively expensive research strategy that needs adequate research funds which should be made available at the right time.

I. INTRODUCTION

Nigeria is fortunate to have a substantial base of agricultural research infrastructure, knowledge as well as human resources. Nigeria occupies a land mass of over 98 million hectares of which about 75% is suitable for agricultural activities, even though the amount of this cultivable land area is somehow diminishing due to natural phenomena such as erosion, desert encroachment and urban development and expansion. Over 70% of the nation's population depends directly or indirectly on agriculture for their livelihood. Rainfall and temperature constitute the two most important features of Nigerian climate, which is characterized by distinct dry and wet seasons.

The country has a wide variation in the agroecological zones ranging from the mangrove fresh water swamps in the south to the Sudan and Sahel savanna zones in the north. In fact, Nigeria is endowed with almost all the six ecological sub-divisions that can be found across West Africa and this makes it a convenient location for agricultural research activities.

The wide variation in climate and vegetation permits the production of a range of crops which include tree and arable crops. The climate also favors the rearing of livestock with the largest concentration in the northern parts of the country. In order to hasten the pace of technology generation, the Nigerian government has established a number of research and training institutions to cater for the crops and livestock in different ecological zones. There are at present 24 research institutes in the Federal Ministry of Science and Technology (FMST). Eighteen of these institutes deal wholly or partially with agricultural problems in addition to 16 universities with faculties of agriculture, two full-fledged universities of agriculture and one international institute (IITA). Each of the institutes has been provided with a set of statute, which defines its functions and areas of influence. Apart from these institutes and other 28 degree-awarding institutions, there are over 55 other institutions which offer middle-manpower level training at certificate and diploma levels. In spite of these natural and human endowments, the country still faces severe food and raw material short-falls like other developing countries.

II. WHY FARMING SYSTEMS RESEARCH?

A number of factors have led to the development and popularity of the FSR approach to research as we know it in Nigeria today. Nigeria has been facing some socio-economic problems which could best be described as a crisis situation. The crisis which has been looming since the early 1970s has rapidly escalated to a critical level during the 1980s. Prominent among the problems is the gradual decline in agricultural and per capita food production resulting in critical food shortages and rising food prices.

Despite the number of institutions dealing with agriculture and all the technologies being generated, there is still a wide gap between the results being obtained by the farmers and on the experimental plots of the research institutes (Table 1). This is because most of the technologies are not being adopted by the majority of farmers. Because agricultural policies are usually based on the belief that available technologies, if adequately exploited by farmers, are capable of leading the country into self-reliance in the production of most food crops and raw materials in the medium-term, the inability of the majority of the farmers to utilize available improved technology has been a source of considerable concern to both agricultural researchers and administrators.

Table 1: Yield performance of major food crops at three levels of technology under sole cropping.

Crop	Farmer's Practice			Research Station Practice	
	Traditional Technology (kg/ha)	Improved Technology (kg/ha)	Increase (%)	Improved Technology (kg/ha)	Increase (%)
Sorghum	785	1680	114	3920	399
Millet	740	1344	82	2800	278
Maize	1046	3002	187	7840	650
Rice	940	144	54	3360*	257
Wheat	1750	**	–	4500	157
Cassava	5570	11263	102	22580	305
Yam	5272	9004	71	20070	280
Groundnut	586	1120	91	2240	282.

Source: Adapted from Abalu, G.O.I., 1987.

*: Refers to upland rice; best swamp rice yields of 4800 kg/ha and irrigated yields of 5600 kg/ha have been recorded.

**: Not available.

Both state and federal governments in Nigeria have attempted not only to arrest the food crisis but also to attain self-sufficiency in food and raw material production by instituting a number of agricultural policies and programmes. These include:

- Operation Feed the Nation (OFN) in 1975 which only created awareness of the importance for farming;

- National Accelerated Food Production Programme (NAFPP) in 1972 to enhance the rate of technology transfer of specific crops;

- River Basin Development Authorities charged primarily with water resources following a huge investment on large-scale irrigation schemes;

- World Bank-Assisted Agricultural Development Projects.

- Green Revolution in 1980 - aimed at rapidly moving the country towards self-sufficiency in food, and recently,

- Directorate of Food, Roads, and Rural Infrastructure (DFRRI) established in 1985.

A critical review of the performances of most of these strategies described above and the huge investments involved indicates that a high proportion of efforts have been wasted and unproductive. This is mainly because the strategies and technologies being promoted are either unprofitable or not feasible for the farmers to adopt under their circumstances. Another constraint is the lack of discussion with the farmers and rural dwellers by those planning the projects and lack of knowledge of the existing farming systems.

This situation gave rise to doubts as to whether the existing technologies are not relevant enough to alleviate the constraints of the small-scale farmers whose productivities have to be increased in order to be able to continue to produce the bulk of food and export crops in the economy. Since the small-scale farmers operate within farming systems that have complex interrelationships coupled with interhousehold complexities, it became obvious that the orthodox disciplinary and commodity approach to technology generation and dissemination could no longer adequately provide the needed relevant technologies acceptable to the majority of the farmers. Farming systems approach is therefore seen as an alternative.

III. FARMING SYSTEMS RESEARCH STRATEGY

The need for Farming Systems Research (FSR) strategy has been prompted by the fact that new technologies that have been developed so far in the country have not made far reaching impact. A new methodology that would lead to the development of improved agricultural techniques appropriate to the needs and circumstances of the majority of farmers in the country could be found in FSR with its orientation towards conducting at least part of the research on farmers' fields.

Farming Systems research approach focuses on the dynamics of small-scale farm operations with a more holistic and interdisciplinary approach. It is concerned with the interactions of all the interacting components making up the farming systems in an area. According to Abalu (1984), FSR is different in the following ways:

(i) It involves an explicit attempt to understand the farm, the farmer and farm environment as a system of interdependent parts;

(ii) It initiates the research process with an attempt to analyze the characteristics of representative target farmers and target villages;

(iii) It permits the entire process of research, including the analysis of the farming systems, the technology development and testing, and the verification of the results to be carried out by interdisciplinary teams of social, technical and biological scientists while involving the target farmers.

FSR requires that the researcher studies the farmer's conditions at the onset, keep these conditions in mind during research and implementation, and use the knowledge of the conditions in evaluating and analyzing results.

IV. EVOLUTION OF FARMING SYSTEMS RESEARCH IN NIGERIA

The Institute for Agricultural Research (IAR), Samaru, is one of the earlier institutes in the country to operate a functional FSR programme. The system in IAR is similar to what other institutions in the country are using today. Although the farming systems research has only recently gained wide-spread interest, it has a long history in northern Nigeria. For many years since the establishment of IAR in 1922, the emphasis was on on-station trials without adequate diagnosis of the problems prevailing at the farmers' level or contribution of the social scientists. As far back as 1958, questions have been asked on the validity of using the highest yield per hectare as a criterion for recommendation without considering how the cultivation of a particular crop could best be fitted into the farming systems of the farmer. With the inception of Rural Economy Research (RERU) in 1966, which was later known as the Department of Agricultural Economics and Rural Sociology, a type of FSR was introduced into the research outfit in the form of Farm Management Studies (Norman, 1972). Crop mixtures as against sole crop started to receive some attention during this time. Norman's pioneering work in Kaduna, Bauchi and Sokoto states provided a definitive diagnostic survey of peasant farming (Abalu and Raza, 1984). Attempts were made in getting farmers involved much earlier in technology development and generation on inter-disciplinary basis. Norman *et. al.,* 1976a and 1976b) tested recommendations for sole crop cotton, maize and sorghum. Ogungbile and Ogborn (1982) investigated an on-farm economic evaluation of herbicide use among farmers in Kaduna state. Similar studies were conducted by Olukosi and Lagoke (1982). In most of these studies, all the production inputs were provided by the researcher while the farmer provided labour and management. Some of these studies were carried out within the crop-based programmes.

With the federalization of Ahmadu Bello University in 1975, a new statute for IAR clearly mandated the institute to conduct research into the development of the farming systems which involve crops in the areas under its mandate. The statute thus paved the way necessary for reorganization and revitalization of research on inter-disciplinary lines by removing the institute from a rigid departmental and sectional headship structure to a more disciplinary crop-based programmes and farming systems research programme.

Research Programmes and Committees in IAR

Prior to 1980, there were no standard guidelines as to the conduct of the FSR Programme. Between 1975 and 1982, FSR was carried on in IAR under what is known as Socio-Economic Committee. By July 1983, research at IAR was organized on the basis of four crop-based programmes and four supporting programmes. The crop-based programmes are: Cereals, Legume and Oilseeds, Cotton and Other Fibres, and Horticultural Crops, and the servicing programmes are: Farming Systems Research, Agricultural Mechanization, Irrigation, and Food Science Research Programmes. The necessary inter-disciplinary communication between programmes is achieved through Research Review Committees (RRC's) identified for each programme. Each programme is headed by a Leader and the RRC which he presides over is comprised of a team of scientists of various disciplines. Attendance of meetings is open to all research staff. It is the responsibility of the committees to prepare research plans which represent the priorities prescribed by the Board of Governors for the approval of the Professional and Academic Board.

FSR is currently popular in Nigeria. It was not so about a decade ago. Its popularity was due to the pioneering work at IAR on this research strategy between mid-1960 and 1981. Today, most of the principal food crop research institutes in the country have active FSR programmes and practitioners, hence the need and justification for the creation of National Farming Systems Research Network.

V. FARMING SYSTEMS RESEARCH PROGRAMME AT IAR

Farming Systems Research Programme (FSRP) is one of the supporting programmes and it is at the centre of the major reorganization at IAR as all the research activities of the other programmes have a direct bearing on its activities. In its present structure, it combined the objective of the original FSRP and Soil and Crop Environment Programme and it is made up of the most important interacting components which make up the farming systems of the area.

The overall objective of the FSRP of the institute is to generate knowledge concerning the farmer, his farm, and the environment in which he works and lives as a system of interdependent parts with a view to evolving improved agricultural technologies which will alleviate his important constraints and enable him to increase his production and improve upon his welfare.

To facilitate the achievement of the general objective of the programme, the activities of the programme are carried out through sub-programmes, projects and sub-projects. The present structure of the programme is shown in Figure 1. Sub-programmes are:

1. Surveys Sub-Programme

The projects of this sub-programme are as follows: (a) Diagnostic Surveys, (b) Soil Surveys, (c) Data Systems, (d) Other Surveys.

Diagnostic Surveys Project

The major objective of the diagnostic or exploratory surveys is to identify and describe important cropping systems and utilize the knowledge in shaping cropping systems research at IAR.

Several diagnostic surveys have been conducted in various parts of the northern states such as in Kano (1982), Plateau (1983), Gongola (1984), Sokoto (1985) and Kaduna (1986).

The results from these surveys have been used to identify cropping patterns and crop mixtures of the survey areas to determine priorities for further research and technical constraints of the area. Other surveys are undertaken on request to provide definite answers to specific problems such as the outbreak of a particular disease or insect attack.

Soil Surveys Project

The main objective of the soil survey projects is to classify, describe and map the soils of northern Nigeria at the reconnaissance level in order to provide useful information for land use planning.

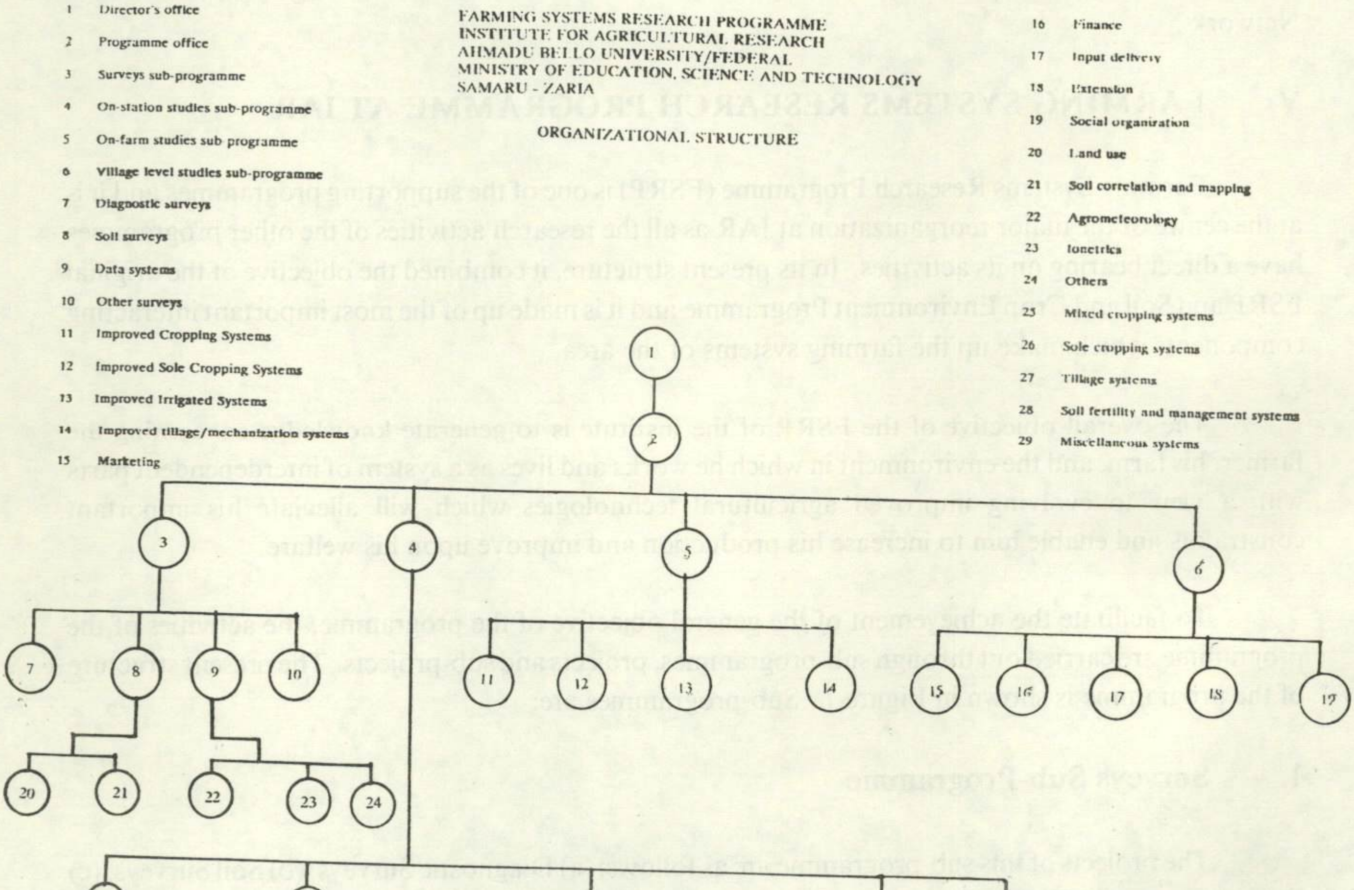

Figure 1: ORGANIZATIONAL STRUCTURE

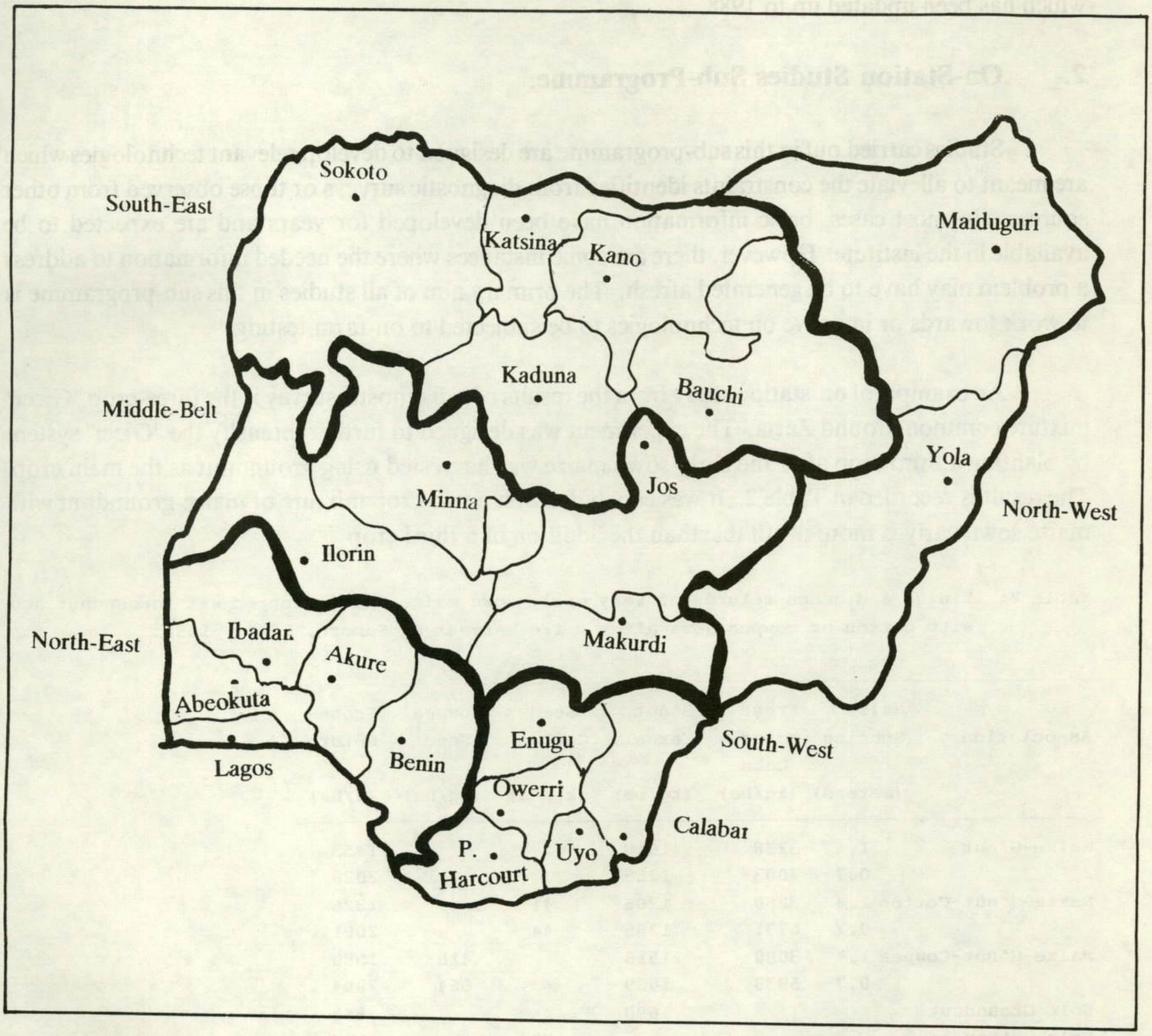

Figure 2: Map showing mandate areas for the five crop-based zonal Agricultural Research Institutes in Nigeria.

Data Systems

This project concentrates on evolving appropriate data computing system. The primary objectives of the data system project are to provide data storage base, to assist in the interpretation of field research and climatic information of relevance of agriculture. An example of the achievements of this project is the production of atlas maps and the "Yearly Bulletin of Meteorological Information" which has been updated up to 1988.

2. On-Station Studies Sub-Programme.

Studies carried out in this sub-programme are designed to develop relevant technologies which are meant to alleviate the constraints identified from diagnostic surveys or those observed from other sources. In most cases, basic information have been developed for years and are expected to be available in the institute. However, there are some instances where the needed information to address a problem may have to be generated afresh. The primary aim of all studies in this sub-programme is to work towards or improve on technologies to be subjected to on-farm testing.

An example of on-station study from the results of a diagnostic survey is the three-crop "Gicci" mixture common around Zaria. The experiment was designed to further intensify the "Gicci" system by planting a third crop after the early-sown maize was harvested using groundnut as the main crop. The result is recorded in Table 2. It was concluded that a two-crop mixture of maize-groundnut with maize sown early is more profitable than the addition of a third crop

Table 2: Yields and gross returns of very early sown maize inter-cropped with groundnut and with cotton or cowpea sown after maize harvest at Samaru, 1980 - 1982.

Association	Maize Spacing (meters)	Fresh Maize Cobs (kg/ha)	G'nut Kernel (kg/ha)	Seed Cotton (kg/ha)	Cowpea Seed (kg/ha)	Gross Return (N/ha)
Maize-G'nut	1.4	3238	1610			1453
	0.7	7003	1255			2028
Maize-G'nut-Cotton	1.4	3280	1296	41		1326
	0.7	6731	1265	44		2001
Maize-G'nut-Cowpea	1.4	3080	1518		410	1580
	0.7	5938	1069		564	2004
Sole Groundnut			1690			845
Sole Cotton				227		114
Sole Cowpea					1088	544
SE +/-		484	291	23	100	

3. On-farm Sub-Programme

The main objectives of most of the studies under this sub-programme are:

(i) to test the most current promising improved technologies arising from on-station studies sub-programme, other research programmes of IAR and other institutes in and outside the country. It is essential that the technology has the potential to alleviate some identified constraints,

(ii) to assess the costs and determine the level of dependability of output and income from a given improved technology, and,

(iii) to identify constraints to adoption and to use the test results to improve further the technology for mass adoption.

Based on the level of management and the involvement of the farmer, on-farm studies are classified as follows: (a) Researcher managed and executed, (b) Researcher-managed and farmer-executed, (c) Farmer-managed and executed.

On-farm studies on the sole crops are for the meanwhile housed in the commodity based programmes while the on-farm studies on crop mixtures are carried out within the FSRP. During 1988/90 cropping season, collaborative studies were undertaken between researchers at IAR and the ADP staff in three of the five states in testing recommended practices for 8 different crop mixtures. The current thinking is that all on-farm studies should be jointly conducted by the institute's research staff and the extension staff of the ADPs.

A typical example of studies conducted to alleviate identified labour constraint is the on-farm evaluation of chemical weed control in maize production (Ogungbile and Lagoke, 1986). The result indicated that the use of herbicide reduced time required for weeding, delayed hoe-weeding and consequently reduced the labour demand during the months of June and July by 38%. Based on income returns and labour use per ha, herbicide technology proved superior to hoe-weeding. A similar study on sorghum production revealed that chemical herbicide (sorgoprim) was not effective in controlling weeds. This gave rise to another study to evaluate alternate herbicide chemicals.

4. Village-Level Studies

Studies carried out in the village-level sub-programme are mainly aimed at identifying institutional constraints operating in the farming systems in the area and finding solutions to the constraints. The research team in this sub-programme is currently looking into different extension methods, input delivery systems, credit schemes which are subject to experimentation with the aim of evolving prototypes suitable to the circumstances and situations being affected by farmers. Routine data collection and analysis of prices of commodities in Zaria area is a major function of the sub-programme. Other project areas include marketing, finance, input delivery, extension and social organizations.

VI. LINKAGE BETWEEN RESEARCH AND EXTENSION

1. Research Extension Linkage

Technologies are generated in the research institutes and extension services disseminate the information to the ultimate users, the farmers. The role of linking research to the farmers has been for a long time the responsibility of the Agricultural Extension and Research Liaison Services (AERLS). Another extension strategy that was intended to pursue an integrated approach of research and extension was the National Accelerated Food Production Programme (NAFPP). These projects' performances have been below expectation as they failed to incorporate the farmers into their programmes of research and extension activities (Abalu, 1987). A new extension that has been introduced into the country to provide effective research extension linkage is the Training and Visit (T & V) system of extension with the Monthly Technology Review Meeting as one of its key features.

2. Monthly Technology Review Meeting

Monthly technology Review Meeting (MTRM) is the hub of the T & V extension system currently in use in Nigeria. The main objective is to train ADPs' extension and technical specialists known as the Subject Matter Specialists (SMSs) directly by researchers, particularly in the production recommendations that the extension workers teach farmers over a four-week period which usually starts about two weeks after the MTRM.

The significance of MTRM lies in the face to face dialogue it affords between research and extension. It gives the SMS the opportunity of gaining first-hand knowledge regarding the production recommendations coming from research institutes. It also allows researchers the opportunity of having a first-hand knowledge of field problems and how all their recommendations are able to address identified problems. It therefore fosters the desired strong linkage between research and extension.

3. On-farm Adaptive Research on Crop Mixtures

For the first time, On-farm Adaptive Research (OFAR) projects were jointly carried out by IAR and state ADP's during 1988/89 cropping season. A total of 127 farmers participated in testing IAR suggested practices for eight different mixtures. The technologies consist of different arrangements and combinations of crops in the mixtures, crop varieties, fertilizer rates, spacing, planting densities, pests and disease co[illegible]l and other improved cultural practices that had been earlier tested at the on-station trials in IAR. [illegible]rity of the participating farmers attested to the superiority of IAR technology.

4. Small Plot Adoption Techniques (SPAT)

The impact of the MTRM is expected to be measured on farmers' fields. The extension messages are expected to be transformed into small adoption plots in which the Village Extension Worker (VEW) teaches the farmers the new techniques on a 10 x 10 m plot size. The SPAT results during 1988 cropping season across states show that the percentage yield increases of the new technologies over the farmers' practices was as high as 60%.

VII. ACHIEVEMENTS OF THE PROGRAMME

As a result of the above strategy, the programme has accomplished the following:

(1) Diagnostic surveys of most of the major farming systems in northern Nigeria have been conducted. These surveys have provided researchers in the institute with a concrete basis for finding solutions to "real" and "identified" farming problems as opposed to conducting research to solve "assumed" problems.

(2) A number of soil surveys have been conducted. These surveys are aimed at classifying, describing, and mapping the soils of the savanna zone of Nigeria at reconnaissance level in order to provide the much needed information for proper land use planning.

(3) The programme is providing environmental data support to aid the interpretation of field research and to determine historical and probable future trends of climatic elements of importance to agriculture.

(4) The programme is developing a range of improved technology strategies both for mixed and sole cropping systems that would successfully remove identified farming constraints in northern Nigeria.

(5) The programme continued to demonstrate the importance of fertilizer in the attainment of self-sufficiency in food production in the country while at the same time identifying fertilizer sources and cultural practices that tend to degrade the soils and suggesting ways of avoiding those negative effects.

(6) The programme continues to evaluate promising crop production strategies at the farm level and under farmer conditions and circumstances. Particular attention is being paid to those strategies and improvements in technologies which may be useful in removing real and identified farm constraints.

(7) The programme is conducting research that would provide government with policy options concerning appropriate institutional support for rapid agricultural development of the country.

(8) The programme is able to establish and foster the desired linkages between research, extension and the farmer through Monthly Technological Review Meetings and On-farm Adaptive Research.

VIII. IMPLEMENTATION OF FSR AT NATIONAL LEVEL

Enhancing agricultural production is one of the major goals of Nigeria's agricultural policy and Nigeria's small-scale farmers are referred to as the centre-piece of the country's agricultural production. But in order to increase the aggregate production, these farmers must be encouraged to adopt and use improved agricultural technologies. To achieve this objective, agricultural research must be linked to farm production i.e. to what is happening on the field. Somehow, the country's agricultural administrators seem to believe that FSR, with its orientation towards grass roots agricultural development and its emphasis on-farm adaptive research, appears to be the right research approach for creating the linkage between agricultural research and production in the country. The Federal Ministry of Science and Technology has so far reacted in the following ways towards the development of FSR in Nigeria.

(i) In 1981, it directed that all research institutes concerned with food production should each evolve a FSR programme.

(ii) In 1982, it organized a training workshop on FSR for the researchers in the institutes.

(iii) In 1983, it appointed a National Coordinator for FSR in the country.

(iv) Between 1983 and 1985, FSR was one of the twelve Nationally Coordinated Research Projects created. Others are on maize, rice, cowpea, soyabean, cassava, small ruminant, sorghum, streptotrichosis. Specific objectives were defined in order to enable the Nationally Coordinated Projects achieve the goals for which they were set up.

(v) In 1986, a proposal for setting up a FSR network in the country was approved and the start up funds for the network provided by the Ford Foundation.

(vi) In 1987, it re-organized agricultural research institutes in the country and allocated specific farming systems research functions to each of the major institutes. The geographical areas of mandate of the institutes happen to coincide with the zoning arrangements for the operations of the National Farming Systems Research Network (NFSRN) (See Fig. 2).

National Farming Systems Research Network (NFSRN)

The network is an association of individuals in the national institutions in the country who are practicing the FSR approach as a strategy for increasing production. The primary objective of the network is to improve the flow of information among researchers and national research institutions. This is to serve as a way of improving the FSR methodology, achieving rapid success in increasing agricultural production, and improving the welfare of farmers throughout the country.

Activities and Achievements of the Network

1. The network is run by a Steering Committee of ten, comprising the National Coordinator as Chairman, five zonal coordinators, and one representative each from the FMST, the Federal Agricultural Coordinating Unit (FACU) and a representative of IITA and AERLS.

2. It is the responsibility of the network to organize workshops which may be national or zonal. The first national workshop was held in May 1988. The zonal workshops are held annually in each of the zones to discuss results and proposals of On-farm Adaptive Research (OFAR) trials.

3. The network produces and distributes network newsletter publications twice a year. The first issue was launched in June 1987.

4. The main source of finance of the network is the grant from the Ford Foundation.

5. The network operates a research fund which can be granted to FSR practitioners in the country. The research grants are obtainable upon presentation of proposals to be approved by the Steering Committee who ensures that the guidelines are followed. Funds have been disbursed to the first batch of successful candidates.

6. The country has been divided into five Farming Systems Zones to facilitate the implementation of network projects and make it possible to involve other major institutions and individuals in FSR activities. The zones have been built around the principal food crops research institutes in the country (Fig. 2). Each zone has a zonal coordinator who normally is a Programme Leader of the FSR programme of an institute.

7. The network makes common consensus on FSR concepts, procedure and methodology to be followed and standard procedures, in general, have been agreed upon in carrying out FSR in the country.

8. Nigeria Agricultural Policy document has clearly recognized the important role in FSR in the nation's agricultural development and the necessity to strengthen research extension linkages.

IX. CONCLUSION

The development of agricultural sector that is capable of producing sufficient food and raw materials to feed the population and industries is a major challenge facing developing nations today. Substantial increases in agricultural productivity and farmers' incomes can be realized only if farmers are encouraged to adopt and use technologies being generated by the research organizations. The orthodox research methodology adopted for many years in technology generation and dissemination had not yielded very good results. Farming Systems Research approach has been universally recommended for developing agriculture where the farming systems are diversified and crop yield are low and unstable.

Experience from practicing FSR in Nigeria has yielded a measure of success. The desired research-extension-farmer linkage is already being realized through Monthly Technology Review Meetings and On-farm Adaptive Trials between research scientists and ADP staff with FACU as the coordinating partner.

Appreciable increases in crop yields have been noticed, especially for cereal crops like maize, sorghum and millet. More dedicated FSR practitioners are being produced all over the country through networking.

It should be noted that no meaningful result could be expected if the inputs required for the technology transferred are not made available to the farmers. FSR is a relatively expensive research strategy, and research funds should be sizeable and made available at the right time.

Until very recently, research results from FSR were not easily amenable to the requirements of most journals. More avenues for publishing results should be created in order to sustain the momentum already generated among FSR scientists.

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PART II

VARIETAL DEVELOPMENT AND AGRONOMIC PRACTICES FOR INCREASED PRODUCTIVITY

DEVELOPMENT OF EARLY-MATURING VARIETIES OF MAIZE AND POTENTIAL FOR INCREASED PRODUCTION IN WEST AFRICAN SEMI-ARID SAVANNA ZONES

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ABSTRACT

Sorghum and millet are steadily being replaced by maize in the socio-agricultural systems of West African savannas. In order to tailor maize production into the short rainfall climatic condition of the semi-arid savanna, it is necessary to develop early maturing varieties. Regional and international research institutions have collaborated with the national agricultural research systems to achieve this goals. For sustainable increased maize production a comprehensive package of technology including streak resistance, soil-water and soil-fertility management practices in addition to the short duration component is needed.

I. INTRODUCTION

Since the introduction of *Zea may* L. into West Africa in the 17th Century, maize has successfully established itself as a dominant staple food grain crop in the cropping systems across several ecological zones in the sub-region. It is cultivated from the coastal humid forest through varying zones of savanna up to the Sahel and from sea level up to 2000 meters altitude.

The unique ubiquity and versatility of maize as a cereal crop is due to its comparative advantage as a source of easy availability and/or fast utilization as food compared to other tropical staple food crops.

II. THE CHANGING STATUS OF MAIZE IN THE SAVANNAS

Although maize remains the principal traditional staple cereal in the coastal forest belt of West Africa where it is usually grown in association with root crops - cassava and yams mainly - it has within the past two decades encroached into the hinterland savanna ecologies.

This evolutionary process can be attributed to a number of factors. The vast and recurring incidences of drought of the early 1970's introduced maize to the front-line victims in the savanna as a relief crop of promise combining relative early maturity and ease of conversion as a food crop when compared with the traditional crops of sorghum and millet. The process of diffusion of maize was assisted by the Major Cereals Project OAU/STRC J.P. 26 which developed improved varieties such as NCB and through its West African Uniform Maize Trials made them available to various national programs in the sub-region. Subsequently, the different national programs became stronger and carried out nation-wide trials which demonstrated that the West African savanna belt was not only suitable for maize production but that it is more productive than the forest ecology. For example, in Nigeria, national zonal trials revealed that the yield of a given maize variety was 150 - 200 % that of its yield in the forest zone. Several countries decentralized their maize breeding programs and initiated the process of developing varieties that will harness the potentials of the different ecological zones for higher yields.

With the availability of improved varieties, the recognition of the productivity of maize, and with increased internal trade including trading across the porous borders of the neighbouring countries, large area is now planted to maize in the savanna belt across West Africa. It is slowly but steadily replacing sorghum and millet. This is most likely the principal factor for the favorable rate of growth of maize production within the past 20 years as shown in Table 1 for countries like Cote d'Ivoire, Nigeria, Senegal and Togo.

Though less evident in the table, the same process of increased popularity of maize in the savanna is true of Benin, Cameroon and Ghana. In some of the countries, maize production has tripled in less than 20 years.

III. CLIMATIC LIMITATIONS AND SEMI-ARID SAVANNA MAIZE PRODUCTION

The Semi-Arid Savanna (SAS) belt of West Africa, characterized by a unimodal rainfall distribution, is composed of three climatic zones differentiated on the basis of total annual rainfall and the length of growing season, both of which decrease from the south to the north as follows:

Zone	Total Rainfall Range	Length of Growing Season
Northern Guinea Savanna	900 1200 mm	4-5 months (May-October)
Sudan Savanna	600 - 900 mm	3-4 months (mid-June - early October)
Sahel Savanna	300 - 600 mm	2-3 months (end-June - early September)

The annual fluctuations of maize production in the SAS appears to be more affected by regional variations in the timing and total supply of rain than by any other single factor. Apart from 1988, the sub-region has since 1967 experienced poorly distributed and/or insufficient rainfall (Muleba, 1987). The rains tend to stop early. Drought spells of 7-10 days or more are fairly common and can occur at any time during the crop growth period. In addition to low and erratic rainfall, high atmospheric and soil temperatures are quite common.

Table 1. Statistics on maize production in West African countries and projections due to increased maize culture in Semi-Arid Savannas.

Country	Area harvested 1983-1985 (000 ha)	Yield 1983-85 (t/ha)	Production 1983-1985 (100 t)	Est. growth rate population 1980 - 2000 (% per year)	Growth rate (% per year) of maize production, from 1961 - 65 to 1983-85				Projections (If early maturing varieties are adopted in Semi-Arid countries)			
					Production	Area	Yield	Per capita cereal production	Increase Area (000 ha)	Increase Production (000 t)	Maize Production Total (000 t)	Maize Production % increase
Benin a	485	0.8	370	3.2	2.5	0.9	1.6	-0.1	121	182	552	49
Burkina a	128	0.7	90	2.0	-0.5	0.0	0.6	-0.4	64	77	167	86
Cameroon a	443	1.2	510	3.3	1.9	1.5	0.4	-0.6	111	189	699	37
Cape Verde b	7	0.4	3	1.1	-d	-	-	-	3.5	3.2	6.2	107
Côte d'Ivoire a	575	0.8	478	3.7	5.4	4.4	1.0	0.5	144	187	665	39
Gabon a	7	1.4	10	2.3	-	-	-	-	10	0	0	0
Gambia b	7	1.6	11	2.2	-	-	-	-	3.5	7.4	18.4	67
Ghana a	418	1.0	402	3.5	3.3	3.3	0.0	-1.0	105	158	560	39
Guinea-Bissau b	15	0.7	10	2.2	-	-	-	-	7.5	9	19	90
Guinea-Conakry b	49	1.0	49	2.5	-	-	-	-	12	18	67	37
Mali b	92	0.8	70	2.8	-	-	-	-	46	60	130	86
Mauritania b	7	0.4	3	3.1	-	-	-	-	3.5	3.2	6.2	107
Niger b	14	0.8	11	3.1	-	-	-	-	7	9	20	82
Nigeria a	2022	1.0	2066	3.4	3.5	2.8	0.7	-2.5	506	759	2825	37
Senegal a	84	1.2	101	2.9	5.7	3.7	1.9	-1.7	42	71	172	70
Sierra Leone b	14	1.2	17	2.0	-	-	-	-	3.5	6	23	35
Tchad b	33	0.9	29	2.5	-	-	-	-	16.5	23	52	79
Togo	179	1.1	191	3.3	4.6	0.6	3.9	0.0	44	70	261	37
Total	4579	0.97	4421						1240 (27%)	1832 (41%)	6253	

a: Except for projections all data were obtained from CIMMYT (1987)

b: Except for projections all data were obtained from World Bank (1986).

In years with good rainfall, full-season (120-day) lowland varieties developed in the coastal West Africa humid zone have grown well in the Northern Guinea Savanna, taking advantage of greater solar radiation and reduced pressure of diseases and pests to produce higher yields than in the forest. Such long-season varieties have, however, failed to establish in Sudan and Sahel savannas. In these drier ecologies, earlier maturing landraces have evolved from the flint grain cultivars introduced from the Carribeans and Nile Valley through Europe.

Maize is grown in the Northern Guinea Savanna as a field crop usually in association with a range of crops but sometimes as a sole crop. The bulk of the production enter the north-to-south internal trade. But maize culture in the sudan savanna is until recently mostly as a compound crop around houses to fulfill domestic consumption. Presently, particularly in good rainfall years, maize is grown as a field crop often as a sole crop. In both ecologies, maize plays an important role as the first crop to be harvested during the year and thus shortens the so-called hunger period before the sorghum and millet harvests. It is consumed mainly as roasted or boiled green maize.

IV. DEVELOPMENT OF EARLY-MATURING MAIZE

In order to fulfill the needs of the farmers in the various ecological zone of sub-Saharan Africa, IITA in 1975 initiated a project on the development of early-maturing maize. The objective was to develop cultivars which could fit into: (1) a second season in the forest zone, (2) a shorter rainy season in Sudan Savanna areas, and (3) mixed and/or relay crop farming systems.

1. Constitution of Early-Maturing Populations

A yellow-grained flint landrace - Upper Volta Early (UVE) - from Burkina Faso (formerly Upper Volta) was used as a primary source of earliness. It flowered (50% tasseling) about 40 days after planting compared to 55-60 days for the late-maturing variety, TZB. UVE was crossed to several cultivars and composites in IITA germplasm and to several other early-maturing materials originating from Africa, India, Indonesia, Mexico and the Philippines. Unfortunately, UVE was susceptible to foliar diseases especially lowland rust (*Puccinia polysora*) and blight (*Helminthosporium maydis*), ear rots and lodging. Disease resistance and a reasonable yield of 3-4 t/ha with a maturity period of about 90 days were the goals. Individual plant selection and the generation of hundreds of full-sib progenies followed by multilocational evaluation in Benin, Nigeria and Togo resulted in the development of 11 early-maturing TZE cultivars (1977 IITA Research Highlights).

Physiological evaluation revealed that the main feature of difference in TZE cultivars compared to TZB is their early date (after emergency) for tassel initiation (18 days compared with 28 days) and consequently their earlier flowering, and lower leaf number (Table 2). Duration of grain fill is also shortened by about 10 days (1978 IITA Annual Report). Therefore, TZE cultivars are 10 -12 days earlier than TZB in flowering and about 25 - 26 days earlier in maturity.

An interesting feature of early-maturing cultivars is the formation of 18 leaves in 18 days compared with 21 leaves in 28 days in late-maturing cultivars. Yield component analysis showed that both size and number of grains per cob are responsible for greater yields of TZB. TZE cultivars had fewer rows per cob, fewer grains per row and fill to a smaller size. The rate of grain fill was found to be similar.

Table 2: Phenology and plant type comparison in Upper Volta Early (UVE), TZE improved cultivars and TZB.

	UVE	Selected TZE cultivars	TZB
Days to tassel initiation	16	18	28
Days to 50% tasseling	40	40 - 45	55 - 60
Days to maturity	80	85 - 90	110 - 115
Duration of grain fill, days	40	45	55
Total No. of leaves formed			
Modal value	17	18	21
Range	16-18	17 - 19	20 - 22
No. of nodes to first ear node			
Modal value	6	79 - 10	
Range	5 - 7	6 - 8	8 - 11
No. of nodes above first ear	5 or 6 in all cases		

Source: 1978 IITA Annual Report

The difference in final grain weight was said to come from the longer grain-fill period but not from greater rate of grain fill. Harvest index did not differ significantly between TZB and TZE cultivars and UVE.

2. Adaptation of Improved Early-Maturing Populations for the Semi-Arid Zone

With the establishment of the SAFGRAD Project in 1978, "the two primary objectives of the Maize Breeding Unit were (1) to conduct research in the development of varieties that combine early maturity (85 - 90 days) with reasonable yield and drought resistance and (2) to evaluate varieties developed by national, regional and international programs so as to immediately have better materials available to SAFGRAD member countries" (IITA, 1983).

Initial breeding efforts at SAFGRAD were concentrated on improving, through multilocational recurrent selection program, two early-maturing cultivars for the Sudan Savanna: one white-grained, TZE-3 and one yellow-grained, TZE-4, and two late-maturing cultivars for the Northern Guinea Savanna: TZPB and TZSR-Y. The two early-maturing cultivars were tested in Regional Uniform Variety Trials conducted by many national programs, some of whom have either released them to farmers or used them in their breeding programs.

In 1980, Pool 16, a white dent grain early maize developed by CIMMYT was identified as among the top yielding varieties in seven out of the nine locations in RUVT across semi-arid zone. Consequently, TZE-3 was replaced with Pool 16 as a source for developing adapted early-maturing, high-yielding varieties. It was maintained in the multilocational recurrent selection program using a full-sib family testing scheme. Based on the performance of 1981 progeny testing trials organized in collaboration with four national programs, an experimental variety, SAFITA-2, was developed from Pool 16. SAFITA-2 is now one of the best performing early maturing varieties in the National Research System in the semi-arid zone of Africa.

3. Improving Yield Stability through Disease/Stress Resistance Breeding

3.1 **Disease resistance.** Although diseases are usually not a serious problem in Sudan Savanna, which is the target zone for early-maturing varieties, certain climatic circumstances induce disease pressure of significant consequence on maize yields. For example, unsteady rainfall at the beginning of the season forces farmers to replant and/or plant late. Under such situation, there is a build-up of foilar diseases. More importantly, the risk of maize streak virus (MSV) epidemic increases with time after the beginning of the rains due to a vector population (*Cicadulina* leafhoppers) build-up and increased source of inoculum in the fields (Fajemisin *et. al.,* 1987). This situation which has recurred many times in recent years in many countries in the semi-arid savanna, underscores not only the need for early-maturing varieties that will "catch-up with the season", but also especially resistant to MSV and other important foliar diseases. This would reduce farmers' risks.

In 1977, four promising early-maturing cultivars (TZE-3, TZE-4, TZE-14 and TZE-15) were crossed to two late-maturing, streak resistant populations, TZSR-W and TZSR-Y. After series of selfing under streak pressure embodying selection for streak resistance and early maturity followed by half-sib recombination, two populations, white (TZESR-W) and yellow (TZESR-Y) were developed that combined early maturity with streak resistance. Each population has since 1981 been maintained by recurrent selection comprising of international multi-location evaluation of full-sib families involving collaborators from national programs. Several experimental varieties have been formed and made available to national programs for testing.

Simultaneously, varieties from the early-maturing populations, Population 30 (white) and Population 31 (yellow) developed by CIMMYT have been identified as high-yielding and consumer-acceptable by many national programs. These have been converted to streak resistance by backcrossing through a joint CIMMYT-ITIA, effort at IITA, Ibadan. Pool 16 has also been converted to streak resistant form.

Also, two maize populations, DMR-ESR-W and DMR-ESR-Y, combining earliness with resistance to streak virus and downy mildew have been developed at IITA and offered to national programs through Early-Maturing Variety Trials.

Therefore, the range of streak resistant early-maturing varieties available to national programs include white or yellow grained with either flint or dent grain texture. These have higher levels of resistance to foliar and other diseases than the traditional varieties.

3.2 **Drought Resistance.** Unpredictable periods of drought are responsible for significant reduction in maize yields (Edmeades *et. al.,* 1987). The effects of dry spell are felt more at either end of the rainy season emphasizing the need for early-maturing varieties as a method of escaping drought. Unfortunately, drought can occur at any stage of crop growth; yield losses may be disastrously large if drought coincides with the period 1 - 2 weeks before or after flowering. Improvement of resistance to drought during this period will reduce farmers' risk. In Sudan Savanna Zone, the risk of drought is accentuated by low water holding capacity of the predominant ferruginous tropical soils which are usually shallow, sandy, with low organic matter and low base exchange capacity and often with compact sub-soil (Rodriguez, 1987).

Using two types of ridging systems, simple and tied ridges, to produce two levels of moisture stress under natural rainfed condition in the Sudan Savanna, Pool 16 was being improved for drought resistance (Diallo and Rodriguez, 1987). The system consisted of a split-plot design: simple and tied ridges as main plots and families as sub-plots with two replications. Selection was made on the basis of yield under the two levels of moisture and other characters such as synchronization between anthesis and silking; some Pool 16 Drought Resistance experimental varieties were developed and offered to national programs in 1988 through the Regional Uniform Variety Trial. The variety Across 86 Pool 16 DR was the most promising. It produced an average yield of 4.45 t/ha across 11 locations in 6 countries in west and Central Africa in 1988.

Effort is also on to develop an early-maturing drought resistant composite from landraces that evolved in semi-arid West African countries and some improved varieties that showed good performance under drought stress.

4. Development of Extra-Early Maize

In order to further reduce the risk to farmers in maize culture in very short season and/or to widen the area of maize culture in the semi-arid zone, extra-early varieties are being developed in the SAFGRAD Collaborative Research Network. Such varieties would mature in 82 days or less compared to 90 days for early varieties. Such maize is needed in the Sudan Savanna in those years when maize cannot be planted as soon as it should or has to be replanted when the remaining part of the growing season is too short for planting early maize.

After an evaluation of early accessions from Burkina Faso, Colombia, CIMMYT (Mexico), and India, two yellow varieties from Bukina Faso - Bursanga Tollo and Kamandaogo Tollo - and a white Colombian variety - Gua 314 - were found to flower 43 days after planting and produced average yield of 2.5 t/ha. Unfortunately, they are susceptible to diseases and lodging and possess poor grain type. They were crossed with improved early-maturing varieties and the resulting populations were subjected to selection for extra-earliness. Several extra-early maturing white and yellow cultivars have been formed and tested in regional trials. Improvement continues for higher level of disease resistance and grain yield, while maintaining the extra-earliness (Fajemisin, 1989).

V. HOLISTIC APPROACH TO SUSTAINABLE INCREASED MAIZE PRODUCTION IN SEMI-ARID SAVANNA

Undoubtedly, increased popularity of maize culture in the Savannas has contributed significantly to the increased production in many West African countries (Table 1). It is a significant positive achievement in fitting maize into new ecologies and widening the food options of the inhabitants. Spencer (1985) has advocated that to generate appropriate new technologies, food crop research in the semi-arid zone must be conducted with a farming systems perspective that considers in its strategy farmers' constraints and limited resources.

The development of early-maturing maize must be seen within an holistic system with the objective of developing more intensive and ecologically sustainable systems. By passing the variety development process through regional testing before further national tests and recommendation for farmers' adoption, feedback is in-built and such improved varieties have greater chances of long life span with farmers; several biological and social causes of instability are considered in the research process.

1. The Biological Component

The development of drought resistant early-maturing maize varieties reduces the risk of drought in the semi-arid savannas. Being open-pollinated varieties, farmers can save seed from previous harvest without any significant yield reduction within the first 3 years of adopting a new variety. These varieties also increase farmer's options because they can fit into the prevalent farming systems of relay or intercropping. For example, Muleba *et al.,* (1985) showed that early-maturing and less leafy maize cultivars like SAFITA-2 were more suited to maize-cowpea relay-cropping than later maturing and more leafy cultivars. The former depressed seed yield of relay-cropped cowpeas than the latter. Similarly, early day length-sensitive cowpea cultivars were found to be better adapted to maize-cowpea relay-cropping than the late day length-sensitive cultivars. Cowpea planted 30 days after maize had no detrimental effect on maize yield. By proper choice of cultivars of both crops, good yields of maize (2.5 to 5.7 t/ha) and cowpea (0.5 to 1.5 t/ha) were achieved.

2. Agronomic Improvement

Rodriguez (1987) has affirmed that the extent to which maize will become a more important cereal in the Sudan Savanna will depend on the farmer's ability to simultaneously solve the zone's fertility problems and to use improved soil-water management practices.

Though erratic rainfall distribution characteristic is a constraint for increased maize production, research results indicate that the complementary use of early-maturing drought resistant varieties and proven improved agronomic practices for increased water use efficiency will reduce the risk of drought stress. Pre-planting soil tillage followed by the use of tied ridges in Sudan Savanna are effective in water conservation through increased infiltration and decreased run-off. To attain a sustainable intensive maize culture in the semi-arid savanna, both the biological and physico-technological components for reducing yield loss due to drought must be combined with improved soil fertility measures such as increased use of crop residue as mulch rather than its systematic removal from the field and the adoption of erosion control measures to reduce further soil loss.

Although the application of nitrogen and phosphorus is needed for a good yield of both improved and traditional varieties, results have shown that local varieties did not perform better than the improved early-maturing varieties when grown under low fertility and/or drought stress (Rodriguez, 1987).

3. Labour-Augmenting Measures

The adoption and sustainability of increased maize culture in the semi-arid savanna depends on the feasibility of the proposed technological package within the prevailing socio-economic context. The adoption of early-maturing varieties will provide more time for pre-planting tillage and the preparation of ridges and their tying for better water conservation. The development of donkey- and oxen-drawn models of ridge tier makes this technology relevant to a zone where labour augmentation by animal traction offers promise for a productive intensive farming.

4. Estimating Returns from Adoption of Early-Maturing Varieties

With the adoption of early-maturing varieties, more area can be opened for maize production in most of the West African countries. Indeed the present maize area in such countries can be increased by 25 to 50%. Presently, national average yields in West Africa varies from 0.4 to 1.2 t/ha (Table 1). If the total package of improved early-maturing streak-resistant varieties and recommended management practices are adopted, an increase of 0.5 t/ha over the present national average can be easily attained. This will lead to an increase in total maize production ranging from 35 to over 100% in the various countries with semi-arid savanna ecology amounting to an overall regional increase of 1.83 million tons or 41% (Table 1).

VI. SUMMARY

In the last two decades, maize has progressively become important in the socio-agricultural systems of West African savannas, replacing slowly but steadily sorghum and millet.

The development of early-maturing varieties is an ecologically efficient way of tailoring maize into the short rainfall climate of the semi-arid savanna. Regional and international research institutions like SAFGRAD, IITA and CIMMTY have, in collaboration with national programs in the sub-region, developed varieties that combine early maturity with good yield. Resistances to streak virus and major foliar diseases have been incorporated to enhance stability of performance and therefore reduce the risks faced by farmers who are often forced by late rains to plant during disease-prone seasons. Furthermore, progress is on to improve early maturing varieties for good yields under drought stress.

A critical appraisal of the semi-arid savanna reveals that for a sustainable increased level of maize production, improved early-maturing varieties must be considered only as one of the vital components of a comprehensive package within a farming systems perspective. The varieties must be managed with all the proven yield-augmenting practices that conserve moisture and soil fertility such as pre-planting tillage, tied ridging and the use of crop residue as mulch.

The simultaneous adoption of early maturing streak-resistant maize varieties and soil-water and soil-fertility management practices by semi-arid savanna farmers has the potential of opening an extra 1.24 million hectares of land in the sub-region with an overall 41% increase in production (1.83 million tons). Such an holistic approach will enhance the development of a sustainable intensive food production system in the rather harsh environment of semi-arid savanna.

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SOIL AND WATER CONSERVATION RESEARCH IN NORTHERN CAMEROON

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ABSTRACT

This paper shows that soil erosion through water is significantly correlated with the amount of rainfall, water runoff and soil water content. Soil erosion losses are higher in cultivated than uncultivated soils. Land under fallow has also shown less soil losses through runoff than that under continuous cultivation. The ridge and furrow system is effective in reducing soil erosion. It also conserves more soil moisture in the areas where soil is slopy, rainfall is low and maize is grown. The benefit from tied ridging was observed to be lower with sorghum and millet cultivation than with maize in Northern Province of Cameroon.

INTRODUCTION

The soil which is the upper loose layer of the earth is an important factor for crop and livestock production. Plants depend on it for support, nutrients, water and air and animals depend on it for grazing. In fact, it is no exaggeration to say that the world exists on the top 20 cm of earth's surface as almost the entire production of vegetable matter on which animals and human life depends is cropped out of this fertile top soil.

Continuous cultivation without proper management of the soil results in the loss of soil fertility by removal of plant nutrients through cropping and leaching, the soil itself suffers erosion. Once the top soil has been washed off it is very costly to restore the productivity of the soil. Fertility losses by erosion have been estimated to be 20 times greater than losses through crop removal or by leaching.

It takes 120 - 400 years for nature to build a single cm of soil. It therefore, follows that if we allow our soils to be destroyed it would take many generations before it can be built up again for use. The menace of these losses, threatening the existence of every agricultural community, whether they are located in valleys, broad plains or slopes of hill range, has come to be realised in increasing measure of soil conservation in the recent decades.

In the semi-arid region of northern Cameroon the uncertainties about the onset and cessation of rains and their distribution have been the major limiting factor in wet season crop production.

A sizable amount of rainfall is wasted as runoff losses (23%, Kowal, 1973) due to undulating terrain. A large portion of the rain water retained in the soil is further subjected to evaporation loss (due to high air temperature and low relative humidity). As a result, a very low amount of total rainfall is actually available for crop use.

Drought is not new to semi-arid regions of Africa in general, and northern Cameroon in particular. The past two drought years (1984 and 1987) have caused severe crop and livestock losses in northern Cameroon. Crop losses were as high as 90% due to drought. However, proper conservation of available rain water and its efficient utilization by using improved soil and crop management practices can help to some extent and drastic yield reductions or complete failure of crops can be avoided.

In northern Cameroon, very limited studies have been carried out on soil and water conservation practices. Earlier works were concentrated mostly on the measurement of water flow in various rivers and their tributaries for planning purposes. For the last 10 years some studies on practical aspects of soil and water conservation method have been taken up by different research, parastatal and government organizations.

General Information About Northern Cameroon

General: Northern Cameroon (Adamaoua, North and Far-North provinces) extends from about 7 to 13 degrees north latitudes. Elevation ranges from 160m at the point where the Benoue river leaves the area, to more than 2000 m in mountains of Admaoua province. Out of the total population of Cameroon which is about 10.68 million people (1986) about 3 million peoples are living in these three provinces. Food production and consumption are about equal. Sorghum, millet, peanuts, rice, corn, manioc, beans and other vegetables are the major food crops and cotton as cash crop.

Climate: Northern Cameroon has a tropical climate. Rainfall decreases from south to north, and there is pronounced dry season persisting long enough that most soils are dry for almost 3 - 8 months. Sub-divisions of these areas are determined by transitions and combinations of rainfall and temperature, modified by abrupt changes in elevation.

Average annual temperatures are closely related to longitude and elevation. Variations in monthly average increase northward. The difference between the average summer (June, July and August) and the average winter (December, January, February) is not greater than 5°C in any area. The variation in daily temperature may be as much as 20°C. The recorded maximum is 45°C and minimum is 12°C.

The range in annual rainfall in north Cameroon is moderately wide, reflecting a sensitive balance in the dominating pressure systems. Data from recording stations indicate that monthly rainfall increases from April to August and decreases rapidly from August to October. Broadly, annual rainfall in northern Cameroon can be categorized into three classes: Less than 500 mm, between 500 and 1000 mm and between 1000 and 1500mm. Area under first rainfall class lies between 12 and 13° N, second between 8° and 12° N and third between 7 and 8° N latitude.

Rain storms in northern Cameroon have high erosivity and their erosion behavior is very much visible. For example, a storm of 105 mm rainfall with an expected return frequency of 10 years may have 86 per cent of the storm's volume having rainfall intensities exceeding 81 mm per hour (USDA/FAC, 1978).

Soils: Five soil order are represented in northern Cameroon: Alfisols, Entrisols, Inceptisols, Ultisols and Vertisols. In general, most of the soils are low in inherent fertility, low in water holding capacity, poor in soil structure and low infiltration rate. There is paucity of basic data on general characteristics of these soils of northern Cameroon.

Research highlights of Soil and Water conservation and related studies carried out in North Cameroon

1) **Soil and Water relationship:** The moisture available to most plants is related to the capacity of the soil to absorb and retain water. The capacity of most of the mineral soils in northern Cameroon to retain rainfall in a meter of soil profile can range from 5 cm in sandy soils to 15 cm or little more in finer textured soils.

Work carried out in Benoue valley area indicate that infiltration rate varies from 1 to 10 cm/H in heavy and light textured soils (Meurillon and Pontanier 1981). The evapotranspirtion rate is 3 mm/day which causes rapid depletion of profile water. Recent study carried out (CCE, 1988) indicates that water content of the soil profile varies with the type of soil, rainfall pattern, and cultivation system. Water content of profile at 40 cm and below is more than 30% by W/V in an Alfisol at Mouda during the month of September. Soil at Mokyo indicates a low water content of less than 15% during the same period. Soils at Mokyo is very light in texture and drainage is free, while, the soil at Mouda has hard pan at 40 cm depth with higher clay content. Water content of soil at Mokyo increased slightly with cultivation as compared to uncultivated one.

A similar study carried out at Mouda in a degraded and eroded planosol for three seasons, indicates that in top 0 - 40 cm soil, the water content increased with increasing amount of rainfall in all the three years. Water content of soil in 40 - 80 cm depth was almost static throughout the year.

Another study carried out at Mouda, Maroua (CCE, 1988) indicates that infiltration rate of rain water could be increased by cultivating the soil rather than keeping soil fallow (Table 2). Water filtration with cultivation was much higher in an eroded and degraded heavy soil as compared to a Vertisol.

2. Runoff and Erosion

There are several factors which affect soil erosion but the following five are the important ones (1) amount and distribution of rainfall (2) temperature (3) topography (4) land cover and (5) soil characteristics.

When the soil is saturated with water, the excess escapes as runoff and therefore, contributes to erosion. Also the soil erodibility is influenced by some of the soil characteristics such as soil texture, structure, organic matter, depth of soil, character of sub-soil etc.

Studies were carried out at IRA farm Mouda (Maroua) on several types of soils in order to measure the runoff under various management practices. Results of two different soils indicate that runoff of rain water was reduced drastically when straw mulch was applied on soil surface. The runoff was very high in bare land (control) and was related to amount of rainfall. The runoff losses of rain water was less in Alfisol as compared to Vertisol. Use of gypsum at 5 t/ha was not effective in reducing the rain water runoff.

A correlation study was carried out between rainfall, soil erosion, runoff and soil moisture content (Table 1). Results indicate that soil erosion is positively correlated with rainfall and runoff. The correlation coefficients vary from one type of soil to another in the same locality. Correlation coefficient between different factors also vary from month to month depending on the rainfall and soil type. Total for the season indicates that highly significant correlation between rainfall and runoff was obtained with the calcareous soil followed by Vertisol (Seiny Boukar, 1988).

A study was initiated in 1986 in Mandara mountain area of Cameroon in order to find out the amount of soil eroded in each month under terraced farming. In 1986 four plots of 100 m² each were identified. The first plot was under fallow for 5 years, plot 2 in 1986, plots 3 and 4 were cultivated in 1986. In 1986 measurements of the amount of soil eroded were taken and presented on monthly basis. In 1987 the first plot was still under fallow, the second was cultivated but not cropped, third plot was left fallow and the fourth plot was cultivated and cropped (Table 2). It is worth mentioning that each terrace was almost flat and levelled. Results (Table 2) reveal that during the year 1986 the amount of soil eroded in each month with every mm of rainfall was much higher as compared to 1987. The rainfall in 1986 was higher than 1987 and that could be one of the reasons for low soil loss in 1987. The mean results indicate that under continuous fallow the losses of soil through erosion is least as compared to cultivated one. Study on this aspect is still in progress.

3. Soil and water conservation practices

In all parts of the country soil erosion can be seen in varying degrees of intensity. Over a period of years many farms have been abandoned because of soil erosion and lack of conservation practices. With major erosion problems, expensive structures often have to be constructed which are beyond the means of an average farmer. Some simple methods have been tried by few researchers and organizations in Northern Cameroon in order to reduce the losses of soil and water under different farm and farming conditions.

i) Ridge and furrow system: Ridging and/or tied ridging had been evaluated as an improved soil and water management practices to alleviate moisture stress. In a study (Rao *et. al.*, 1988) eight out of sixteen experiments conducted on tied ridging in North Cameroon showed significant yield increase of sorghum varying from 19 to 80% over simple ridging. In absolute term the extra production of sorghum was about one t/ha (Table 3). The authors also assessed that manual construction of tied ridges needs about 15 man days/ha and at the prevailing costs (CFA Francs 1000 man/day and CFA Francs 50/kg of rainy season sorghum) tied ridging gives a benefit: cost ratio of 3.3:1 which is attractive for adoption by farmers. While positive effect of tied ridging was observed on sloppy terrace where erosion and runoff were high, the lack of benefit was associated with relatively flat land (Rao *et. al.*, 1988), light textured soil and well distributed rainfall (Singh 1986; and Rao *et. al.*, 1988).

Recent study on tied ridging (Talleyrand *et. al.,* 1988) on maize, sorghum and pearl millet carried out in Northern province of Cameroon indicates a highly positive response and yield increase over simple ridging (Table 4). Also a study by researchers of SAFGRAD in Cameroon (1986, 1987 and 1988) indicates that tied ridging is beneficial only where land is sloppy and for maize crop only. Johnson *et. al.,* (1986) understook an on-farm study of different methods of cultivation and results indicate that there was no benefit of tied ridging on sorghum yield (Table 5).

ii) **Strip Cropping:** No systematic work has been done but a preliminary study conducted at Kismalari farm of IRA (unreported) was a very effective way of controlling soil erosion on a sloppy land. Several crops such as groundnut, cowpea, crotolaria, millet, sorghum and maize were planted in strips of 10 - 20m. Further study is needed to assess the effectiveness of this simple and practically viable system of controlling soil erosion and water runoff.

iii) Contour bunding or terraces: Terraces are very effective in conserving water where annual rainfall is 600 - 800 mm. The terraces are economical only when slope is between 1 - 10%. Unfortunately, no systematic study had been done in Northern Cameroon in the past except the recent one (Seiny Boukar, 1988) where erosion losses of soil was monitored in the Mandara mountain area. However, terrace farming is very prominent and peculiar in the Mandara mountain of extreme North province of Cameroon where crops are grown from top to bottom of mountains in strip. The terraces formed by the farmers are mainly from the stones. Intensive study is needed in this area.

iv) Studies on dikes: Between 1986 and 1988 a preliminary study was carried out by NCRE Agronomists based in Maroua in order to find out the effect of dikes on moisture conservation in Vertisol. So far results indicate that construction of dikes on fairly flat land has no advantage in terms of moisture retenion vis-a-vis sorghum (muskwari) yield.

v) **Agroforestry and soil water conservation:** Although emphasis has been placed on the planting of trees in order to improve the whole eco-system but not much research work has been done on the effectiveness of tree planting on soil conservation. An experiment by the SAFGRAD (1987) at Kismatari (Garoua) on sloppy land where several tree species were planted with the objective to reduce the erosion losses. Trees are still young but have established and it appears that the erosion losses will be minimized as the trees grow.

vi) Watershed management Study: A study was initiated by IRA/NCRE (Sachan 1987) for the management of Vertisol in Maroua by constructing a watershed (catchment) in order to improve soil and water management to facilitate cropping during rainy season preceding the traditional crop of transplanted sorghum (muskwari) on residual moisture in the post-rainy season. The watershed was completed in December, 1987. The runoff of rainfall is collected from the experimental area of about 2 ha while the various rainy season crops are still in the field. The runoff so collected was used for suppiemental irrigation to the second crop in the sequence (dry season muskwari sorghum). Thus two crops in a year were possible whereas in thetraditional system, these vertisols are left fallow in rainy season and only dry season muskwari sorghum is planted. This system of managing water an Vertisol could be economical on the long run and also with diversification of crops on the and cropping system. The results of 1988 - 89 croping season is preliminary but very encouraging.

River System in North Cameroon

Northern Cameroon has two principal river systems, the Benoue and the Logone. The Benoue river in North Cameroon makes up the upper sector of a major drainage, basin of the Niger river network. It flows permanently almost 800 Km to south west and in Cameroon, its channel is 350 Km long. Many branch streams join the Benoue river that is steep enough in the upper reaches so that the velocity is high (Table 6). The flow rate varies greatly and soil erosion is severe in high areas. As a result, large volumes of rock debris and earth deposits typically impede the channel discharge of tributaries and thus cause flooding and deposition of sand on fertile soils on the valley feet slopes.

The Logone river flows 900 Km from its headwaters to its confluence with the Chari river which then flows another 100 km into Lake Chad. This river system in North Cameroon is made up of three separate elements: (1) the upper Logone Occidental, the segment of which are the Vina du Nord and the Mbare rivers (2) the sub water-sheds parallel to the Dimare Plains and (3) the alluvial flood plain of the lower Logone river and the Logone-Chari delta. Watershed characteristics of the upper Logone Occidental are similar to those of tributary sections of the Benoue system. These characteristics include irregular flow rates and severe hazards of erosion and sedimentation.

Groundwater

Hydro-geological investigations in North-Cameroon have been fragmental throughout both the colonial and independence periods. The Ministry of Mines and Energy carriedout a comprehensive study of groundwater resources in North Cameroon under the direction of UNDF/FAO, Rome (1973). The study indicates that (i) groundwater resources are non existent or impractical to develop due to high relief and massive, crystalline rock substrata (ii) potential is moderate for shallow groundwater supply in Benoue valley area at an elevation of less than 250m (iii) The Lake Chad basin area of Yagoua, Limani, and Maroua-Bogo vicinity has good to moderate potential for groundwater use development (iv) artesian groundwater development is practical in Waza and Pouss aréa (v) Springs are moderately productive in Adamaoua Plateau.

In general, hydro-geologists advise against the broad-scale use of artesian groundwater to avoid depletion of resources that are a part of the delicate balance sustaining Lake Chad. The use of groundwater for small-scale local irrigation project is feasible and economical in the Diamare Plains and North wards where water table is within 10 m. Figure 7 shows the depth to a useful phreatic water table in the Chad basin low lands.

Irrigation: Presently the irrigation system of SEMRY (Secteur Experimental de Modernization de la Riziculture de Yagoua) is operational in Yagoua. There is good potential of extending into adjacent down stream sites. Also there is good potential for irrigation development in Logone-Birni and Kousseri vicinity suitable for rice and wheat cultivation. The other potential area is Benoue Basin. At present very limited area is being irrigated in Benoue Basin with Lagdo-dam water. Table 10 gives an estimate of the irrigated area and development by the year 1990.

Although irrigation system is being exploited and expanded but very limited studies are being carried out on the irrigation water management.

Drainage: More than 9800 Km land in Logone-Chari alluvial plain is flooded every year by bank overspill and by runoff from precipitation. The flood season generally extends from mid-August to the end of January. Flood flow begins to subside in September but water drains slowly because relief is flat. Most of the water flooding the grand Yaere, a region of about 5000 km² is lost by evaporation. Less than one-fourth of the water is delivered to the El Beid delta channel. If the drainage system is improved, this area could be effectively used for settlement of large population with good natural resources and plenty of food.

Water quality: The earlier analysis of water indicates that no harmful concentrations of toxic elements, particularly selenium and boron are found. Both surface and underground water supplies have low salt content and are well suited to irrigation. Locally, outcropping seepage waters, especially north west of Kousseri, may be saline and sometimes sodic as a result of percolation through sodic soils in the vicinity. Artesian groundwater varies in salinity. An occasional discharge exceeds 500 ppm of total solids and has marginal potential for irrigation. Lake Chad waters vary somewhat from south to north; however, available water supplies have less than 200 ppm of total solids and present no hazard to use (USDA/FAC, 1978).

Some practical suggestions for soil and water conservation

1) **Control of runoff losses:** Whenever rains fall faster than what can be soaked into bare land, a sheet of water collects on the surface and moves down the slope. Runoff losses are likely to be particularly high in the undulating topography. Runoff losses can be retarded by the following practices:

(a) Land levelling will ensure even distribution of rain water and excess water will move out slowly.

(b) Contour tillage on gentle slope and planting of crops at right angle to the slope of land help increasing obstruction to the flow of water in the field and thus increase water infiltration.

(c) Contour ridges and furrows when formed across the slope to improve water in the furrows. This also check the velocity of runoff water and checks the erosion.

(d) Bench terracing in hilly areas on very steep land (20-50% slope) should be followed. In the slopes are transformed into a series of level or nearly level strips/steps running across the slope and separating the strips by almost vertical risers made of rocks or earth protected by heavy growth of vegetation. It is quite helpful in controlling soil erosion and conserving soil moisture.

(e) Deep ploughing of levelled land after crop harvest will allow the rain water to soak in quickly. This is important where compacted layer or hardpan exists in the sub-soil either naturally or as a result of cultivation for a long time.

II. **Checking or reducing evaporation losses:** High evaporation rate on account of hot and dry climate under reduced rainfall and short rainy season is one of the major factors of water loss in arid and semi-arid regions. Evaporation losses can be reduced by adopting the under mentioned practices:

(a) **Using soil as mulch:** On a bare soil, the beating action of rain drops results in sealing of soil surface which reduces infiltration rate and consequently either results in increased runoff or make water stand on surface for longer time thus enhancing the chances of evaporation. Secondly, the resulting crust on a drying bare-soil establishes close contact with sub-soil and acts like a blotting paper sucking water from the soil profile and evaporating it into air. Such soil crust formed should be broken by using hand-hoe or toothed harrow. This way dry soil mulch is prepared on the soil surface to check water loss from below.

(b) **Using crop residue as mulch:** Depending upon the availability of crop residues, and if it is economically feasible, these can be used as a good mulching material to retard evaporation. Besides checking evaporation, use of crop residues reduces the soil erosion and water runoff and increases the organic matter content of soil, thereby improving soil physical conditions and its nutrients and moisture retention capacity.

(c) **Eradicating weeds:** Weeds waste huge amount of soil water. They propogate and multiply faster and if unchecked exhaust the stored soil water and available plant nutrients in the soil profile in the short period. Eradication of weeds is therefore, a must for soil-water, conservation and crop production. Various control methods of control that can be afforded should be tried rather than applying any one single method alone.

III. **Improved Soil and Crop Management Practices:** The available rain water can be further conserved and utilized more efficiently by maintenance of soil fertility and by choosing the most appropriate cropping system.

(a) **Use of manure and fertilizer:** Most of the soils in northern Cameroon are light textured, low in organic matter and in inherent fertility and poor in soil structure and water holding capacity. Under such soils, use of large amount of organic matter, choosing high yielding cropping system that produces large amount of crop residues, incorporation of residues into and use of animal manures (FYM) will be quite beneficial. This makes soil more porous, aeration of sub-surface layers is facilitated, microbial activities are enhanced, water holding capacity and tilth are improved.

(b) **Cropping System:** Mixed cropping which is traditional in most part of arid and semi-arid Africa in general, and northern Cameroon in particular and crop rotation in which deep-rooted (cotton) and shallow-rooted (millet,maize, groundnut) crops are included are quite helpful in utilizing the moisture from upper and lower layers of the soil. At the same time mixed cropping with crops like cowpea and groundnut will give good cover to soil which is helpful in reducing a wasteful evaporation and runoff losses. The deep roots will create channels for better penetration of rain water and thus retard runoff losses. Burning of crop residues, bush burning and forest burningshould be avoided. In addition to almost total loss of N and S, burning exposes other nutrients to be readily washed off from the soil due to excessive runoff.

(c) **Minimum tillage:** Following minimum tillage practices, i.e. the least amount of tillage required to create suitable soil conditions for seed germination, crop growth and weed control, have been found helpful in soil and water conservation.

(d) **Grazing:** As far as possible grazing areas for each locality should be big enough to meet the requirement of the animals. The people should be requested through the council to rotate the grazing areas and avoid over grazing. Where the grazing area is limited farmers should supplement from their own crop residues and concentrates. Burning should not be permitted.

(e) **Role of forestry and Agroforestry:** As much as possible people should be encouraged to plant trees, fruit trees, shrubs, live fences including wind breaks etc. Also intercropping with trees and crop should be encouraged in order to minimize soil erosion and runoff losses and at the same time improving soil fertility and crop productivity.

Future research needs.

As seen in the presentation, available information on soil and water conservation research in Northern Cameroon is not enough. Therefore, it is imperative that research work in this area should be intensified. Some of the suggested major areas where basic and applied research is needed are:

(1) Characterization of soils for their water holding, water retention and infiltration rate under different ecological zones and under different cropping systems.

(2) Studies on soil erodibility and runoff study under various degrees of slopes and crop cover.

(3) Role of crops and trees and their combinations in controlling erosion and runoff losses.

(4) Use of heavy implements and their effect on soil compaction and inturn on water infiltration and root development.

(5) Studies on minimum tillage method of cultivation as means of reducing soil losses through runoff and wind.

(6) Intensive studies are needed in management or irrigation water, irrigation system, irrigated soil and cropping pattern.

(7) Analysis of irrigation water (surface and underground water) for their fitness as irrigation water.

(8) Studies on agroforestry, wind breaks etc. should be carried out and many more.

Summary and Conclusion

Northern Cameroon (Adamaoua, North and Far-North provinces) extends from 7° N and 13° N latitude with the elevation range of 160m to 2000m above the sea level. The annual rainfall varies from less than 500 mm to more than 1500 mm and the mean annual temperature from 22° C to 29° C.

Areas having mean annual rainfall less than 1000 mm are prone to frequent drought that could be early, mid or late in the crop season. Also the rain fall is erratic and often heavy which causes heavy losses of rain water through runoff.

The capacity of most of the mineral soils in northern Cameroon to retain rainfall in a meter of soil profile ranges from 50 mm in sandy soil to 150 mm or little more in fine-textured soils. For about 100 days from July through October the available water in the soil exceeds the potential evapotranspiration especially in Maroua and plant growth is rapid. This period may be shorter or longer depending on the rainfall distribution and other climatic factors such as temperature, humidity etc.

Soil erosion through water is significantly correlated with the amount of rainfall, water runoff and soil water content. Erosion losses of soil through runoff are higher in the cultivated soil as compared to uncultivated. Soil cover such as straw mulch is very effective in controlling runoff losses. In Mandara mountain area the terraces are under fallow for longer period and loss less soil through runoff as compared to the one under continuous cultivation.

The ridge and furrow system or tied ridging is effective in reducing soil erosion and conserving more soil moisture in the areas whereas soil is slopy, rainfall is low and crops like maize is cultivated. Low benefit with tied ridging was observed with sorghum and millet as compared to maize in Northern province of Cameroon.

The work initiated by Agroforester in Garoua for controlling soil erosion looks promising and needs to be continued and detailed study is needed. Also the watershed management technology on Vertiols should be studied in detail in the context of diversification of cropping system. So far results are quite promising.

Very little information is available on the management and system of irrigation and at the sametime effect of irrigation water, drainage and water table on the soil properties. Several areas of research have been suggested for effective soil and water conservation and related studies for northern Cameroon.

Acknowledgements:

USAID, Yaounde Mission, Cameroon
ITA, Ibadan, Nigeria
NCRE Chief of Party - Dr. E.A. Atayi
Director, IRA, Yaounde - Dr. J. Ayuk-Takem
Chief of Centre, IRA, Maroua - Mr. Z. Boli
OAU/STRC/SAFGRAD, Burkina Faso
Mr. Aboubakar, akouba, Karewa Experimental Station, Garoua and
Mr. Seiny Boukar, L., IRA, Maroua.

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TABLE 1: CORRELATION BETWEEN RAINFALL, EROSION, RUNOFF AND SOIL MOISTURE IN DIFFERENT TYPES OF SOIL AT MOUDA, MAROUA (MEAN VALUE OF 1986 - 87).

PERIOD	DEGRADED AND ERODED SOIL WITH HARD PAN	SOILS WITH CALCAREOUS CONCRETIONS	DEGRADED VERTISOL	TRUE VETRISOL
Before 1 August	Er = 4.00LR + 8.98 R^2 = 0.688 (*)	Er = 13.42LR - 43.0 R^2 = 0.583 (**)	- -	- -
	LR = 326HP + 0.254 IK-6.887 R^2 = 0.882 (*)	LR = 0.39HP+0.254 IK-8255 R^2 = 0.943 (**)	LR=0.184HP+0.291 IK-3.396 R^2 = 0.939 (*)	LR=0.597HP+0.175 IK-7.831 R^2 = 0.952(**)
1 - 8 to 31- 8	- -	- -	Er = 2.02LR + 4.46 R^2 = 0.501 (**)	- -
	LR = 0.247HP + 0.235 IK - 4.437 R^2 = 0.861 (*)	LR = 0.55HP + 0.126 IK - 5.360 R^2 = 0.945 (**)	LR = 0.231HP + 0.251 IK - 4.126 R^2 = 0.912 (**)	LR = 0.278HP + 0.221 IK - 4.077 R^2 = 0.916 (**)
After 31 August	Er = 4.78LR + 9.35 R^2 = 0.680 (*)	Er = 13.10LR - 33.9 R^2 = 0.640 (*)	- -	- -
	LR = 0.405HP + 0.167 IK - 5.281 R^2 = 0.861 (*)	LR = 0.497P + 0.163 IK - 5.844 R^2 = 0.956 (**)	LR = 0.400HP + 0.197 IK - 4.559 R^2 = 0.931 (**)	LR=0.302HP+0.327 IK - 3.902 R^2 = 0.966 (**)
Total of the season	- -	-	Er = 2.24LR-0.20 R^2 = 0.760 (**)	- -
	LR = 0.546HP-3.120 R^2 = 0.615 (*)	LR = 0.636HP - 2.156 R^2 = 0.844 (**)	LR = 0.575HP-3.877 R^2 = 0.682 (*)	LR = 0.679HP-4.413 R^2 = 0.744 (**)

* Significant at 5%, ** Significant at 1%

Er = Erosion Loss, LR = Surface runoff (mm), IK = Soil Moisture (%), HP = Amount of rainfall (mm).

TABLE 2: AMOUNT OF SOIL ERODED IN KG/HA/MM OF RAINFALL UNDER DIFFERENT CULTIVATION SYSTEMS IN A TERRACED FARMING IN MANDARA MOUNTAIN AREA, CAMEROON

PLOT NO.	CULTIVATION SYSTEM	YEAR	M O N T H S				
			MAY/JUNE	JULY	AUG.	SEPT.	MEAN
1.	FALLOW	1986	230	130	90	7	90
	FALLOW	1987	20	10	40	0	20
2.	FALLOW	1986	200	90	90	10	70
	CULTIVATED	1987	50	30	60	80	40
3.	CULTIVATED	1986	260	110	50	50	120
	FALLOW	1987	110	50	30	6	60
4.	CULTIVATED	1986	210	80	40	40	90
	CULTIVATED AND CROPPED	1987	70	50	30	26	50

TABLE 3: **RESPONSE OF SORGUM TO MOISTURE CONSERVATION PRACTICES (TIED-RIDGING) IN NORTHERN CAMEROON.**

Year	No. of trials conducted	No. of trials that showed significant response	Magnitude of response over simple ridges	
			%	Kg/ha
1985	4	1	19	1040
1986	6	3	28 to 48	820 to 1020
1987	6	4	26 to 80	750 to 1720

Adapted from Rao et. al, (1988) (Unpublished data).

TABLE 4: **TIED RIDGING AND SEED TREATMENT WITH FURADAN ON CROP YIELD AT DJALINGO, 1988**

TREATMENT	GRAIN YIELD (kg/ha)				
	MAIZE		SORGHUM		MILLET
	TZPB,K-81	CMS 8501	CS - 61	CS - 95	IKMV 8201
Simple ridge without Furadan	4070	4300	340	490	820
Simple ridge with Furadan	6190	6470	2290	2580	1310
Tied ridges without Furadan	5580	5900	650	760	1170
Tied ridges with Furadan	6930	7000	2590	2910	1560
L.S.D.	450		250		200
C.V.(%)	12		25		11

Adopted from: Synthesis of Annual Report, 1988 by Talleyrand et. al., NCRE, Cereal Agronomy, IRA/North, Garoua, Cameroon.

TABLE 5: EFFECT OF TIED-RIDGING AND OTHER SOIL PREPARATION PRACTICES ON SORGHUM YIELD AND STRIGA COUNT ON FARMER'S FIELD IN EXTREME NORTH PROVINCE OF CAMEROON.

TREATMENT	SORGHUM (KG/HA)*	STRIGA COUNT/HA*
Tied ridging	1475	89,000
Plowing	1439	104,000
Dry scarification	1395	128,000
Direct seeding	1330	105,000
L.S.D. (5%)	189	-
C.V. (%)	22.3	-

*Mean of 23 trials

Adopted: Johnson et. al., (1986).

TABLE 6: WATER DISCHARGE AT SELECTED CROSS-SECTIONS IN NORTHERN CAMEROON (CUBIC MM/SECOND)

RIVER	STATION	LOW WATER STAGE	FLOOD STAGE
Benoue System:			
Benoue	Garoua	1	2,375
Logone System:			
Kalliao	Maroua	Underground	228
Tanaga	Bogo	Underground	210
Vina	Wakwa	7	164
Logone	Yagoua	50	905
Logone	Kousseri		920

Adopted from "Resource inventory of North Cameroon, Africa, 1978.

AGRONOMIC PRACTICES TO MINIMIZE DROUGHT STRESS FOR SUSTAINABLE MAIZE PRODUCTION IN THE SUDAN AND NORTHERN GUINEA SAVANNA ZONES

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ABSTRACT

The Northern Guinea and Sudan Savanna zones of West Africa offer a great potential for increased maize production. Yield reductions due to drought stress occur in both zones, but they appear to be relatively greater in the Sudan Savanna Zone. A wide range of soil and crop management options are available to minimize the risk of drought stress. They include: a) soil tillage; (b) tied ridges; (c) inter-row ditches; (d) cultivations; (e) planting maize on lower slope and bottom lands; (f) use of crop residues as mulch; (g) matching phenology and expected water supply (appropriate choice of varieties and planting dates); (h) appropriate plant densities. For increased and sustained maize production, however, other yield-limiting factors need to be addressed, in particular, low soil fertility, soil compaction, and weeds, pests and diseases. In the long run, erosion control is also essential for sustainable maize production.

I. BIOCLIMATIC ZONES IN THE WEST AFRICAN SAVANNA

The West African Savanna is a strip of territory lying nearly parallel with the equator, between the High Forest and the Sahara Desert, and where grasslands are the predominant natural vegetation (Kowal and Kassam, 1978). Three main zones are generally recognized: the Guinea, the Sudan and the Sahel Savannas. Authors, however, differ widely not only in the terminology used to refer to the different zones within the Savanna, but also in the bioclimatic parameters used to separate these zones (Cocheme and Franquin, 1967; Ahn, 1970; Kowal and Knabe, 1972; Charreau, 1974; Jones and Wild, 1975; Kowal and Kassam, 1978; Lawson and Juo, 1979; Virmani *et, al.,* 1980). The Guinea Savanna zone is divided into the Northern and Southern parts, with monomodal and bimodal rainfall patterns, respectively (Kowal and Kassam, 1978).

Defining the "moist period" as the part of the rainy season when rainfall is more than half the potential evapotranspiration, PE, (Kassam *et. al.,* 1976), for the purposes of this paper, the Savanna zones are defined as shown in Table 1.

Table 1: Annual rainfall and length of moist period in the Savanna zones of West Africa with monomodal rainfall.

Savanna Zone	Annual rainfall (mm)	Moist period (months)
Sahel	300 - 600	2 - 3
Sudan	600 - 900	3 - 4
Northern Guinea	900 - 1400	4 - 6

The length of the growing season is greater than the length of the moist period since some moisture will be stored in the soil towards the end of the rainy season; the latter goes from May to October in the Northern Guinea Savanna (NGS) and from late May to September in the Sudan

Savanna (SS) zones. Although annual PE exceeds annual rainfall, there are some months during the rainy season when rainfall is greater than the monthly PE. Daily PE values during the growing season are 4 - 6 mm/day.

II. SOILS

In the soil taxonomy, the predominant soils in NGS and SS zones are Alfisols followed by Inceptisols, both probably accounting for more than 60% of the total surface area; other soil orders less commonly found are Entisols, Vertisols and Oxisols. In the French Soil Classification System (CPCS), the predominant soils are the Ferruginous Tropical Soils (mostly Alfisols, also Inceptisols and Entisols), Ferralitic Soils (Alfisols, Entisols, Inceptisols and Oxisols), and Weakly Developed Soils (Inceptisols). Hydromorphic Soils (less than 10% of the total area) are common in bottomlands and have variable characteristics not associated with a particular soil order (Ahn, 1970; Charreau, 1974; Jones and Wild, 1975; Lawson and Juo, 1979; Smalling, 1985).

Ferruginous Tropical Soils occur widely between the 500 and 1200mm isohyets. The surface soil tends to have a sandy texture, with low (around 10%) but variable clay contents (10 - 25%), because of the downward movement of clay within the profile. The subsoil tends to be compact due to the accumulation of clay. The predominant clay is kaolinite, with illite sometimes present. This, and the low organic matter contents (usually below 1.5%) account for the low cation exchange capacities (1 - 10 me/100g) and low available moisture capacities (Jones and Wild, 1975).

III. MAIZE CULTURE IN THE WEST AFRICAN SAVANNA

Traditionally, maize has been a more important crop in the Humid Forest zone than in the NGS and SS zones of West Africa. Although in 1976 it could be said that maize in the north had never become a major grain crop because of the importance of sorghum and millet (Kassam, 1976), maize has been moving northwards from the Forest to the Savanna zone, slowly replacing other cereal crops. In the NGS zone, maize is generally grown in fields that are tilled and receive fertilizer application, but do not necessarily receive an intensive management from the point of view of manure or crop residue application. Maize has become a major crop in this ecology in countries like Nigeria and Ghana. In the SS zone, maize tends to be grown mostly as a compound or garden crop (Kassam, 1976), i.e. in fields adjacent to the houses, where both the soil physical and chemical properties have been improved by the continuous additions of household refuse, animal manure and crop residues; sometimes, maize is also grown in hydromorphic soils (Lawson and Juo, 1979). Maize is very important in the SS zone as a crop to fill the hunger period before sorghum and millet harvests, but its present role in terms of acreage is minor. Maize is grown sole or intercropped in the NGS, whereas it is mostly grown sole in the SS zone.

The largest potential for maize production in West Africa lies in the savanna areas, especially the NGS zone, based on climatic factors and relative maize performance in relation to the local sorghums and millets. Experimental maize grain yields of 8 - 10 t/ha or more have been obtained in the NGS zone, with lower yields in the SS zone, but not lower than in the Forest areas (Kassam, *et al.,* 1975).

Approximate maximum grain yields which may be achieved in the NGS zone, based on average seasonal rates of dry matter production of 22 g/m²/day, from 80-, 100- and 120-day maize are 7.0, 8.8 and 10.6 t/ha, respectively, if the harvest index is 40%. Higher grain yields are possible in the SS zone, at least for 80-day maize, since incoming solar radiation increases with latitude (Kassam *et. al.*, 1975). Taking a maximum PE of 6 mm/day, the water requirements of 80-day maize would be 480 mm. Considering the seasonal rainfall and the low present grain yields of about 1 t/ha, there is then a large potential for yield increase if improved production practices are adopted, in particular, those that improve soil fertility and minimize drought stress. This is, of course, possible only if the rainfall pattern and soils are such that dry periods during the growing season do not lead to complete or nearly complete crop failure. Socio-economic factors (profitability, labour availability, etc.) have to be taken into account also.

IV. FACTORS INVOLVED IN THE RISK OF DROUGHT STRESS

Among the main factors involved in the risk of drought stress are:

a) Low rainfall. Rainfall is equal to or greater than PE in only 2 to 5 months of the year.

b) Erratic rainfall patterns. Dry periods of 1 - 2 weeks during the growing season are common and unpredictable. Moreover, rains may be established late or cease earlier than expected.

c) Soil surface sealing and/or crusting. As a result, water infiltration rates are low and runoff losses high (Charreau, 1972; Lawes, 1961). Compounding factors are high rainfall intensities and systematic removal of crop residues.

d) Soil and/or subsoil compaction. Infiltration and percolation rates as well as root growth are reduced.

e) Low available moisture capacities.

f) Shallow soil or restricted rooting depths due to compact subsoil layers.

g) Low soil fertility. Root growth and density are reduced.

Although Kowal and Kassam (1978) reported runoff losses of only 12% of the rainfall for Ferruginous Soils in the NGS zone, greater runoff losses (32 - 80%) were reported by Charreau (1972) and Perrier (1987) for the West African Savanna.

The risks of drought stress for maize culture are greater in the SS than the NGS zone due, inter alia, to factors such as lower total rainfall, greater PE during the growing season and greater variability of the rainfall pattern. In addition, given the higher human population densities in the SS zone (Kowal and Kassam, 1978), it is likely that soil degradation in this zone is greater. On the other hand, problems of soil surface compaction and sealing due to rainfall impact can be expected to be greater in the NGS zone. Since, generally speaking, drought stress is less likely in the NGS zone, either the need for cultural practices to reduce such risk is less or the yield response to such practices is likely to be smaller than in SS zone. However, specific local conditions such as serious surface sealing or "capping" can lead to marked yield responses to practices that improve water infiltration (Lawes, 1961).

Given that rainfall greatly exceeds PE during part of growing season, cultural practices that minimize the risk of drought stress could lead to conditions of excess moisture and depress growth or yield (Jones and Wild, 1975; Lawes, 1961; Kowal and Knabe, 1972; Kowal and Kassam, 1978; Hulugalle, 1987), particularly, but not only, in the NGS zone. It is therefore important, when assessing cultural practices for minimizing drought stress, to take into account the timing and intensity of application. For instance, it is likely that in some environments there is a negative maize yield response to early tying of every furrow, but a positive response to late tying of the ridges or tying of only every other furrow. Given the variability of the rainfall pattern, it is also important to establish the response to a cultural practice over a representative period of years.

V. SOIL AND CROP MANAGEMENT OPTIONS TO MINIMIZE DROUGHT STRESS

Drought stress can be reduced and maize grain yields increased by soil and crop management options that: (a) increase water infiltration and reduce runoff; (b) increase soil water storage; (c) promote root growth; (d) reduce evaporation losses; (e) allow maize to escape drought stress; (g) locate the crop in soils with lower risks of drought stress; (h) optimize harvest index; (i) use varieties adapted to the general environmental conditions; (j) promote good weed control and/or (k) protect the root system against damage by mechanical agents or pests and diseases. The options discussed below can influence one or more of the above, sometimes even in opposite directions.

Many of the experimental results presented here were produced by the IITA/SAFGRAD Maize Agronomy Program from 1979 to 1987 and some were presented in a previous paper (Rodriguez, 1987)

Soil Tillage: Tillage increases soil water storage by improving water infiltration and movement through the tillaged layer and improving soil porosity. These effects are therefore greater in soils with surface sealing or crusting and topsoil compaction. In the absence of tied ridges, tillage (soil preparation) usually gave higher yields than zero tillage and grain yields tended to be positively correlated with tillage depth. Tillage methods were ranked at tractor > oxen > donkey = hand-hoe, for their effects on maize yields. The effect of tillage was only temporary and not enough to ensure high water infiltration rates throughout the growing season, which explains the response to tied ridges under all tillage methods at Saria and Kamboinse stations (Figs. 1 and 2), both in the SS zone of Burkina Faso (Rodriguez, 1987).

Nicou (1981) reviewed IRAT's research on cultural practices for maize culture in West Africa and reported grain yield increases of 50 to 73% due to tillage in leached Ferruginous Tropical Soils; tillage improved soil porosity and root density. In Weakly Ferralitic Soils (Farako-Ba), maize grain yield increases due to oxen or tractor tillage were 46 - 49%.

Tied Ridges. Tied ridges are very effective in decreasing runoff losses and increasing water infiltration, especially in soils where surface sealing or compaction problems give low water inflilatration rates. High maize grain yield responses to tied ridges were found in all positions along the toposequence at the Kamboinse station, except hydromorphic soils in the bottomland (Rodriguez, 1987; Fig. 3).

Long-term trials evaluating the effect of old tied ridges on maize grain yield at Kamboinse (Rodriguez, unpublished data) under a low level of fertilizer application (37N - 10P - 12K kg/ha), gave an average yield increase of 820 kg/ha/year (Table 2). Only in 1986 tied ridges had a negative effect on grain yield and this was attributed to a combination of factors: no fertilizer was applied in 1986, no preplant furrow cultivation, and high rainfall early in the growing season.

Tied ridges can be established before planting. The farmer can also plant on the flat (or on ridges) and later earth and tie (or tie) the ridges, when the plants have reached a minimum height of about 25 cm and when labor availability is less limiting. Another alternative is for farmers to plant directly on the flank of old tied ridges, without previous soil preparation (Table 2), except for weeding; ridges and ties are remolded during the earthing operation.

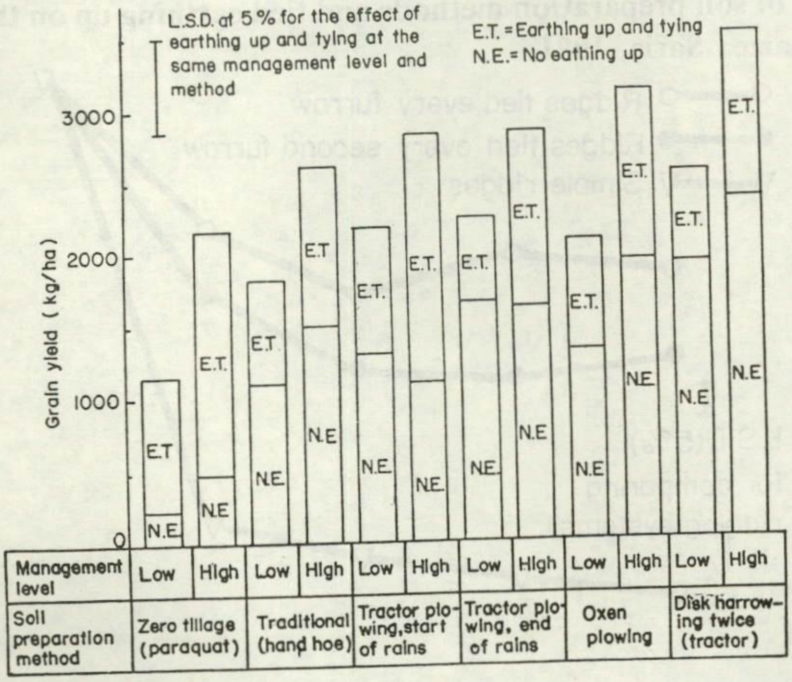


Figure 1: The effect of different soil preparation methods and of earthing up on the grain yield of maize. Kamboinse, 1981.

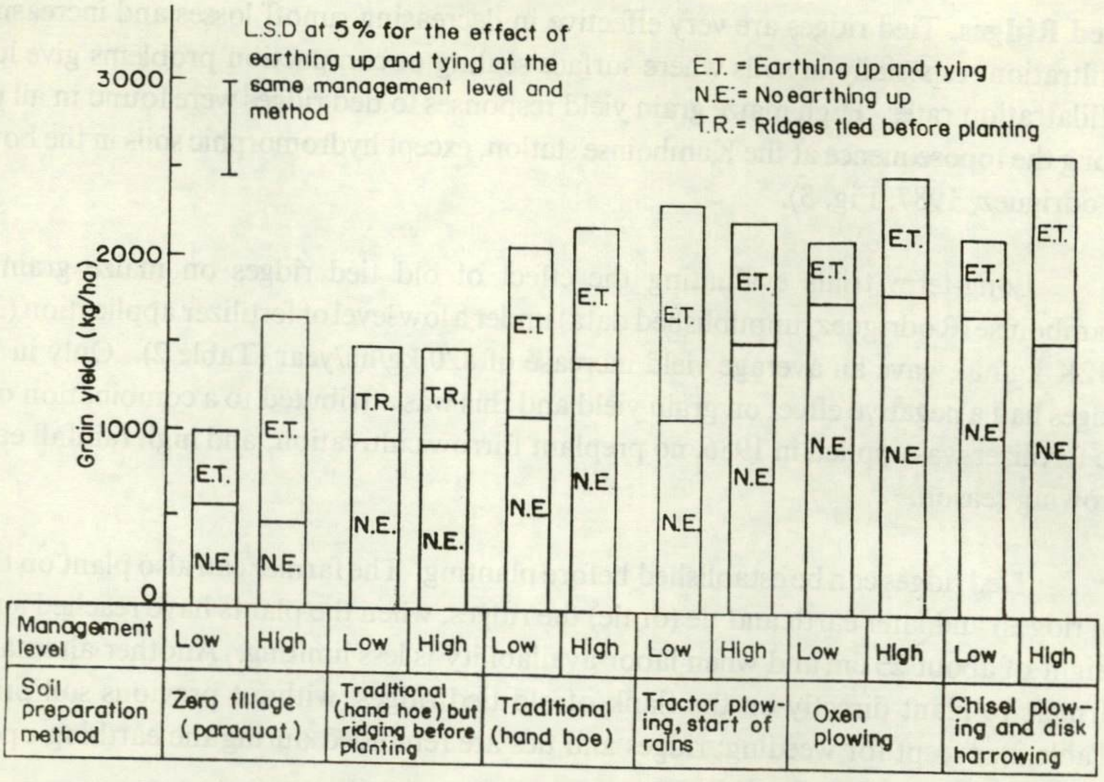


Figure 2: The effect of soil preparation methods and tied earthing up on the grain yield of maize. Saria, 1981.

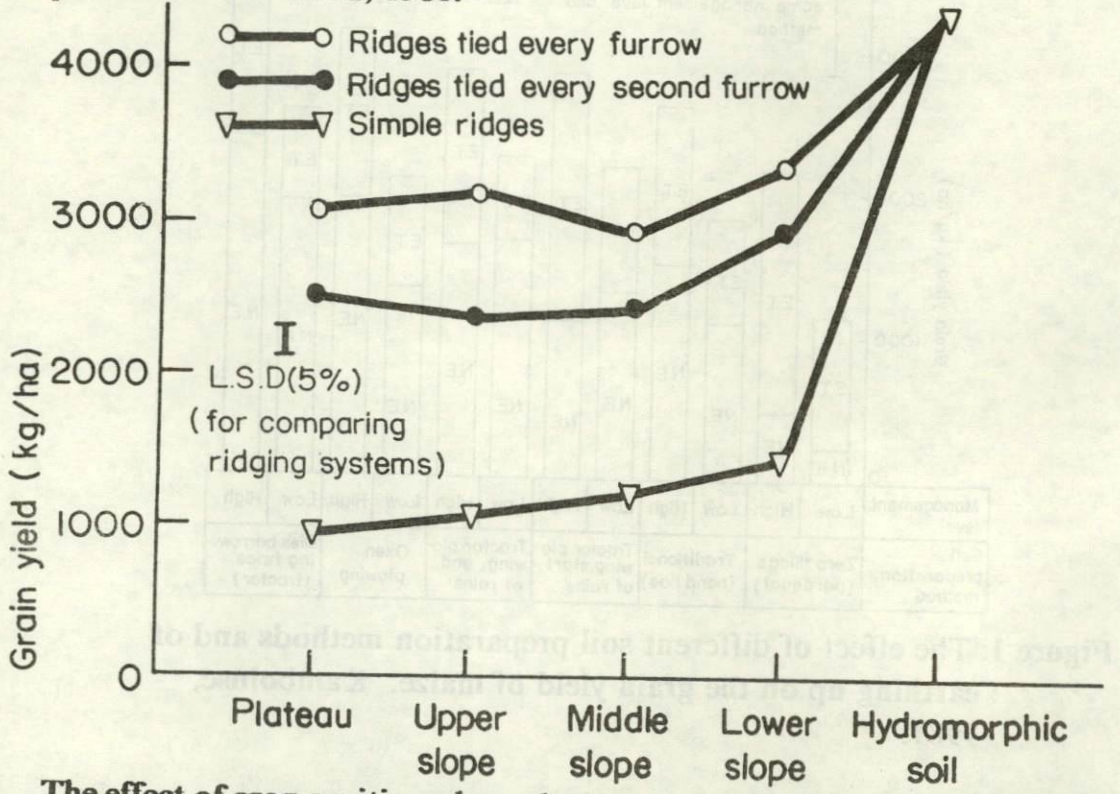


Figure 3: The effect of crop position along the toposequence and of tied ridges on the grain yield of maize. Kamboinse, 1981.

TABLE 2: Maize grain yield response to old ridges tied every furrow under low fertilizer application, from 1980 to 1987, Kamboinsc.

Year	Grain yield (kg/ha)			Annual raintall (mm)
	Flat	Tied ridges	Difference	
1980	2120	2440	+ 320	783
1981	1040	2040	+ 1000	690
1982	1270	2230	+ 960	714
1983	390	2620	+ 2230	663
1984	22	357	+ 335	414
1985	2140	2660	+ 520	574
1986	1520	730	- 790	764
1987	720	2560	+ 1840	582
Mean	1150	1970	+ 820	648

Hulugalle (1989) compared simple and tied ridges at Kamboinse station and found that the latter had greater soil profile water content, greater relative leaf water content of maize, more maize root growth in the 0.30 - 0.50 m depth, and greater total and grain yield dry matter production of maize. On-farm researcher-managed and farmer-managed trials in Burkina Faso showed significant maize yield increases and economic returns to the additional labor required for tied ridges (Purdue University, 1986).

No maize yield response to tied ridges was found at Farako-Ba, NGS zone of Burkina, on an Oxisol (Weakly Ferralitic Soil) from 1983 to 1985 (Rodriguez, 1989). These results, however, should not be generalized to all the NGS zone, where leached Ferruginous Soils predominate.

Maize grain yield increases due to tied ridges under experimental station conditions in the SS zone were often about 1 t/ha, and sometimes 2 t/ha when fertility was not a yield limiting factor. The labor cost of making tied ridges by hand was estimated at 216 man-hours/ha by Rodriguez (1987), and at least 100 hours/ha by Purdue University (1986). The latter estimated an average of 75 man-hours/ha for the manual tying of ridges constructed with animal traction.

In addition to planting on old tied ridges, several alternatives could be considered to reduce the labor requirements for tied ridging or tied earthing by hand:

a) Make smaller ridges and ties;

b) Space the ties as far apart as possible;

c) Widen the row spacing;

d) Tie only every second furrow;

e) Tie only eery third furrow, possibly using different row spacings for tied and untied furrows;

f) Earth up only one side of the row in those cases where not all furrows are tied;

g) Make tied ridges when the soil is less hard (appropriate moisture);

h) Use of a hand-hoe of appropriate size and shape;

i) Earth when the crop canopy is sufficiently developed to better protect ridges and ties against rainfall impact;

j) Combine tied earthing with other cultural operations (weeding, fertilizer incorporation);

k) Use animal traction for the ridging or earthing operation, tying or both.

The IITA/SAFGRAD Maize Agronomy Program developed a mechanical device (Fig. 4) for making tied ridges with donkey or oxen traction (Wright and Rodriguez, 1985); the former was successfully tested under farmers' conditions (Nagy *et. al.*, 1986). Additional improvements are underway at IITA/SAFGRAD to make the ridge tier lighter, cheaper, and easier to operate.

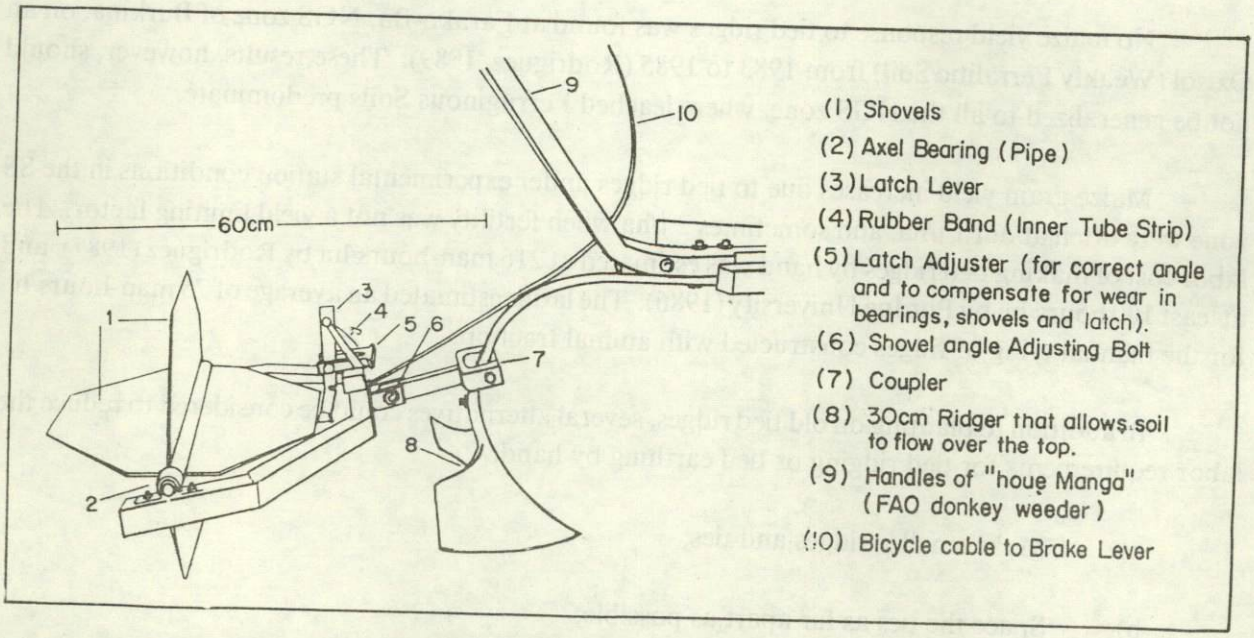


Figure 4: The IITA/SAFGRAD trap ridge-tier (Donkey version).

Shallow Ditches. Digging shallow ditches or small holes between the maize rows also increased water infiltration and decreased runoff (Table 3). Maize grain yields obtained with such ditches were usually greater than those obtained with one or more hand-hoe cultivations, but smaller than those obtained with tied ridges.

Table 3: Cultivation (Scarification) trial, Kamboinse, 1981-1983. Maize grain yield (kg/ha, at zero percent moisture).

Cultivation System	1981	1982	1983
1. No cultivation after planting	685	806	201
2. One cultivation at 4 WAP (Weeks after planting)	844	–	–
3. Two cultivations at 2 and 4 WAP	1151	718	276
4. Three cultivations at 2, 4 and 6 WAP	1178	–	–
5. Four cultivations at 14, 24, 34 and 44 DAP (Days after planting)	1634	933	660
6. Four cultivations at 14, 28, 42 and 60 DAP	–	898	600
7. Two cultivations at 2 and 4 WAP. The second cultivation is simultaneous with digging of small basins or holes (40 x 20 x 10 cm^3) between maize rows, without earthing up	2470	1292	1250
8. Two cultivations at 2 and 4 WAP. The second cultivation is simultaneous with tied earthing.	–	1418	1840
Mean	1327	1011	800
C.V. (%)	27.1	25.8	47.7
L.S.D. (5%)	475	344	506

The labour cost of digging shallow ditches with a hand-hoe was estimated at 144 man-hours/ha (Rodriguez, unpublished data). An oval wheel developed by ICRISAT Socio-Economics Program in Burkina Faso (Fig. 5) makes inter-row ditches with donkey and oxen traction; labour costs are not available, but are likely below 50 men-hours/ha. Joint tests between the IITA/SAFGRAD Maize Agronomy Program and ICRISAT Socio-Economics Program gave excellent results for the oval wheel in monocropped maize and sorghum and in intercropped maize and cotton in the SS zone (Rodriguez and Matlon, unpublished data).

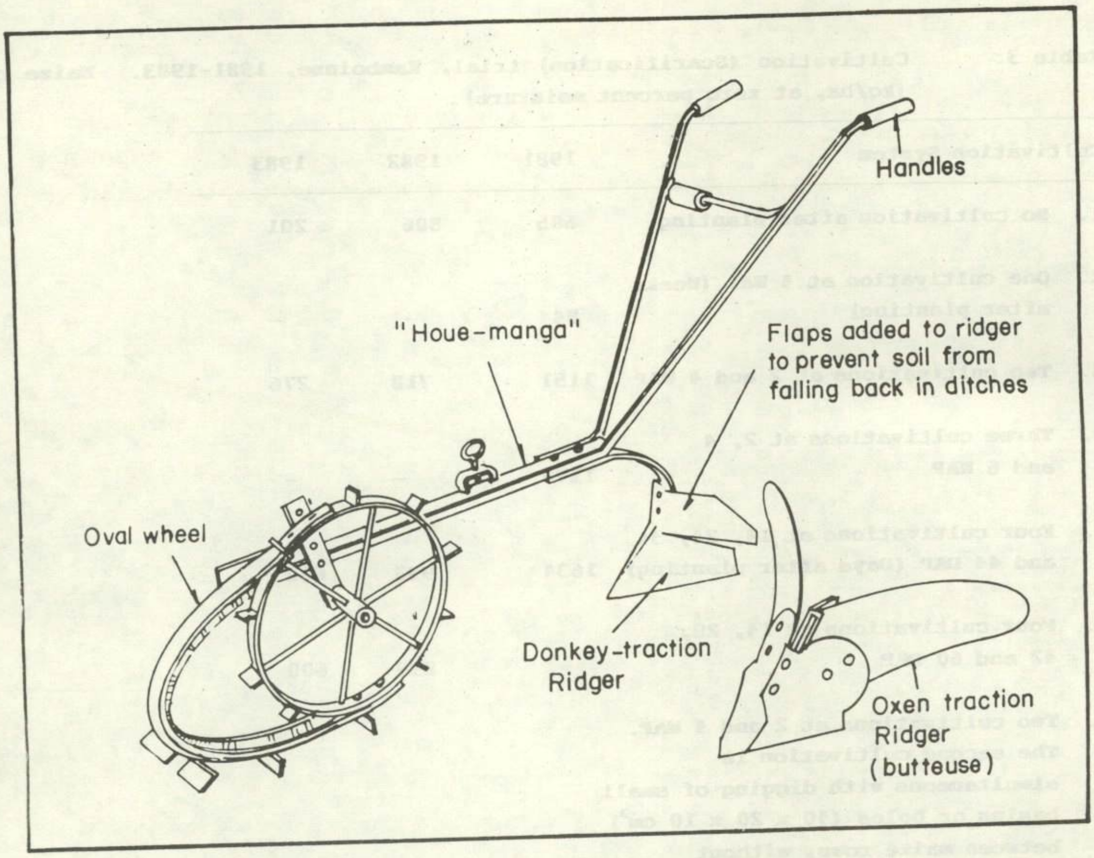


Figure 5: **Oval wheel for digging inter-row ditches, shown attached to a "houe-manga" for donkey traction. Larger ditches are made with the ridger for oxen traction on the right.**

Cultivations (Scarification). Surface sealing and crusting reduce water infiltration and restrict soil aeration. In this case, cultivations (after planting) increase water infiltration, improve aeration and increase maize grain yields (Table 3), even in the absence of weeds (Rodriguez, 1987).

Planting Maize on Lower Slope Soils and Bottomlands. Experiments at the Kamboinse station showed a very marked toposequence effect on maize grain yield (Fig. 3). Yields were lowest in the upper parts of the toposequence and highest in the lowest parts, even when tillage, tied ridges and fertilizer were used (Rodriguez, 1987).

Use of Maize Crop Residues as Mulch. Crop residues help maintain soil organic matter content and promote a higher level of biological activity, particularly that of termites, and improve water infiltration and soil aeration. An experiment conducted at Kamboinse station from 1979 to 1987 showed significant maize grain yield increases due to the application of maize residues as mulch only when at least 4 t/ha dry matter were applied (Fig. 6). This is the residue produced by a maize crop with a grain yield of about 2.8 t/ha. When crop residues were systematically removed, there were no significant differences in grain yield between management (fertilizer) levels, even when tied ridges were used. Although the reason for this has not been elucidated, the systematic removal of crop residues appears to be detrimental for sustaining or improving the productivity of these soils (Rodriguez, 1988).

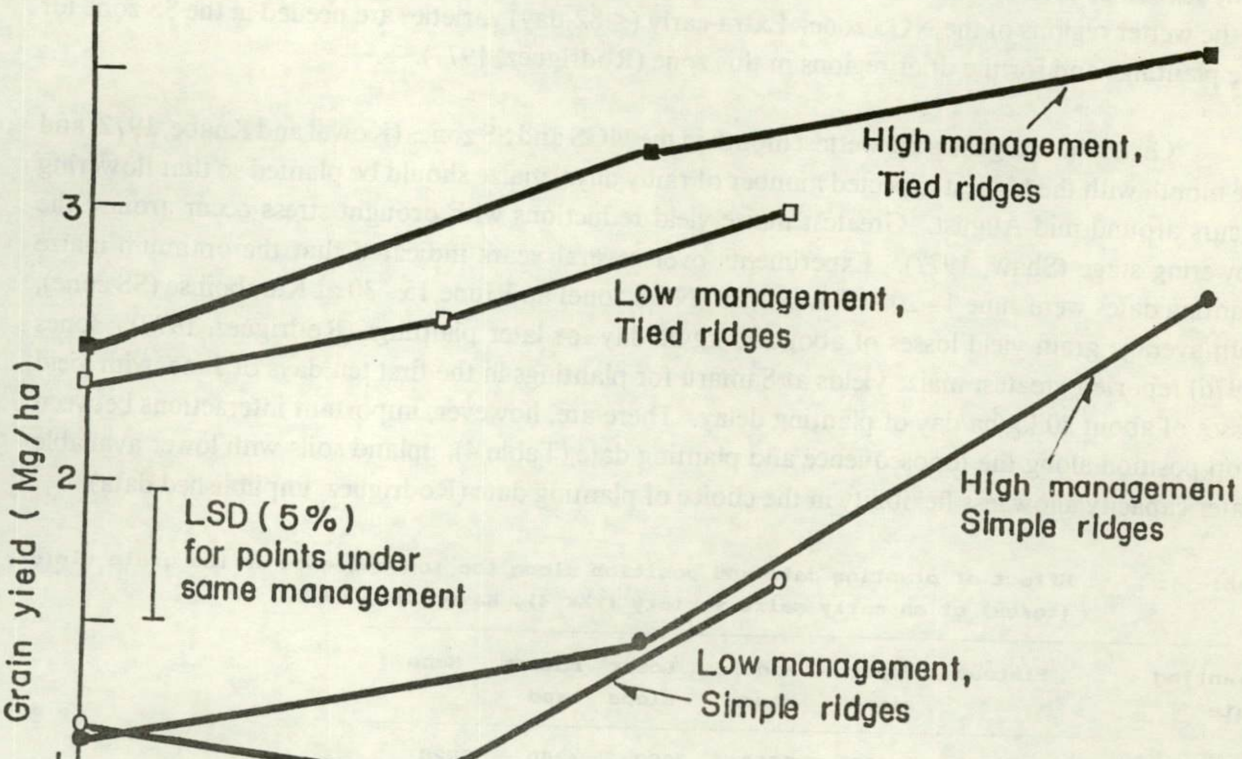


Figure 6: **Effect of maize residues on maize yield under two ridging systems and two management levels (Rodriguez, 1985).**

Matching Phenology and Expected Water Supply. Matching the phenology of the crop to the expected water supply is the most important trait to increase sorghum and cowpea grain yield per unit of precipitation under intermittent and terminal drought stress environments (Ludlow and Muchow, 1988). This should be equally true for maize, being a less drought tolerant crop than sorghum and cowpea. Choice of varieties and planting dates are involved in matching phenology and expected water supply.

From the experience of the IITA/SAFGRAD Maize Agronomy Program, under "average" rainfall conditions and for simple maize monocropping systems aimed at maize grain production, early (82 - to 95-day) varieties are most appropriate for the SS zone, and intermediate (96- to 110-day) varieties can be used for the NGS zone. Late (about 120 - day) varieties can be used in the better soils or the wetter regions of the NGS zone. Extra-early (< 82-day) varieties are needed in the SS zone for late plantings and for the drier regions in this zone (Rodriguez, 1977).

Given that August is the wettest month in the NGS and SS zones (Kowal and Knabe, 1972) and the month with the highest expected number of rainy days, maize should be planted so that flowering occurs around mid-August. Greatest maize yield reductions with drought stress occur around the flowering stage (Shaw, 1977). Experiments over several years indicated that the optimum maize planting dates were June 1 - 20 at Farako-Ba (NGS zone) and June 15 - 30 at Kamboinse (SS zone), with average grain yield losses of about 50 kg/ha/day for later plantings (Rodriguez, 1977). Jones (1976) reported greatest maize yields at Samaru for plantings in the first ten days of June, with yield losses of about 80 kg/ha/day of planting delay. There are, however, important interactions between crop position along the toposequence and planting date (Table 4); upland soils with lower available water capacity allow less flexibility in the choice of planting date (Rodriguez, unpublished data).

Table 4: Effect of planting date and position along the toposequence on the grain yield (kg/ha) of an early maize variety (TZE-4), Kamboinse, 1980.

Planting date	Plateau	Upper slope	Middle slope	Lower slope	Bottom land	Mean
June 14	1590	2180	2650	3990	4200	2920
July 5	620	845	1030	2120	4040	1730
July 17	110	520	390	955	1900	775
Mean	775	1180	1360	2350	3380	1810

C.V. (%) = 21.0

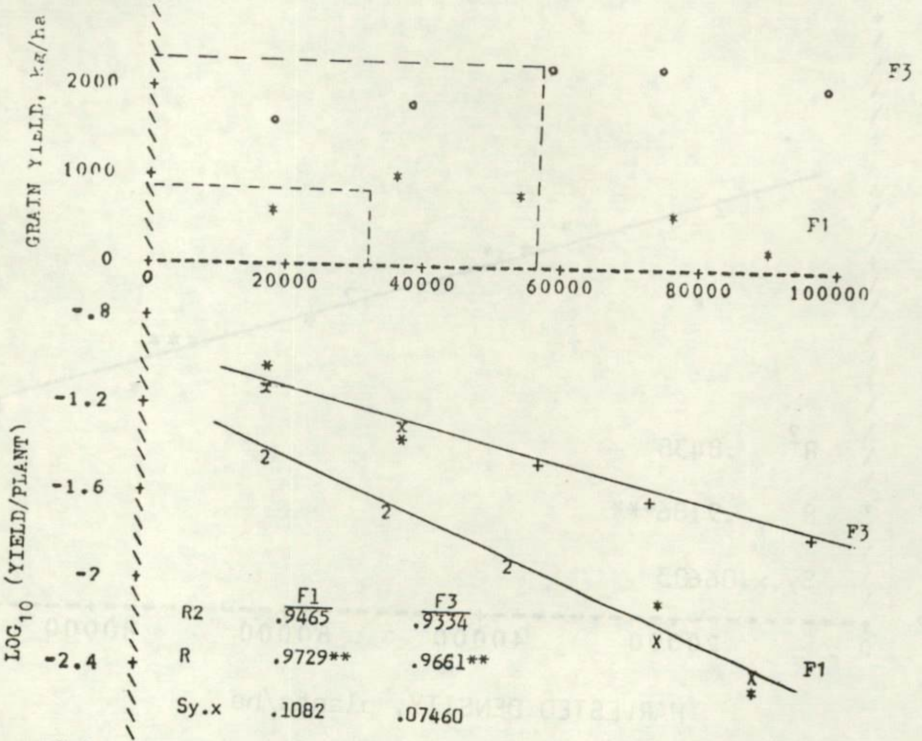
L.S.D. (5%): Planting dates = 524
positions = 592

Plant Density. Plant population density affects the relative contribution of evaporation and transpiration to actual evapotranspiration. Under conditions of drought stress, plant population may also affect the harvest index and maize grain yield.

The optimum plant density for maximum maize grain yield changes with soil fertility, planting date and cycle (maturity) of the variety. Rodriguez (1987) reported that when soil fertility is not a major yield limiting factor, and if the planting date is appropriate, optimum maize densities in the NGS and SS zones were similar to those found in more humid zones: 50,000 to 65,000 plants/ha for intermediate varieties, and 65,000 to 90,000 plants/ha for early varieties (Figs. 7 and 8). These optimum densities can be reduced by 20 - 30% with only a small (less than 5%) loss of grain yield, thus decreasing planting and harvesting costs to the farmer, and reducing the risk of crop failure if grain filling occurs during severe terminal drought.

Optimum densities decrease as soil fertility becomes a yield limiting factor. The effect of Planting date on optimum density become important when most of the grain-filling period occurs under conditions of terminal drought. In this case, optimum density drops to about 20,000 plants/ha.

Termite Control. Drought stress is increased by damage to the maize roots by termites. Often, termite presence goes unnoticed because it is not always accompanied by above ground termite activity and damage. The extent of this problem, which occurs both in the NGS and SS zones, has not been assessed, but it is likely to have been underestimated. The damage is sometimes easily recognized by the presence of wilting plants in soil with adequate moisture. Carbofuran was more or less effective in controlling termite damage, but it is rather expensive and toxic to people. More research needs to be conducted on methods of controlling termite damage in maize.



Above : The dotted lines show the estimated optimum density and maximum yield.
Below : * : observed values
× : estimated values
+,2 : the observed and the estimated values coincide.

Figure 7: **The effect of plant population on the grain yield and log (yield/plant) of TZPB grown at two fertilizer levels at Farako-Ba, 1979.**

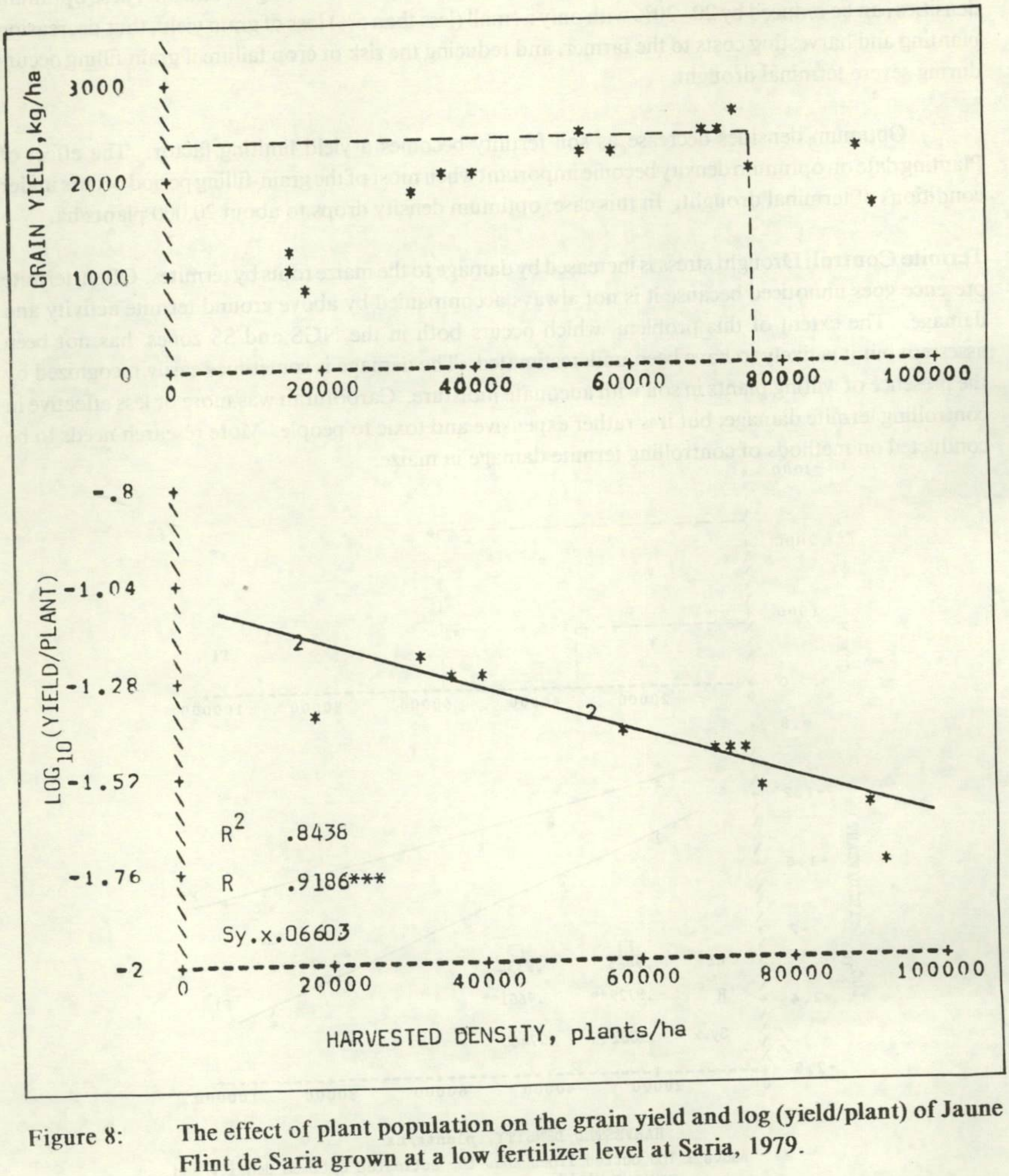


Figure 8: **The effect of plant population on the grain yield and log (yield/plant) of Jaune Flint de Saria grown at a low fertilizer level at Saria, 1979.**

Above : The dotted lines show the estimated optimum density and maximum yield.
Below : * : observed values
2 : two observed values coincide.

VI. CONCLUSION

The risk of drought stress is greater in the SS zone than in the NGS zone. Many agronomic options are available to reduce the risk of drought stress for maize production. There is a need for characterizing the best combination of cultural practices for different soils and environments, taking into account profitability and other socio-economic factors related to adoption. Increase and sustainable maize production requires that, in addition to practices for reducing the risk of drought stress, other management options be developed and adopted for dealing with other important yield limiting factors, especially low soil fertility, soil compaction, and weed, pest and disease damage. Control of soil erosion is also essential for sustainable maize production in the NGS and SS zones.

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CROP AND SOIL MANAGEMENT STUDIES FOR INCREASING FOOD PRODUCTION IN THE SUDANIAN ZONE OF BURKINA FASO

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ABSTRACT

The National Farming Systems Research (NFSR) Programme-Kamboinse team - of INERA has conducted on-farm experiments in the Sudanian zone of Burkina Faso since 1985. Two major constraints to crop production, i.e., soil moisture and nutrient deficiencies, were addressed.

Marked yield increments were obtained with some combinations of soil-moisture storage, variety and/or fertilizer treatments. The effect was, however, influenced by seasonal rainfall, technology and crop. For example, tied-ridging significantly increased the yields of major crops when rainfall was 500 - 700 mm; the increase was even higher when tied-ridging was combined with fertilizer. When rainfall was about 400 mm, the effect of tied-ridging was significant on cowpeas and peanuts, but not on millets or sorghum. Also, sorghum response to tied-ridging and/or fertilizer was higher than that of millet, with 500 - 700 mm seasonal rainfall.

Findings indicate that a wide choice of technologies is required in order to cope with environmental diversity. A more detailed characterization of the physical environment is also needed for efficient technology transfer.

I. BACKGROUND

Farming systems research has been carried out in Burkina Faso by FSU/SAFGRAD, ICRISAT and IRAT, mostly on cropping systems. In 1985, a national farming systems research (NFSR) program was elaborated, which was viewed as a link between the other seven programs of INERA - the national agricultural research institute, extension agencies, and farmers.

Five teams were created within the NFSR with mandates covering five different regions of the country. The first of these teams was established at Kamboinse station and has been conducting research activities in the Sudanian zone (Central Plateau) since 1985.

1. Objective and Approach of the NFSR

The principal objective of the NFSR program is to promote intensive and stable farming systems which increase agricultural productivity and restore the natural resources of the area. This is to be achieved through research which permits better integration of the crop, livestock and forestry enterprises.

It was hypothesized that the need for agricultural intensification would be more crucial where population density was highest. Assuming other factors remain comparable, areas with high population emigration would indicate that the existing farming systems can no longer meet the requirements of all residents. Therefore, farmers would be ready to collaborate in the search for new technologies, and successful technologies would benefit more people (INERA/SAFGRAD, 1986). Accordingly, the Central Plateau, which is the most densely populated region of Burkina Faso, was selected as the target area of the NFSR program based at Kamboinse.

Three representative subregions in the Central Plateau were identified:

- Ouahigouya area, in the Sudano-Sahelian zone, with migration rate of 34%;
- Koudougou area, in the Sudanian zone, 28% migration rate;
- Koupela area, also in the Sudanian zone, with 15% migration rate.

In early 1986, one primary research village site was selected per subregion (Fig. 1).

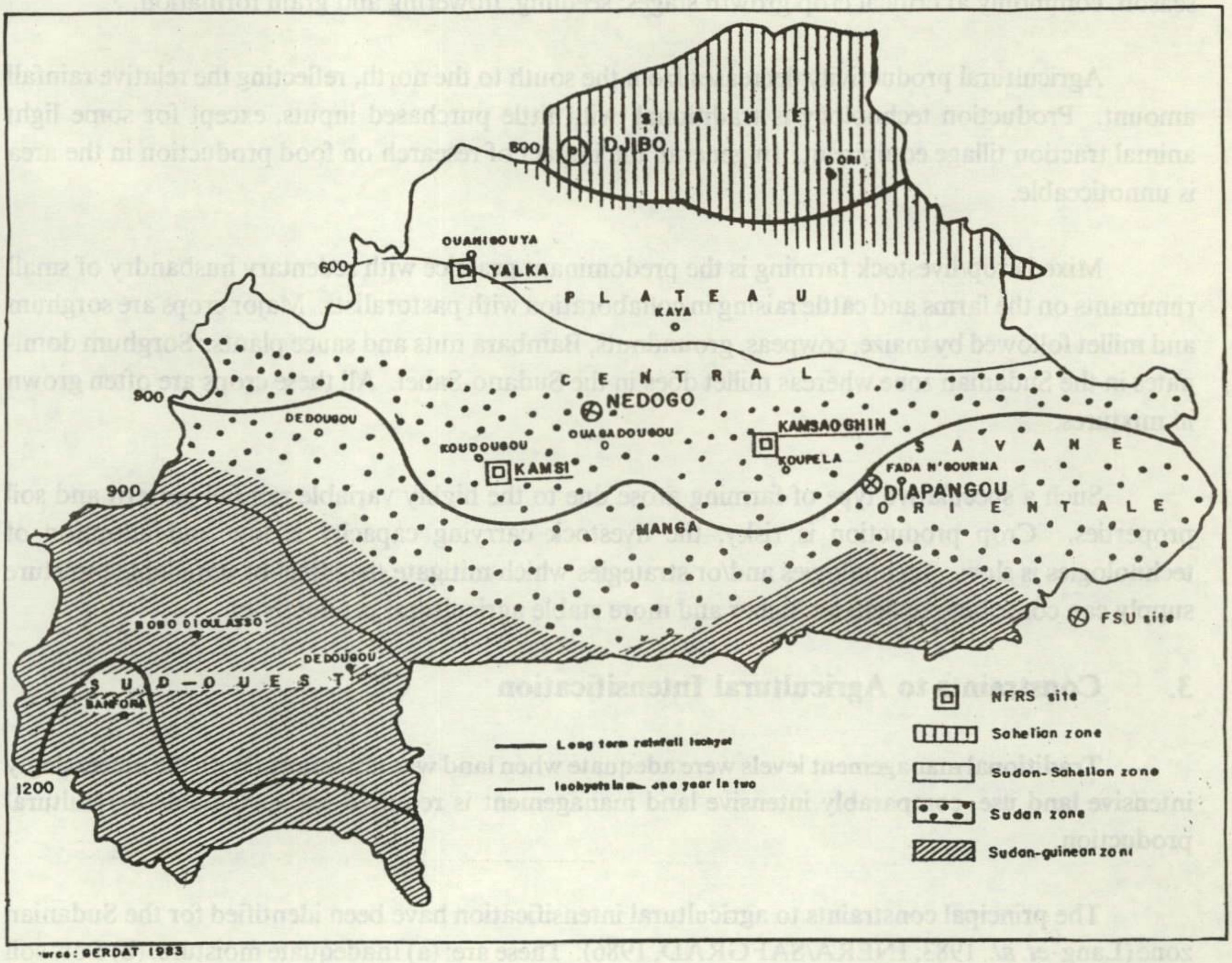

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Figure 1: Geographical location and agroclimatic classification of the selected study sites in Burkina Faso.

2. Agricultural Production Environment of the Central Plateau

The central Plateau, located in the Sudanian agro-ecological zone, covers 94000 sq. km, which is 34% of the area of Burkina Faso. It supports 50% of the population at a density of 20 - 70 inhabitants per sq.km. The mean population density per sq. km of arable land is estimated at 107 (INERA/SAFGRAD, 1986). Soils are in general sandy (Alfisols) with low fertility levels, especially those around Ouahigouya area. Vertisols and Hydromorphic soils are also found in lowlands. The vegetation is composed of scattered tree and shrub species typical of the savanna.

Mean annual rainfall ranges from 600 mm in the north to 1000 mm in the South. High temperatures, coupled with hot dry winds from the Sahara desert are common, leading to as much as 1900 mm potential evapotranspiration. Periods of moisture stress occur frequently during the growing season, commonly at critical crop growth stages: seedling, flowering and grain formation.

Agricultural productivity decreases from the south to the north, reflecting the relative rainfall amount. Production technology is traditional, with little purchased inputs, except for some light animal traction tillage equipment. In general, the impact of research on food production in the area is unnoticeable.

Mixed crop/livestock farming is the predominant practice with sedentary husbandry of small ruminants on the farms and cattle raising in collaboration with pastoralists. Major crops are sorghum and millet followed by maize, cowpeas, groundnuts, Bambara nuts and sauce plants. Sorghum dominates in the Sudanian zone whereas millet does in the Sudano-Sahel. All these crops are often grown in mixtures.

Such a speculative type of farming arose due to the highly variable rainfall pattern and soil properties. Crop production is risky, the livestock carrying capacity is low and adoption of technologies is slow. Technologies and/or strategies which mitigate the effect of unreliable moisture supply can contribute to achieve higher and more stable agricultural productivity.

3. Constraints to Agricultural Intensification

Traditional management levels were adequate when land was abundant. With the increasingly intensive land use, comparably intensive land management is required for sustainable agricultural production.

The principal constraints to agricultural intensification have been identified for the Sudanian zone (Lang *et. al.,* 1983; INERA/SAFGRAD, 1986). These are: (a) Inadequate moisture: (b) Low soil fertility and land quality deterioration; (c) Labour bottlenecks during periods of peak demand, (d) Lack of adequate agricultural implements; (e) Insect pests and diseases; and (f) *Striga* weed.

Labour bottlenecks, *Striga* and lack of implements were of concern uniformly in the three subregions. Problems associated with moisture deficit and poor soil fertility were more crucial in the Sudano-Sahelian than in the Sudanian subregions. Damage to crops due to insects (leaf hoppers, army worms, stem borers and termites) were of major concern in the Sudanian zone. Additionally, birds were found to cause serious damage to crops in the Koupela area.

Technologies addressing these major constraints have been identified by research and development organizations, and needed to be evaluated at farmers' fields level. Major emphasis was on those addressing moisture and nutrient deficiencies, and, to a lesser extent, labour constraint. Therefore, the influence of *in situ* moisture storage technologies (tied-ridging, mulching), fertilizer application, and cereal/legume inter-cropping on crop yields was investigated in the Sudanian zone of Burkina Faso by the National Farming Systems Research (NFSR) Program, from 1985 to 1988.

II. TESTING OF TECHNOLOGIES - MATERIALS AND METHODS

Field experiments were initiated in 1985 in three villages which were former research sites of the FSU/SAFGRAD project. Subsequently, trials were carried out at new village sites, i.e., Kamsi, Kamsaoghin and Yalka (Fig. 1), for three years (1986 - 1988). Trials of succeeding years were designed to complement findings of preceding years.

1. Objectives

The experiments initiated in 1986 were designed to evaluate:

(a) the potential yield increment that would result from combination of improved soil management and crop variety, as compared to current farmers' practices;

(b) yield variability across and within villages, in order to estimate environmental heterogeneity, which would help in defining recommendation domains for new technologies.

Researcher-managed trials were conducted at different locations in each study village for the major cereal and legume crops of the area in sole or cereal/legume mixed cropping. White sorghum, millets, cowpeas, peanuts and Bambara nuts were tested in all three villages; in addition, red sorghum and maize were tested in the two Sudanian villages (Kamsaoghin and Kamsi).

2. Materials and Methods

2.1 1986 Trials

Cereals: Two management levels were assigned to whole plots in replicated split-plot design, with crop varieties as subplot treatments. Management levels were:

-Traditional: flat cultivation without fertilizer;
-Improved: tied-ridging + fertilizer.

Tied-ridging was done one month after planting (MAP). fertilizer was side-dressed two weeks after planting at the rate of 100 kg/ha N: P205:K20, followed by urea at the rate of 50 kg/ha one MAP.

Planting density was about 33000 plants/ha for sorghum and maize and 16000 for millet. Varieties planted were those recommended for the subregion by breeders and farmer's varieties.

Each experiment was repeated at 4 - 6 locations per village.

Legume Grains: The objective of the experiment was to determine the effect of land management and sources of phosphate on cowpeas, peanuts, and Bambara nuts. Recommended and local varieties of these legume grains were assigned to whole plots in a replicated split-plot design with soil management as subplot treatments. The subplot treatments were:

-Control: flat cultivation without fertilizer;
-Burkina phosphate (BP): 400 kg/ha band applied at planting;
-Super phosphate (SP): 100 kg/ha;
-Tied-ridging (TR) + BP one MAP;
-TR + SP.

Legume grains were planted at a density of 31000 plants/ha. Insecticide was applied twice, at flowering and pod formation, on cowpeas.

Each experiment was repeated at two locations per village.

Cereal/Legume Intercropping: The objective was to estimate the supplementary yield of legume grains that could result from inter-cropping them with the major cereals. Several trials were conducted on sorghum (red and white)/cowpea and millet/(cowpea or *Phaseolus aureaus)* intercrops.

The experimental design was a split plot with soil management as main plots and intercropping types as subplots. Main plot treatments were:

-Control: flat cultivation, no fertilizer;
-Fertilizer on cereal: 100 kg/ha N:P205:K20 + 50 kg.ha urea;
-TR one MAP + fertilizer on cereals.

Cowpea monocrop was fertilized with 50 kg/ha N:P205:K20. Subplot treatments were:

Sorghum/Legume	**Millet/Legume**
-Sorghum sole;	- Millet sole;
-Sorghum + Cowpea, no insecticide;	- Millet + Cowpea;
-Sorghum + Cowpea, insecticide on cowpea;	- Millet + *P. aureus*:
-Cowpea sole, with insecticide.	- Cowpea sole;
	- *P. aureus* sole.

The intercropping was additive with sorghum population at a density of 33 000/ha and that of millet at 16000.ha. Legumes were planted two weeks to one month after cereals, between cereal rows and at a density of 31000/ha. No insecticide was applied to legumes intercropped with millet. Both introduced and local cowpea varieties were tested in cereal/legume intercrops.

2.2 1987 Trials

This second year's trials followed those of 1986 with some changes. The number of locations was reduced to two per village for each experiment. Soil management treatments were increased in order to separate the individual effects of fertilizer and tied-ridging. The number of cereal/legume intercropping trials was also increased, and testing on mulching and, to a lesser extent, manuring, was initiated.

Cereals: The experimental design was the same as in 1986. The main plot treatments were: Control; Fertilizer; TR one MAP (TR1); TR two MAP (TR2). Both TR treatments were with or without fertilizer.

TR2 was added on sorghum and millet in order to determine whether TR done later in the season, i.e., when labour pressure is less, could increase grain yields of long-cycle crops. The effect of mulching, with and without fertilizer application was investigated at one location per village with white sorghum.

Legumes: The legume grain trials were the same as in 1986, with a modification in soil management treatments: Control: TR; TR + BP; and TR + SP.

Cereal/Legume Intercropping: The design was similar to that of 1986.

2.3 1988 Trials

The experiments covered soil management influence on the two major cereals: sorghum and millet sole or intercropped with legumes. Only one variety was tested per crop, and the experimental design was a randomized block. In the case of intercropping, the design remained a split plot, as for the previous years.

III. RESULTS AND DISCUSSIONS

1. Environmental Conditions 1986 - 1988

Long-term average rainfall regimes range from unreliable at Yalka to moderately reliable at Kamsaoghin to reliable at Kamsi, with values of 667, 790 and 816 mm, respectively. The past seasons have been deficient in the two drier villages, especially at Yalka, whereas at Kamsi, seasonal rainfall either exceeded (1987)or equaled (1986, 1988) the long-term average (Table 1).

Table 1: Rainfall characteristics at Yalka, Kamsi and Kamsaoghin during 1986 - 1988.

Site	Year	Amount (mm)	Period	Distribution
YALKA (Sudano-Sahel)	1986	468	Mid June-Sept	Fair
	1987	394	Early June - early October	Very poor
	Long-term mean (Ouahigouya)	667	-	Highly variable
KAMSAOGHIN (Sudanian)	1986	663	End June-Sept	Fair
	1987	694	Early June - early October	Very poor
	1988	742	Early June - end September	Good
	Long term mean (Koupela)	790	-	Variable
KAMSI (Sudanian)	1986	818	End May - early October	Poor, early Season
	1987	1058	End May - early October	Poor
	1988	846	Early June - end September	Good
	Long term mean (Koudougou)	816	-	Variable

Rainfall distribution was poor for the first two seasons with frequent dry spells around mid-June to end-July, and mid-September to early October (Fig. 2). Only in 1988 was distribution uniform, with dry spells not exceeding a decade for the two Sudanian villages. High storm intensity also characterized the rainfall; a major share of the rainfall was contributed by a few intense events. For example, 20% of the rain events accounted for 50% of the rainfall amount in 1987 (Fig. 3). The high erosivity of these storms, coupled with low infiltration rates, resulted in serious runoff losses.

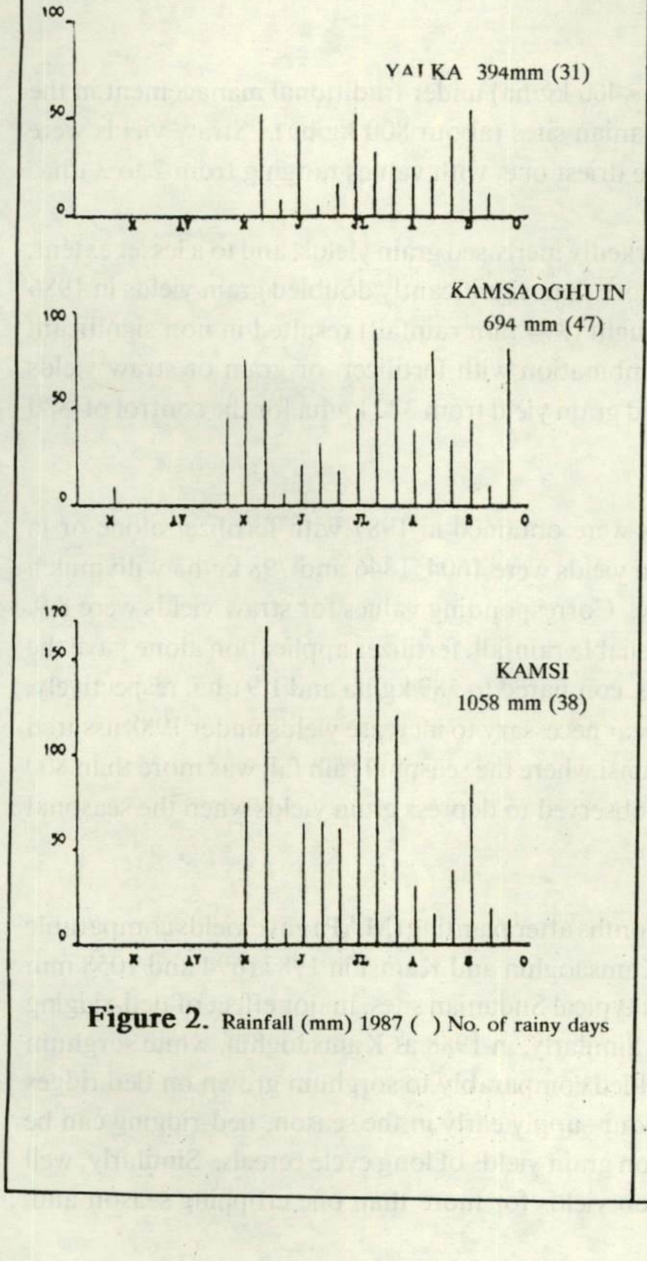

Figure 2. Rainfall (mm) 1987 ( ) No. of rainy days

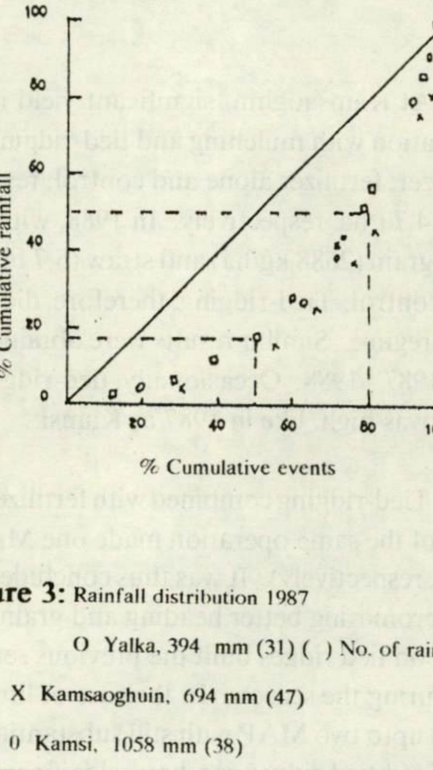

Figure 3: Rainfall distribution 1987

O Yalka, 394 mm (31) ( ) No. of rainy days

X Kamsaoghuin, 694 mm (47)

0 Kamsi, 1058 mm (38)

In 1987, insect infestation was a serious problem at Kamsaoghin and Kamsi. Armyworm attack at the beginning of the season caused heavy damage. Insect damage was especially high on cowpea at Kamsi. Cereals suffered from termite and stemborer attack. Bird damage occurred on cereals and was serious at Kamasaoghin.

2. White Sorghum

2.1 Response to Management

White sorghum grain yields were very low (<400 kg/ha) under traditional management in the Sudano-Sahelian as compared to those in the Sudanian sites (about 800 kg/ha). Straw yields were highest in the medium rainfall site and lowest in the driest one, with values ranging from 2 to 3 t/ha.

In all three sites, improved management markedly increased grain yields, and to a lesser extent, straw yields. At Yalka, tied-ridging and fertilizer more than significantly doubled grain yields in 1986 (468 mm rainfall). In 1987, however, extreme drought (394 mm rainfall) resulted in non significant effect of tied-ridging and mulching alone or in combination with fertilizer, or grain or straw yields (Table 2), although mulching with fertilizer increased grain yield from 372 kg/ha for the control of 880 kg/ha.

At Kamsaoghin, significant yield increases were obtained in 1987 with fertilizer alone or in combination with mulching and tied-ridging. Grain yields were 1604, 1346 and 798 kg/ha with mulch + fertilizer, fertilizer alone and control, respectively. Corresponding values for straw yields were 8.9, 5.6 and 4.7 t/ha, respectively. In 1988, with more reliable rainfall, fertilizer application alone gave the highest grain (2688 kg/ha) and straw (5.7 t/ha) yields, compared to 589 kg/ha and 1.9 t/ha, respectively, for the control. Tied-ridging, therefore, did not appear necessary to increase yields under 1988 assured rainfall regime. Similar results were obtained at Kamsi where the seasonal rain fall was more than 800 mm in 1987 - 1988. Occasionally, tied-ridging was observed to depress grain yields when the seasonal rainfall was high, like in 1987 at Kamsi.

Tied-ridging combined with fertilizer two months after planting (MAP) gave yields comparable to that of the same operation made one MAP, at Kamsaoghin and Kamsi in 1987 (694 and 1058 mm rainfall, respectively). It was thus concluded that at typical Sudanian sites, major effect of tied-ridging was in promoting better heading and grain filling. Similarly, in 1988 at Kamsaoghin, white sorghum planted on tied ridges built the previous season yielded comparably to sorghum grown on tied ridges made during the season. In the case of limited labour supply early in the season, tied-ridging can be delayed upto two MAP with still substantial effect on grain yields of long cycle cereals. Similarly, well maintained tied ridges can have significant effect on yields for more than one cropping season and, thereby, avoid tedious yearly ridge construction.

Table 2: Summary of white and red sorghum yield response (kg/ha) to management levels (selected treatments).

Site	Year (rainfall, mm)	Management level	Grain (Factor)	Straw (Factor)
YALKA	1986 (468)	TR + F	979 (2.5)	-
		CONTROL	389	-
		LSD 0.05	304	-
	1987 (394)	M1 + F	880 (2.4)	4792 (1.5)
		TR + F	507 (1.4)	2941
		F	726 (2.0)	4468 (1.4)
		CONTROL	372	3222
		LSD 0.05	689	2381
KAMSAOCHIN	1986 (663)	TR + F	1812 (2.1)	
		CONTROL	857	
		LSD 0.05	795	
	1987 (694)	M1 + F	1604 (2.0)	8880 (1.9)
		TR + F	1590 (2.0)	6618 (1.4)
		F	1346 (1.7)	5595 (1.2)
		CONTROL	798	4734
		LSD 0.05	310	862
	1988 (742)	M1 + F	2031 (3.4)	5011 (2.6)
		TR + F	1896 (3.2)	4396 (2.3)
		F	2688 (4.5)	5667 (3.0)
		CONTROL	589	1911
		LSD 0.05	613	1535
KAMSI	1988 (846)	M1 + F	1947 (2.2)	7976 (3.6)
		TR + F	1447 (1.6)	6964 (3.2)
		F	1637 (1.9)	5476 (2.5)
		CONTROL	881	2203
		LSD 0.05	680	2973

TR = Tied-ridging one MAP; M1 = Mulch (5 t/ha); F= Fertilizer (100kg /ha NPK + 50 kg/ha urea)
NPK = N: 23 P205 : 15 K20.

Effect of mulching on sorghum was either greater than or comparable to that of tied-ridging. Unlike tied-ridging at times (at Kamsi, 1987) no yield depression resulted from mulching.

Grain yields of sorghum under improved management in the Sudano-Sahelian zone barely approached those obtained under traditional management in the Sudanian zone, which indicated that relative zonal advantage existed for the crop.

2.2 Varietal Effects

In the Sudano-Sahelian site two introduced varieties, IRAT 204 and SPV 35, were evaluated. The two varieties were comparable to the local cultivars with respect to grain yield under traditional management, whereas they were superior under improved management (Table 3). On the other hand, the local cultivar produce more straw than both improved varieties. Under severe drought conditions (1987) variety differences were not significant.

Table 3: White sorghum grain yield (kg/ha) under two management levels in the Sudanian zone of Burkina Faso, 1986.

Sites	Variety	Management Trad.	 Improv.	 Mean	Remarks
YALKA	IRAT 204	411	1052 a	732 a	LSD 0.05 Mngt.= 304**
(468 mm)	SPV 35	411	1099 a	755 a	Variety = 82**
	Local	345	786 b	566 b	Var. for same
					mngt. = 116**
					C.V. = 13%
	Mean	389 b	979 a		n=20/location, ns.
KAMSAOGHIN	IRAT 277	49	1383	966 b	LSD 0.05
	ICSV 1002	972	2194	1583 a	Mngt. = 795*
	KANFIAGUI	1040	1699	1370 a	Var. = 303*
	Local	865	1971	1418 a	C.V. = 22
					n = 16 for each
	Mean	857 b	1812 a		location (4), ns

Trad. = Traditional management, flat cultivation, no fertilizer;

Improv. = Improved management, tied-ridging one MAP + fertilizer (100 kg/ha NPK + 50 kg/ha urea). NPK = 14 N:23 P205:15 K20.

ns, *,** = non significant, significant at $P < 0.05$ and significant at $P< 0.01$ respectively.

In the Sudanian zone, the variety ICSV 16-5 BF occasionally out-yielded locals cultivars for grain production. This variety was however susceptible to lodging. Another variety, ICSV 1002 BF was comparable in yield behavior to ICSV 16-5 BF, but had the disadvantage of poor seedling established when early rains were erratic. The variety IRAT 277 had lower grain yield than the local. Of all the introduced materials, Kanfiagui, a variety form the eastern region of Burkina Faso, was equal to or performed better than farmers' cultivars. It was noted that the yield increment associated with variety substitution rarely exceeded 60%, that is, it was much lower than increments obtained with improved management. Furthermore, farmers' varieties produced significantly higher straw yields than introduced cultivars.

3. Red Sorghum

Red sorghum was evaluated primarily at Kamaoghin and to a lesser extent at Kamsi. In the Sudano-Sahelian zone (Yalka), red sorghum is a minor crop.

3.1 Response to Management

In 1986, the grain yield of red sorghum in response to tied-ridging combined with fertilizer was significantly higher than for the control. Mean values were 3558 and 1957 kg/ha, respectively.

In 1987, there was a significant effect of tied-ridging alone or in combination with fertilizer. Grain yields were 4033, 3333 and 2894 kg/ha with fertilizer, tied-ridging + fertilizer and control, respectively; corresponding straw yields were 8.9, 9.4 and 6.0 t/ha. Low response to soil management was due to the fact that the experiment was conducted on a well-manured, compound field.

In 1988, only fertilizer application significantly effected grai yields; due to the favorable rainfall of the season, tied-ridging or mulching alone did not have any significant effect on yield. Mean grain yields were 3761, 3750, 3458 and 2438 kg/ha with tied-ridging + fertilizer, mulch + fertilizer, fertilizer alone and control, respectively. Corresponding means for straw yields were 11.4, 9.1, 9.5 and 8.9 t/ha.

3.2 Varietal Effects

One introduced variety, Framida, from ICRISAT, was tested along with local varieties. Framida was comparable to, or performed slightly better than local cultivars under traditional management, but definitely out-yielded local cultivars under improved management. In 1986, for example, both Framida and farmer's variety had grain yields of about 2 t/ha, under traditional management. With tied-ridging and fertilizer, Framida produced 4 t/ha vs 3 t\ha of grain for the local (LSD 0.05 - 0.8). Additionally, straw yield of Framida was similar to that of the local (6 - 8 t/ha).

Other positive attributes of Framida include good To and beer taste, resistance to *Striga,* and good palatability of its stalks for animal feeding.

4. Millet

4.1 Response to Management

In 1986, grain and straw yields were significantly higher with combination of tied-ridging and fertilizer (1266 kg grain/ha, 2810 kg straw/ha) than with control (711 kg grain/ha, 1467 kg straw/ha), at Yalka (468 mm rainfall).

Extreme drought in 1987 (394 mm) resulted in low yields (200 kg grain/ha and 800 kg straw/ha). Some response to fertilizer application was noted for straw yields, with mean values of 1188 kg\ha compared to 501 kg/ha for the control. However, any effect of management was blurred by the high experimental error associated with stress. Like for sorghum, tied-ridging was not adequate under the extreme conditions of the season (Table 4).

Summary of millet yield response (kg/ha) to management levels (selected treatments), 1986 - 1987.

Site	Year (rainfall, mm)	Management level	Grain (Factor)	Straw (Factor)
YALKA	1986	TR + F	1266 (1.6)	2810 (4.9)
	(468)	CONTROL	771	1467
		LSD0.05	214	512
	1987	TR + F	134	684
	(394)	F	250	1188
		CONTROL	139	501
		LSD 0.05	142	693
KAMSAOGHIN	1986	TR + F	1631 (1.7)	–
	(663)	CONTROL	983	
		LSD 0.05	173	
	1987	TR + F	1133 (1.9)	7634 (1.3)
	(694)	F	1099 (1.8)	6979 (1.2)
		CONTROL	608	5816
		LSD0.05	296	586
KAMSI	1987	TR + F	396 (4.0)	1920 (2.4)
	(1058)	F	476 (4.8)	2232 (2.8)
		CONTROL	99	789
		LSD 0.05	105	335

TR = Tied-ridging one MAP; F = Fertilizer (100 kg/ha NPK + 50 kg/ha urea). NPK = 14 N: 23 P205 :15 K20.

At Kamaoghin, millet responded to management in 1986 and 1987 and produced acceptable yields in both years. In 1986, Millet grain yield increased from 983 kg/ha under traditional management to 1631 kg/ha with tied-ridging + fertilizer. In 1987, fertilizer alone resulted in significantly higher grain and straw production compared to the control, whereas, tied-ridging alone promoted more straw than grain production. Combination of tied-ridging with fertilizer did not significantly improve yields over fertilizer alone (Table 4).

At Kamsi, millet grain yield was low in 1987. Fertilizer application was the only treatment that significantly increased grain yield (from 99 kg/ha for the control to 476 kg/ha) and straw yield (from 789 kg/ha for the control to 2232 kg/ha).

In general, millet responded less than sorghum to tied-ridging with or without fertilizer. While sorghum yields under the highest management level were often two to three times greater than those under traditional management, the increment factor was well below two for millet. Millet is traditionally planted on relatively poorer fields than sorghum, and field history, therefore, may have induced the differential response observed for these crops.

4.2 Varietal Effects

The following improved varieties were compared to local cultivars: IKMP 5 and IKMV 8201, in the Sudano-Sahelian site; P8, Zalla, IRAT 172, IRAT 173, and IKMC 1, in the Sudanian sites.

Yields were very low under very dry (e.g. Yalka) and very wet (e.g. Kamsi) conditions in 1987 cropping season. Any varietal difference, therefore, was of little practical interest.

When rainfall was adequate, as was the case at Kamsaoghin (1986, 1987) and at Yalka (1986) more relevant differences were recorded. At Yalka, IKMP 5 was comparable to the local cultivar, whereas, at Kamsaoghin, improved varieties P8, Zalla and IKMC 1 yielded slightly higher (13 - 22%) than the locals. Varietal differences were taken as negligible due to high variability in yield.

5. Cowpeas

5.1 Response to Management

Cowpea grain yields without fertilizer input or tied-ridging were lower than 500 kg/ha irrespective of rainfall amount (Table 5). However, response to management depended on rainfall. In 1986, at Yalka (468 mm rainfall), grain yield tended to increase with phosphate application, alone or in combination with tied-ridging. Average yields ranged from 348 kg/ha for the control to 460 kg/ha with tied-ridging + superhosphate. In 1987, when rainfall was only 394 mm at Yalka, tied-ridging alone contributed to significant yield increase, from 295 kg/ha for the control to 756 kg/ha. When phosphate was added to tied-ridging, the yield increased to 866 kg/ha, but this was not significantly different from the effect of tied-ridging alone.

At Kamaoghin, rainfall was adequate in 1986 (663 mm) and this resulted in significant response of cowpea to phosphate applied alone or in combination with tied-ridging. The response was higher for TVX 3236 compared to the local variety. Grain yields were 490, 682 and 1153 kg/ha with control, superphosphate, and superphosphate + tied-ridging, respectively, for TVX 3236. Corresponding yields of the local cultivar were 292, 424 and 491 kg/ha. Additionally, rock phosphate (Burkina phosphate) gave comparable yields to superphosphate. In 1987, phosphate application, especially superphosphate, resulted in significant grain yield increment. At Kamsi, only response to phosphate was noted in 1987, because the season was wet. Also, cowpea yields rarely exceeded 1000 kg/ha, even under improved management.

Table 5: Effect of soil management techniques on the grain yield (kg/ha) of cowpea varieties grown under different rainfall regimes in Burkina Faso, 1986 - 1987.

Location	Year	Rainfall (mm)	Variety	Grain Yield				LSD .05	
				CONT	TR	TR+BP	TR+SP	Mgt.	Var.
YALKA	1986	468	Local	380	-	363	370	100	203
			SUVITA 2	315	-	472	550		
	1987	394	Local	140	747	974	852	280	248
			SUVITA 2	449	764	758	805		
KAMSAOGHIN	1986	663	Local	292	-	454	491	118	308
			TVX 3236	490	-	1070	1153		
	1987	694	Local	371	434	474	443	140	131
			KN-1	329	385	447	677		
KAMSI	1987	1058	Local	No grain					
			TVX 3236	385	-	422	642	229	-

TR - Tied-ridging one MAP;
BP - Burkina phosphate (400 kg/ha)
SP - Superphosphate (100 kg/ha).

5.2 Varietal Effects

The following varieties were evaluated along with the locals: SUVITA 2 for the Sudano-Sahelian site, TVX 3236 and KN-1 for the Sudanian sites. All three improved varieties produced more grain than local controls, with TVX 3236 giving the highest yield. This cultivar responded very well to either rock or superphosphate application. Under conditions of high rainfall (at Kamsi, 1987), locals produced high straw yields but no grain.

6. Cereal/Legume Intercropping

6.1 Sorghum/Legume

The sorghum cultivar Framida was grown in association with the cowpea varieties TVX 3236 in 1986 and 1988 and KN-1 in 1987, in the Sudanian zone. No significant difference was found between inter- and sole cropping for grain yield of the cereal crop (Table 6).

Table 6: Grain and straw yields (kg/ha) of sole and intercropped sorghum and cowpea under three soil management levels at *Kamaoghuin, in the Sudanian zone, in 1987.*

	Soil Management							
Intercrop	CONT	FERT	TR+FER T	Mean	CONT	FERT	TR+FERT	Mean
	------Grain yields----------				-------Straw yields----			
			Sorghum					
S	986	1208	1216	1137	7236	9500	6167	7634
S / C	1152	882	1088	1041	5995	6724	7147	6622
S / C + 1	904	758	690	784	4463	6476	5076	5338
Mean	1014	950	998	987	5898	7567	6130	6531
LSD 0.05								
Management =	786		n.s		2647 n.s.			
Intercrop =	328		n.s		2050 (P < 0.10)			
Managt x Intercop =	570		n.s		-			
C.V. (%)								
Management =	80				16			
Intercrop =	39				22			
		Cowpea						
C	555 b	576 ab	910 a	680 a	1792	2775	2306	2291a
S / C	198	252	240	230 b	519	455	689	554b
S / C + I	298	363	462	374 b	672	541	764	659b
Mean	-	-	-	-	994	1257	1253	1168
LSD 0.05								
Management =	131 **				723 n.s.			
Intercrop =	95 **				563 **			
Managt x Intercrop =	104 **				-			
C.V. (%)								
Management =	35				62			
Intercrop =	29				56			

S = Sorghum sole
C = Cowpea sole
S/C = Sorghum/Cowpea intercrop
I = Insecticide on cowpea

CONT = Control
FERT = 100 kg.ha NPK + 50 kg/ha urea on sorghum; 50 kg/ha NPK on cowpea (NPK = 14 N: 23 P205: 15 K20)
TR = Tied-ridging one MAP.

Under intercropping, cowpea grain yields with and without insecticide application were not significantly different; both yields were however significantly lower than that obtained with sole cowpea (Table 6).

Fertilizer application increased significantly cereal grain yield both under association and sole cropping in 1986 and 1988, but not in 1987. Cowpea also benefited from fertilizer application to the associated sorghum in 1986 and 1988, but not in 1987. Straw yield of the cereal was consistently height and not significantly affected by soil management.

6.2 Millet/Legume

Several millet/grain legume intercropping trials were also conducted during 1986-1988. In 1987, at Yalka, the millet cultivar IKMP 5 produced significantly more grain when grown in association with either cowpea (cv SUVITA 2) or *Phaseolus aureaus* than when grown sole. Mean grain yields were 448, 896 and 817 kg/ha for monocrop, mixture with *P. aureaus,* and mixture with cowpea, respectively (LSD 0.05 = 261, Table 7). Supplementary legume grain yields were 774 and 506 kg/ha (LSD 0.05 = 261) for pure and intercropped cowpea, respectively;, and 677 and 531 kg\ha (LSD 0.05 = 346) for pure and intercropped *P. aureaus,* respectively.

Similar results were obtained with millet cultivar P8 intercropped with *P. aureaus* or local cowpea, at Kamsaoghin. Millet grain yields were 433, 899 and 1088 kg/ha (LSD 0.05 = 334), and straw yields were 3.8, 5.4 and 6.3 t/ha (LSD 0.05 = 0.97), for pure millet, millet with *P. aureus* and millet with cowpea, respectively.

P. aureus produced about 400 kg/ha of grain under intercropping whereas local cowpeas performed poorly.

In 1988, millet varieties IKMC 1 and local were studied in intercropping trials with local cowpea cultivars at Kamaoghin and Kamsi, respectively. Millet grain yield, unlike in previous years, was significantly reduced by intercropping as compared to sole cropping, although straw yield was not affected. The grain yields of IKMC 1 were 1048 and 731 kg/ha (LSD 0.05 = 192) for pure and intercropping, respectively. Corresponding values for the local millet cultivar were 511 and 323 kg/ha (LSD 0.05 = 124). Local cowpeas produced abundant straw but no grain. No significant interaction was observed between soil management and cropping pattern for millet.

Table 7: Effect of intercropping and soil management on the grain yields (kg/ha) of millet and grain legumes at Yalka, 1987.

Intercrop	Soil Management				Remarks		
	CONT	FERT	TR+FERT	Mean	Factor	LSD.05	CV(%)
Millet yields							
Millet sole	400	479	465	488 b	Mngt	348ns	48
Millet + P. aureus	712	1063	913	896 a			
Millet + cowpea	744	856	850	817 a	Intcrop	215**	35
Mean	619	799	743	720			
Cowpea yields							
Cowpea sole	754	688	882	774 a	Mngt	396ns	51
Millet + cowpea	406	500	612	506 b			
Mean	580	594	747	640	Intcrop	261**	44
P. aureaus yields							
P. aureus sole	601	694	736	677	Mngt	389 ns	53
Millet +P. aureus	513	550	531	531			
Mean	556	622	634	604	Intcrop	346 ns	62

Variety: Millet = IKMP5 CONT = Control
Cowpea = SUVITA2 FERT = 100 kg/ha NPK + 50 kg/ha urea no insecticide
on millet: 50 kg/ha NPK on cowpea (NPK = 14 N: 23 P205: 15 K20)
TR = Tied-ridging one MAP

Miscellaneous Results

Maize: Maize is grown on small (0.05 ha/household), rich compound fields in the two Sudanian sites. Good yields (1.5 - 2.0 t grain /ha and 2.0 - 5.0 t straw/ha) were observed even with no extra input. Therefore, maize could be an attractive crop, with improved land management, for the area. Farmers' varieties were comparable to introduced cultivars.

Peanuts: Peanuts responded to phosphate application, but to a lesser extent than did cowpeas. No significant varietal effect was observed.

Bambara Nuts: The yield was highly variable, reflecting large heterogeneity among farmers' varieties. A need for intensive research on station exists before on-farm testing can be conducted.

Manuring: Ten t/ha of manure affected sorghum yields in the first year of application in the same way as did mulching.

Yield variability: Yields differed markedly between locations, even in the same season, thus indicating the influence of land quality. For example, in 1986 at Yalka (468 mm), millet yields ranged from 542 to 2435 kg/ha (LD 0.05 = 448) at one location. Yields at 4 other locations were intermediate. Similarly, at Kamsaoghin (663 mm), millet yields ranged from 886 kg/ha on a *Striga* infested field to 1925 kg/ha on another field (LSD 0.05 = 238). Similar significant differences were observed for other crops. These observations suggest that there is a need for better characterization of edaphic properties of the soils in order to facilitate technology transfer.

IV. CONCLUSION

Several techniques aimed at alleviating soil moisture and fertility deficiencies and optimizing crop production were evaluated in the Sudanian Savanna zone of Burkina Faso. Effects of tied-ridging on crop yield, expectedly, depended on the rainfall. Under severely dry conditions (400 mm) cowpea yields were significantly increased by tied-ridging but not those of sorghum or millets. For rainfall amounts in the 500 - 700 mm range, cereal and, to a lesser extent, legume, grain yields tended to increase with tied-ridging alone or combined with fertilizer application. Under adequate rainfall conditions, tied-ridging either had little effect on or depressed crop yields. Thus, tied-ridging appeared to be most effective for areas with rainfall ranging from 500 to 700 mm. A major constraint for the adoption of tied-ridging is its intensive labour requirement.

Crop response patterns to mulching were similar to tied-ridging effects. Mulching, however, tended to be more advantageous than tied-ridging in the driest area with no depressive effects on yields at the wettest site. Thus, mulching could be regarded as a technology with wider potential adaptation zone than tied-ridging. Constraints to adoption of mulching are: scarcity of materials as a result of multiple demand for crop residues, transport of material, and limited labour supply.

Fertilizer effects depended on soil moisture. Under reliable rainfall conditions (750 mm or more), sorghum, maize, and to, a lesser extent, millet yields were significantly increased by application of minimum doses of fertilizer. Fertilizer effect was increased when combined with tied-ridging or mulching. Under poor rainfall conditions (400 mm, 1987) fertilizer application, even in combination with moisture conservation techniques, was risky. Legume crops responded to phosphate application alone (wetter seasons) or in combination with tied-ridging (drier seasons). This suggests that policies to promote fertilizer use can be recommended in areas of reliable rainfall, taking into account soil hydrologic characteristics. Economic rates will need to be specified on a crop x agroecologic matrix basis.

Promising improved cultivars were noted for red sorghum, cowpeas and, to a limited extent, white sorghum. The red sorghum variety FRAMIDA gave high grain and straw yields, responded well to soil management improvement, and was well appreciated by farmers for its human food value (grain) and feed quality (straw). Similarly, a white sorghum cultivar from the eastern region of the country, KANFIAGUI, showed good response to improved management and was appealing to farmers. Cowpea cultivars TVX 3236, KN-1 and SUVITA 2 performed better than the locals and were able to produce grain without insecticide application in association with cereals, i.e., under traditional cropping practices. This could encourage their adoption by farmers.

Sorghum/cowpea (FRAMIDA/TVX 3236, FRAMIDA/KN-1) or millet/cowpea (P8/SUVITA2) crop associations were promising. Advantages of inter-cropping were: (a) full yield of cereal can be harvested with some bonus grain of cowpeas or mungbeans; (b) improved cowpeas produced grain under intercropping without insecticide application, whereas insecticide application is normally required for grain production under sole cropping; and (c) intercropping requires relatively light adjustment to the current practices of farmers, i.e., row-planting instead of broadcasting, changes in plant density and selection of compatible legume crop species or varieties. Therefore, intercropping can offer an entry point for crop intensification in the area.

V. ACKNOWLEDGEMENTS

Mr. Adama Sohoro participated in the research activities of 1986 season. The contribution of field technicians in data collection in village sites and of station technicians for assistance in data analysis is gratefully recognized.

The NFSR programme (Kamboinse team) benefitted from generous resource assistance (technical and financial) of OAU/STRC/SAFGRAD through IFAD funding.

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MILLET-BASED CROPPING SYSTEMS FOR IMPROVING FOOD PRODUCTION IN THE SOUTHERN SAHELIAN ZONE

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ABSTRACT

Pearl millet is the major cereal of the low soil fertility and frequently drought-prone Sahelian zone (average annual rainfall, 300-600 mm) of West Africa. However, its very low production growth rate (<1% per annum) in the last 25 years has contributed to the slowest growth rate for total food production in sub-Saharan Africa. Improvement of millet production in this zone depends on amelioration of the inherent low soil fertility, the improvement of cultural practices and cultivar choice.

This paper highlights component and operational-scale research findings at the ICRISAT Sahelian Center, Sadore, Niger, which demonstrates that through better management pearl millet cropping systems in West Africa have the potential to be much more productive. An array of crop management options which can improve production are available: improved varieties and cropping systems, use of judicious quantities of fertilizer inputs to alleviate soil nutrient deficiencies, tillage techniques to reduce the damaging effects of sandstorms and drought spells, and improved cultivation methods to optimize labour requirements for various operations. Results reported in this paper substantiate previous findings that soil fertility is the principal limitation to improving food production from millet-based cropping systems.

I. INTRODUCTION

Pearl millet *(Pennisetum glaucum* [L.] R.Br.) is the major staple cereal in the Sahelian zone (average annual rainfall, 300 - 600 mm) of West Africa which is characterized by low soil fertility and frequent drought. In this region, it is grown on 13.1 m ha, equivalent to 49% of the world's hectarage. Major producers are Nigeria, Niger, Mali, Chad and Senegal. Average grain yields are uniformly low, around 520 kg/ha. Of all the regions of sub-Saharan Africa, West Africa has shown the slowest growth rate for total food production, mainly due to the very low production growth rate of the major staples, sorghum *(Sorghum bicolor* [L.] Moench) and millet, and the decline in groundnut *(Arachis hypogea* L.) production (Spencer and Sivakumar, 1987). Bidinger and Parthasarathy Rao (1988) observed that, in the last 25 years, area sown to pearl millet increased by less than 1% per annum. Production grew about 1% in the 60s, but was static in the 1970s, because grain yields declined by 0.8% per annum.

The poor production performance of pearl millet can be attributed to the fact that millet is traditionally grown under harsh dryland conditions characterized by poor soils and erratic rainfall. Few inputs are used in production. This, coupled with the demographic pressure to increase area cultivated by reducing the fallow period and utilizing the poorer, marginal lands, has led to a reduction in per hectare yields (Bidinger and Parthasarathy Rao, 1988).

In a recent review, Fussell, *et. al.* (1987b) indicated that the principal limitations to millet yields in semi-arid West Africa are, in order of priority: (1) inherent low soil fertility, (2) limited and untimely cultural practices, and (3) the frequent occurrence of drought periods. Improvement of millet production in the southern Sahelian zone is, therefore, dependent upon the amelioration of soil fertility, the improvement of cultural practices, and cultivar choice. This paper describes current research on various components of improved millet production systems at the ICRISAT Sahelian Center (ISC). and the performance of these components in operational-scale research on the research station.

the improvement of cultural practices, and cultivar choice. This paper describes current research on various components of improved millet production systems at the ICRISAT Sahelian Center (ISC), and the performance of these components in operational-scale research on the research station.

II. SOIL FERTILITY AND SOIL STRUCTURAL MANAGEMENT IN MILLET PRODUCTION SYSTEMS

Pearl millet production in the Sahelian and Sudanian zones of West Africa is primarily limited by the soils of the area, rather than moisture in most years (Charreau, 1972; Penning de Vries and Djiteye, 1982; Fussell *et. al., 1987b).* These soils have poor physical properties for capture and storage of moisture/nutrients and for root growth, and have low soil fertility (for more detailed discussion, see Charreau and Nicou, 1971; Charreau, 1974, Fussell *et. al.,* 1987a). As a result, agronomic research on millet production systems at the ISC has focussed largely on methods of improving soil physical properties and soil fertility.

1. Soil Fertility Management

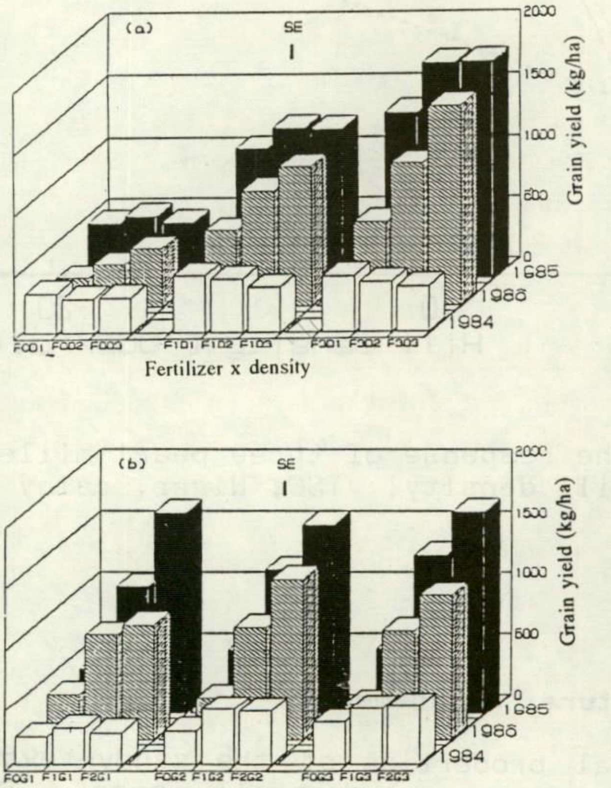
Soils in the semi-arid tropics of West Africa are low in inorganic matter (OM), available phosphorus (P), total nitrogen (N), and cation exchange capacity (Charreau, 1974). Many fertilizer trials have shown that low P and N are major constraints to millet production in the region (Bationo *et. al.,* 1986; Mughogho *et. al.,* 1986; Pieri, 1985a). Despite these findings, fertilizer use in pearl millet growing areas of West Africa is the lowest in the world (Paulino, 1987).

Amelioration of the poor soil fertility status results in both immediate production increases and enhances the returns from other improved production technologies. For example, a trial was conducted at the ISC over three rainy seasons (1984 - 1986) to examine various agronomic practices and their effects on varietal performance and as means of intensifying crop production. Total season rainfall varied considerably between years: 1984 was an extreme drought year with a total season rainfall of only 260 mm; 1985 (545 mm) and 1986 (657 mm) were better rainfall years.

Results of this trial indicated that there were year x fertilizer x density (Fig. 1a) and year x genotype interactions (Fig. 1b) for grain yield. There was little or no response in grain yield to increased plant density in the absence of fertilizer, whereas, with the addition of fertilizer, increased plant densities resulted in higher grain yields, but only in the better rainfall years of 1985 and 1986. (Fig 1a). In 1984, there was a decrease in grain yield with increased density at all fertilizer levels (mean increase = 71 kg/ha or 17%). The year x fertilizer x genotype interaction arose from the greater responsiveness to fertilizer of the improved cultivars ICH412 and CIVT than of the local cultivar in 1984 and 1985, compared to 1986 (Fig. 1b). The improved cultivars were also more responsive to increased plant density than the local cultivar (Fig. 2).

Interestingly, the addition of fertilizers increased water-use marginally (Fig. 3a,b), but improved water-use efficiencies substantially for both grain yield (Fig. 3c,d) and dry matter production (not shown here), even in an extremely low rainfall year. This is a finding supported by results from other parts of the semi-arid and arid areas for other crops (Cooper *et. al.,* 1987).

It can be concluded from these results that the improved pearl millet cultivars are more responsive to added fertilizer than the local cultivar. Furthermore, the improved cultivars will make better use of added fertilizer if sown at higher densities than those traditionally practiced (5000 vs 10000 hills/ha). Increasing plant density, without improving soil fertility, is not warranted. Although intensifying production through the use of higher plant densities may result in marginally lower yields in drought years (71 kg/ha or 17% in 1984), this will be more than compensated for in the better rainfall years (379 kg/ha or 52% in 1985 - 1986, Fig. 1a), particularly if fertilizers are used. The fear that added fertilizer and higher plant densities will enhance the detrimental effects of drought on grain yield appears not warranted; in fact, the contrary appears possible, where judicious quantities of fertilizers, particularly phosphatic fertilizers, are used. Under these production conditions, maximum use is made of the limited quantities of available moisture, such that water-use efficiencies are greatly increased.

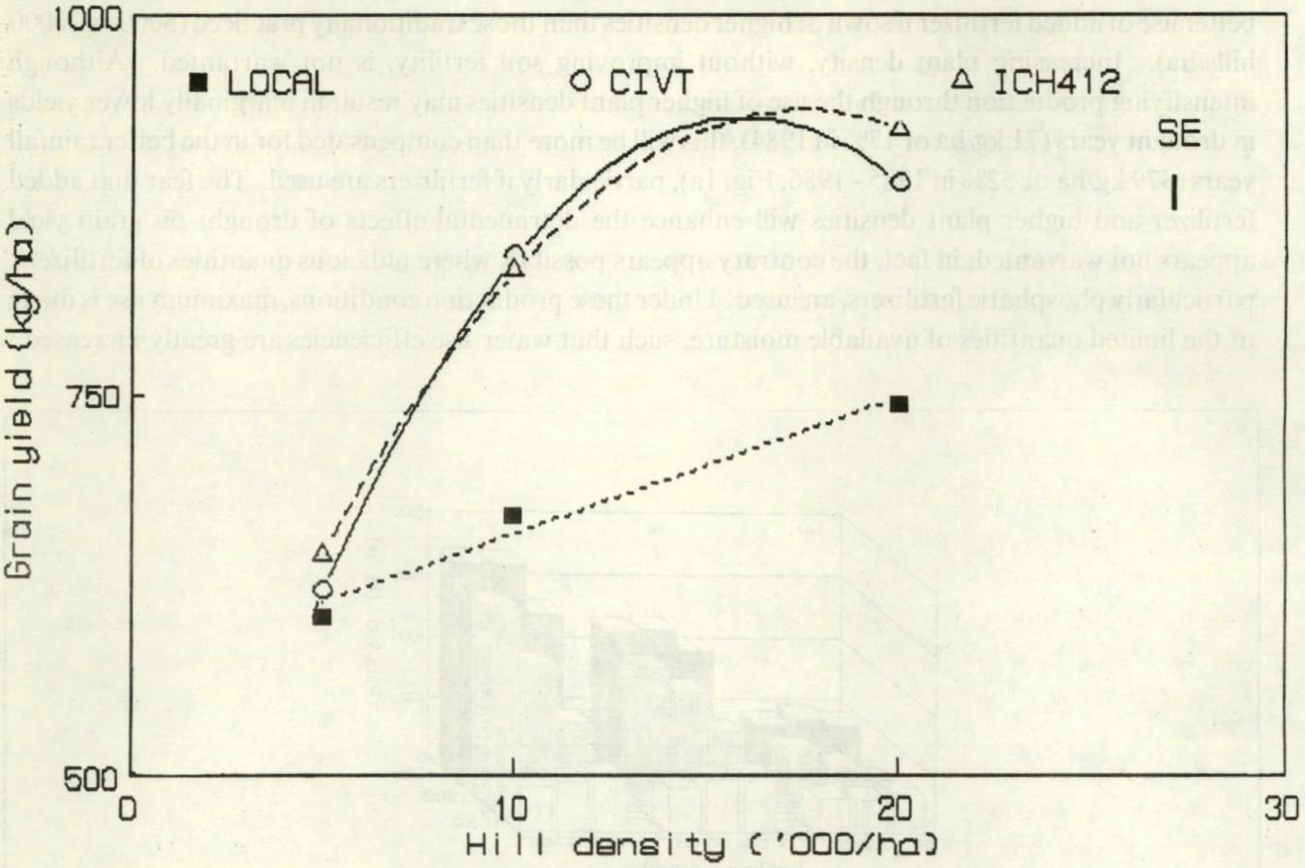


Fertilizer Levels:
F0 = 0 N: 0 P2O5 (kg/ha)
F1 = 23N: 20P2O5 (kg/ha)
F2 = 46N: 40 P2O5 (kg/ha)

Density Levels:
D1 = 5000 hills/ha
D2 = 1000 hills/ha
D3 = 2000 hills/ha

Genotype:
G1 = Sadore Local
G2 = CIVT
G3 = ICH 412

Figure 1: **Variations in grain yield of Pearl millet in different years due to (a) fertilizer and density and (b) fertilizer and genotype, at Sadore, 1984 - 1986.**



The response of three pearl millet genotypes to hill density. ISC, Niger, rainy season 1984-86.

2. Soil Structural Management

The physical properties of the sandy-textured soils where pearl millet is grown are generally poor. Surface soils are structurally weak, tend to compact, and are susceptible to crust formation. Available soil moisture is limited by inherently low water holding capacity and often by profile depth. These major limiting properties are confounded by the high rainfall intensity typical for West Africa. Research on improved soil management practices which aim at alleviating limiting factors to increased crop production on an annual basis, and at maintaining soil productivity is being carried out at the ISC. These practices include tillage, in combination with chemical fertilizers, crop residue management and crop rotation.

2.1 Primary Tillage. The direct effects of primary tillage result from a reduction of apparent soil bulk density, which is often accompanied by an increase in soil surface roughness and shape (Klaij and Hoogmoed, 1987). Reduction in bulk density of sandy soils reduces soil's resistance to root penetration (in both time and space) which is correlated to higher crop yields (Chopart, 1983). Tillage incorporates OM and/or chemical fertilizers, and improves weed control, thus saving soil moisture. Pieri (1985b) reports improved soil productivity over time when plowing was combined with fertilization and use of crop residues.

Tillage can be used primarily to increase soil surface roughness which improves rainfall infiltration, and reduces wind erosion (Klaij and Hoogmoed, 1987). Managing soil surface shape is very important in terms of soil and moisture conservation. Ridging has been shown to reduce soil losses due to wind erosion by as much as 85% on other continents (Fryrear, 1984).

At the ISC, a long term soil management experiment was started to study effects of primary tillage, fertilization, and the management of crop residues on millet production. Tillage treatments consisted of plowing to a depth of 15 cm, ridging without prior tillage, and a control treatment without primary tillage. The tillage treatments were carried out immediately after the first rainfall that exceeded 8 mm in May or June. Leaving crop residues (millet stover from the previous season) on the soil surface or partially incorporating them by plowing or ridging was compared to their removal. Effects of these treatments are presented in terms of dry-matter production.

Important interactions occurred between tillage, fertilizer addition, and crop residues (Table 1). In the absence of added fertilizer, crop residues increased dry-matter production by 1.5 t/ha, when incorporated by plowing. In the case of ridging and zero tillage, crop residues also increased dry-matter yield but to a lesser extent. It is hypothesized that reduced soil bulk density enhanced crop root growth and that the plowed-in residues decomposed faster than those left on the surface, releasing more nutrients compared to the other tillage treatments.

Table 1. Effect of fertilizer, primary tillage, and maintaining crop residues, on dry matter yield (t/ha) of pearl millet. ISC, Niger, averaged over 1985 - 1987 rainy seasons.

Treatment	Unfertilized		Fertilized (a)		
	(b)	(c)			
	- residue	+ residue	-residue	+ residue	Mean
Plowing	2.29	3.79	5.14	5.39	4.15
Ridging	1.84	2.61	4.42	5.43	3.58
Zero-till	2.01	2.96	4.39	5.20	3.64
SE±		0.23			
Mean	2.05	3.12	4.65	5.34	
SE±		0.18			0.09

(a): 17 kg/ha of P-fertilizer and 40 kg/ha of N/ha

(b): Crop residue removed at end of season.

(c): Crop residue not removed at end of season.

In the presence of added fertilizer, yield differences due to the treatments were much smaller. Crop residues did not increase yield in the case of plowing, because of the availability to the crop of the P-fertilizer. Ridging and crop residues tended to improve productivity more than in the plowed and zero-till situations when fertilizer was added. While the effect of primary tillage on dry-matter production was relatively small, soil bulk densities, typically ranging from 1.55 to 1.76 mg/m^3 prior to tillage (corresponding to a soil porosity range of 42% - 34%), were markedly reduced to 1.22 mg/m^3, thereby increasing soil porosity to 54%.

The beneficial yield effects of maintaining crop residues may, in part, be due to changes in soil chemical and biological processes, which have been observed by other researchers (Pichot *et. al.*, 1981). Between 1985 and 1988, crop residues increased soil OM from 0.26% to 0.29% (SE = ± 0.006). Furthermore, maximum soil temperatures (42° C at 5 cm depth) during crop establishment were slightly reduced by 1 - 2° C, by the sparse residue cover on the soil surface.

As reported in the section on soil fertility management, higher inputs (fertilizers, tillage, crop residues) had little effect on crop water-use, as measured by total evapotranspiration. The average seasonal crop water-use across treatments, ranging from 300 to 350 mm, increased only by 10 - 35 mm on high input plots. However, water-use efficiency improved considerably with intensified management because of the yield gains that accompanied the increased water-use.

2.2 Pre-season or Post-Harvest Tillage and Crop Rotation Effects.

We started a soil and crop management experiment in 1986 to evaluate tillage practices and crop rotation in a continuous cultivation system. Tillage methods consisted of plowing to a depth of 10 - 15 cm, ridging without prior tillage (75 cm between ridges, ridge height 15 cm), and no primary tillage referred to as zero-till. Post-harvest tillage was included because of timeliness problems associated with carrying out tillage immediately prior to planting and the poor physical status of draft animals at the end of the dry-season. Possible soil moisture conservation over the dry-season with post-harvest tillage and wind erosion control are other important aspects. The tillage operations were carried out either before sowing, as soon as possible after the first rain(s) had moistened the soil to a depth of 15 cm, or as soon as possible after harvest.

Pre-sowing tillage resulted in higher grain yields than the zero-till treatment (Table 2). Post-harvest tillage in 1987 was done on a rapidly drying soil. This resulted in a rather poorly structured surface soil particularly after ridging, which is shallower tillage than plowing. Subsequent sandblasting in 1988 reduced grain yields in the post-harvest tillage treatments compared to the pre-sowing tillage treatments, more so in the continuous pearl millet plots compared to the rotated millet.

Table 2: Grain yields (t/ha)* of pearl millet cv CIVT and cowpea cv Suvita 2 as a unction of tillage, timing of tillage, and rotation. ISC, Niger, rainy seasons 1986 - 1988.

Treatment	Continuous pearl millet			Rotated pearl millet		Continuous cowpea		
	1986	1987	1988	1986	1988	1986	1987	1988
Pre-sowing tillage								
Plowing	0.91	0.57	0.69	0.73	0.83	1.28	0.41	0.52
Ridging	0.91	0.46	0.87	0.75	0.76	1.10	0.32	0.46
Post-harvest tillage								
Plowing	-	0.63	0.38	0.80	0.62	-	0.34	0.41
Ridging	-	0.44	0.36	0.66	0.71	-	0.30	0.49
Zero-till	0.76	0.43	0.78	0.48	0.91	1.06	0.32	0.53
SE (±)	0.06	0.03	0.06	0.03	0.06	0.07	0.03	0.06
Mean	0.86	0.51	0.62	0.68	0.77	1.15	0.34	0.48
CV (%)	28	22	36	22	36	18	23	37

* : SE for comparing rotation effect on yield of pearl millet is +/- 0.02 in 1987 and 0.04 in 1988.

One advantage of post-harvest tillage is that it kills weeds and thereby reduces evapotranspiration. However, maximum soil moisture gains at planting were modest from tillage following the previous harvest averaging only 18 mm.

Ridging enhanced early-season soil moisture accumulation. On 15 July 1986, total soil moisture in the 0.3 - 2.6 m profile was 199 mm for ridged plots, 173 mm for plowed plots and 168 mm for the plots without primary tillage (SE = +/- 10). Runoff from the ridge into the furrow and subsequent deeper infiltration probably caused this.

Crop rotation increased pearly millet grain yields consistently over the years by 0.16 t/ha, on average (Table 2). Cowpea responded well to pre-sowing tillage except in 1988. Generally, effects of tillage on stover and hay yields were more pronounced than on grain yields (data not shown).

III. ANIMAL TRACTION

Soil and crop management activities are currently done by hand by most farmers. This limited power, coupled with the highly seasonal nature of crop production, leads to severe labour bottlenecks, particularly at the time of land preparation and weeding (Norman *et. al.,* 1981). Animal traction (AT) offers the Sahelian farmers the only alternative for mechanizing tillage and weeding operations for the foreseeable future (Klaij and Serafini, 1988). It can increase the labour-use efficiency of these operations, which can lead to a more land-extensive cropping strategy (McIntire, 1983). The use of AT for tillage and weeding can also enhance production from inputs such as chemical fertilizers and improved cultivars, raising land productivity (Bansal *et. al.,* 1988).

Hand weeding may be the farmers' major input during the cropping season especially on sandy soils. Labour times on operational scale plots illustrate the labour bottleneck of hand weeding in a traditional millet/cowpea intercrop. Of a total of 292 man-hours required per hectare, 178 were spent on two weedings within the first eight weeks. In a more intensive system including the use of chemical fertilizers, timely weeding becomes even more crucial. Here is where the use of AT for weeding has great potential in alleviating the bottleneck. The same study showed that the use of a simple cultivator pulled by a donkey reduced the requirements to 87 hours, a substantial saving in time. Moreover, unit area yields and, therefore, labour productivity increased considerably using AT.

The constraints to the successful introduction of AT in millet-based production systems are of socio-economic and technical nature. There is a learning curve for the use of AT, infrastructural support systems (equipment supply and repair, veterinary services) need to be developed and the problem of animal feed will have to be addressed (Klaij and Serafini, 1988). However, AT has a potentially important role to play in increasing production from millet-based cropping systems.

IV. CROP MANAGEMENT OF MILLET PRODUCTION SYSTEMS

Increased productivity of millet production systems can be achieved through the choice of appropriate cultivars, cropping strategies (sole vs intercropping or rotation) and agronomic management, all of which can aid in maximizing the use of available water and in improving water-use efficiencies.

Intercropping of pearl millet and cowpea is a common practice by farmers in the semi-arid zone of West Africa (Fussell and Serafini, 1985). This system has been developed under conditions involving both risk and constraints which limit crop production. Farmers use this system to lower risks and labour requirements (Norman, 1974; Matlon, 1980) and as a response to scarcity of resources. The parity and, often, superiority of intercropping over sole crop in terms of insurance from risk, better resource use and higher returns has been highlighted (Willey, 1979; Francis, 1981). Recent review (Fussel and Serafini, 1985; Ntare *et. al.,* 1989) have concluded that millet/cowpea intercropping generally improves and stabilizes yields (Fusell and Serafini, 1987). Because of the widespread practice of intercropping and sole cropping of millet, crop management will be addressed in terms of both intercropping and sole cropping of millet, primarily with cowpea, the dominant intercrop in the southern Sahelian zone.

1. Cultivar Choice

The traditional millet and cowpea cultivars are adapted to flower during the months of September-October in the Sahelian zone. This period coincides with the average end of the rainy reason. In years of erratic rainfall, both crops are severely affected by drought. Where intercropped, crops of similar maturity compete for light, soil nutrients, and water throughout their growth period.

With the increasing availability of new cultivars of both crops, often with different plant types and maturity cycles shorter than those of the traditional cultivars, there is scope to develop more productive and stable millet/cowpea cropping systems. Such systems must have the stability typical of traditional systems. Appropriate maturity of the cultivars selected of both crops is very important. In the Sahelian zone for example, the rainy season is short (<90 days, Sivakumar, 1988). Cultivars should reach maturity before soil moisture is exhausted. Therefore, breeding for earliness is a pre-requisite in this situation. Early maturity is desirable for two reasons. Firstly, with a shorter growing season, earlier varieties avoid unpredictable moisture stress both at the start and end of the rainy period. Furthermore, earlier millet varieties such as CIVT and ICH412 use less moisture (Fig. 3a,b). Secondly, there is much more freedom in selecting a more favorable planting time. Both of these advantages result in much lower chance of crop failure and, thus, a more stable cropping system.

Millet/Cowpea intercropping experiments conducted at ISC since 1984 are demonstrating the importance of cowpea plant types in the system. Early-maturing (60 - 70 days) erect cultivars reduce millet yields less than do the medium-to late-maturing cultivars (>80 days)(Table 3). Indeterminate cultivars produce higher grain and fodder yields than erect cultivars. On the other hand, late photoperiod sensitive types produce more fodder than grain and have a more pronounced negative effect on millet yields. These results indicate that for a stable intercropping system, a suitable cowpea cultivar for intercropping with pearl millet will be a compromise between grain and fodder type cowpeas. Such cultivars would be weakly competitive with millet, early enough to escape end-of-season drought and would produce both grain and fodder. Earlier, shorter-statuted millets than the local cultivers have been shown to also enhance cowpea hay and grain production, further improving the productivity of the system (Fussell, Personal Communication).

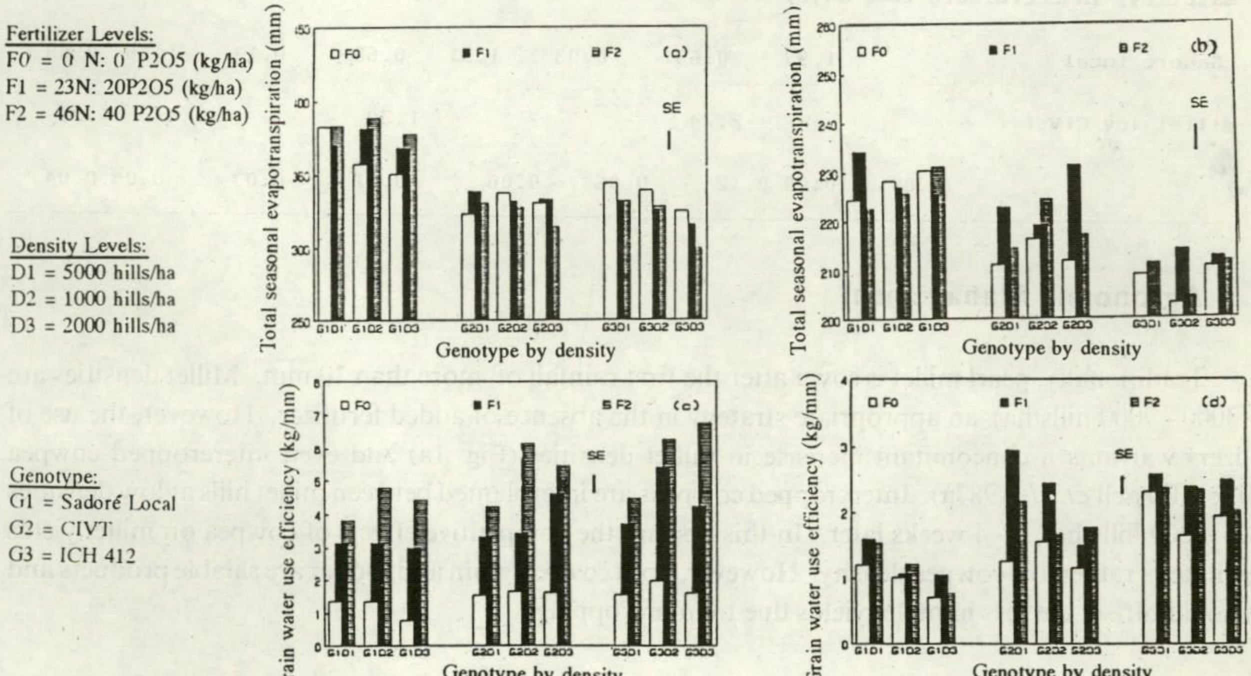


Figure 3: **Total seasonal evapotranspiration and grain water-use efficiencies for 1985 (a,c) and 1984 (b,c) for pearl millet as a function of year, fertilizer, density and genotype. ISC, Niger rainy season 1984-1986.**

Table 3: Effect of cowpea plant type on grain and fodder yields (t/ha) of intercropped cowpea and pearl millet. ISC, Niger, rainy season 1985, 1986, and 1988

Plant type/cultivar	1985 Cowpea grain	1985 Cowpea fodder	1985 Millet grain	1986 Cowpea grain	1986 Cowpea fodder	1986 Millet grain	1988 Cowpea grain	1988 Cowpea fodder	1988 Millet grain
Extra early determinate (60 - 65 days)									
IT82E 60	0.10	0.32	2.04	0.09	0.11	1.30	0.10	0.21	1.01
IT82D 716	0.12	0.40	2.17	0.10	0.18	1.14	0.19	0.41	0.99
Early, spreading determinate (70 days)									
TVX 3236	0.40	0.83	1.79	0.20	1.23	1.10	0.22	0.54	0.72
SUVITA 2	0.62	1.34	1.55	0.43	0.50	1.13	0.26	0.61	0.77
Medium maturity, indeterminate (80 days)									
TN88-63	0.42	1.06	1.60	0.18	0.46	1.23	0.30	0.58	0.54
58 - 57	0.60	1.30	1.56	0.38	1.77	1.17	0.41	0.91	0.77
Late maturity, indeterminate (120 days)									
Sadore local	-	1.97	0.63	0.03	1.31	0.68	0.17	1.16	0.68
Sole millet (cv CIVT)	-	-	2.24	-	-	1.30	-	-	1.20
SE (±)	0.08	0.08	0.12	0.06	0.06	0.21	0.03	0.05	0.04

2. Agronomic Management

Traditionally, pearl millet is sown after the first rainfall of more than 10 mm. Millet densities are low (3000 - 7000 hills/ha), an appropriate strategy in the absence of added fertilizer. However, the use of fertilizers warrants a concomitant increase in millet densities (Fig. 1a) and even intercropped cowpea densities (Fussell *et. al.,* 1987a). Intercropped cowpeas are interplanted between millet hills at low densities (1000 - 5000 hills/ha), 2 - 4 weeks later. In this system, the competitive effects of cowpea on millet yields necessitates a rather low cowpea density. However, both cowpea grain and fodder are salable products and this should off-set the loss in millet yields due to intercropping.

Millet/cowpea intercropping research conducted at ISC has shown that the grain yield from early-maturing cowpeas is substantially increased without the intercrop adversely affecting millet yield, when sown with or shortly after millet, than when sown in the traditional manner, 2 - 4 weeks later (Ntare and Fussell, 1988). Planted in this way, cowpea grain and fodder yields were higher in paired rows than single alternating rows, whereas millet yields were similar to those produced under sole crop. Increasing the density of an early-maturing cowpea did not reduce millet yields below that of traditional cowpea/millet intercrop.

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3. Cropping System Choice

Present cereal cropping systems are expected to change as improved germplasm of cereals and legumes, as well as other new technologies, become available, and as increasing population pressure demands more intensive land use and greater productivity from farm labour. Such a change may include a gradual change from the traditional mixtures of cereals and legumes towards more structured land potentially more productive cropping systems. These may involve sole cropping in some cases, or strip cropping which preserves the multiple crop output of the traditional system but in a more structured fashion, or possible various forms of relay cropping. Any of these may be suited to realizing the yield potentials of improved germplasm and other new technologies(including AT and use of agricultural chemicals), which can be more profitable and alleviate the land-use pressure of traditional systems.

Though sole crop cowpea is not a traditional system in the Sahel, it still holds promise. The role of legumes in the soil N-economy cannot be over emphasized. Yields of cereals that follow cowpeas are often improved. AT ISC, researchers have begun to quantify the beneficial effects of cowpea on millet (see preceding and following sections). As cowpea is becoming popular as a cash crop in the region, it may also be feasible and desirable to use purchased inputs such as fertilizers and pesticides. Enhancing cowpea yields through fertilization and protection from insect pests, results in greater millet yields the following season through the additional soil-N through symbiosis and residual-P (ICRISAT, 1989). This is one way of intensifying millet-based cropping systems.

V. OPERATIONAL SCALE TESTING OF MILLET PRODUCTION TECHNOLOGY ON STATION.

From the findings of research on various components of millet-based production systems, scientists at ISC identified new production methods that showed promising results (ICRISAT, 1986). These were: application of a small quantity of P (13 kg/ha); improved varieties of pearl millet (ICMV5) and cowpea (TVX3236); sowing at higher densities; ridging (which resulted in better establishment and survival of pearl millet); and the use of AT for ridging and weeding.

These individual components were systematically combined and tested over three years (1986 - 1988) in operational scale on-station research to verify the results obtained in smaller plots. Crop rotations were included to assess the residual effects of a legume on a following pearl millet crop. In the traditional (control) treatment, local cultivars of pearl millet and cowpea were grown with only hand cultivation and no added fertilizer. Pearl millet was sown with the first rains of the season and cowpea sown later (2 - 3 weeks) depending on the onset of the rainy season.

Rainfall was 657 mm in 1986, 448 mm in 1987, and 699 mm in 1988. In both 1986 and 1987, ridging (with AT) increased grain and stover yields of pearl millet in both sole and intercropped systems (Table 4, stover yields are not presented). In 1987, millet grain yields were severely reduced by pests and cowpea suffered from drought stress during the flowering period. Soil cultivation resulted in better grain production than in non-ridged plots in 1986 and 1988. Fertilizer application (13 kg/ha) uniformly increased yields of pearl millet in all years. In 1987, there was a positive effect on millet yields of the legume-cereal rotation, either with pure cowpea or millet-cowpea-millet. On the other hand, millet/cowpea intercrop followed by cowpea depressed cowpea yields.

In 1988, a comparison of yields in the continuous systems with those in the legume/cereal rotated system showed a marked advantage of the rotation system over the continuous systems. Pearl millet in inter- and sole-cropped systems after cowpea gave almost twice as much as the continuous improved system (Table 4). Production of stover was nearly doubled.

The contribution of AT in reducing labour time was not consistent over the three years of the study. In 1986, use of AT resulted in 41 - 51% reduction in the weeding time when compared to manual cultivation.

Table 4: Grain yield (t/ha) recorded in different treatments in operational scale research, ISC, Niger, rainy seasons 1986 - 1988.

	Pearl millet			Intercropped (cow pea) (2)			(Sole cowpea)		
System/treatment (1)	1986	1987	1988	1986	1987	1988	1986	1987	1988
Traditional									
Continuous cropping									
M/C	0.30	0.30	0.27	0.12	(2)	(2)	–	–	–
SE ±	0.03			0.01					
Improved									
Continuous cropping									
Manual - M/C	0.64	0.40	0.48	0.10	(2)	(2)	–	–	–
Manual - M/C	0.68	0.38	0.50	–	–	–	–	–	–
Animal - M/C	0.86	0.37	0.56	0.11	(2)	(2)	–	–	–
Animal - M	0.92	0.51	0.70	–	–	–	–	–	–
Rotation cropping									
Manual - M/C	0.64	–	0.93	0.10	–	(2)	–	0.25	–
Manual - C:M/C	–	0.55	–	–	(2)	–	0.66	–	0.43
Manual - M:C	0.68	–	0.94	–	–	–	–	0.41	–
Manual - C:M	–	0.51	–	–	–	–	0.66	–	0.48
Animal - M/C:C	0.86	–	1.12	0.11	–	(2)	–	0.40	–
Animal - C:M/C	–	0.68	–	–	(2)	–	0.80	–	0.66
Animal M:C	0.92	–	0.96	–	–	–	–	0.50	–
Animal - C:M	–	0.58	–	–	–	–	0.80	–	0.77
SE ±	0.02	0.07	0.08	0.01	–	–	0.02	0.05	0.05
CV (%)	31	41	31	45	–	–	24	35	23

(1): Explanation of systems and treatments:

Traditional: Local cultivars, no fertilizer, no animal traction.

Improved: Improved cultivars with fertilizer (13 kg P/ha).

Manual: Manual labour for sowing and weeding

Animal: Animal traction for ridging and weeding.

M/C: Millet (M)/cowpea (C) intercrop.

M/C:C: Millet/cowpea intercrop rotated with cowpea.

M:C: Millet crop rotated with cowpea.

(2): In 1987 and 1988, cowpea grain yields were lower than 0.1 t/ha.

These grains were off-set by increases needed for harvesting, resulting in only 15-32% reduction in total labour times through using AT in place of manual labour. In 1987, there was less benefit of AT in weeding in sole-cropped and intercropped pearl millet compared with 1986. In 1988, there was no significant reduction in labour time with the use of AT.

The findings of this operational scale trial are consistent with the result of the component research, reported in the previous sections, which indicated that increased production in millet-based systems can be achieved through the use of AT tillage, improved varieties sown at moderately higher densities with P-fertilizer, and rotational system of sole or intercrops of millet and cowpea. These production increases from better crop management are clearly seen with the comparison of the traditional intercrop grain yields with any of the improved systems (Table 4). However, the variation in results across years due to the vagaries of the Sahelian climate highlights the need to conduct such research over a number of years to determine the stability of these improved production technologies.

VI. CONCLUSION

Pearl millet cropping systems in West Africa have the potential to be much more productive by better management: improved varieties and cropping systems, judicious quantities of fertilizer inputs to alleviate soil nutrient deficiencies, tillage techniques to reduce the damaging effects of sandstorms and drought spells, and improved cultivation methods to optimize labour requirements for various operations.

The findings reported in this paper substantiate the conclusion that soil fertility is the principal limitation to the production of millet-based cropping systems. A pre-requisite to improving output of these systems is the improvement of the soil-fertility base, particularly with regard to P-levels. The economics of millet production may mean that improvement of soil fertility needs to be arrived at through P-fertilization to a cash rotational crop, such as cowpea. The sale of cowpea hay and grain can be used to pay for the fertilizer. Improved millet yields will result from the residual P and symbiotically fixed-B left by cowpeas.

There is strong evidence that the return of crop residues to fields is also an important component of improvement of pearl millet cropping systems for both soil fertility restoration and productivity maintenance (Bationo, 1987). This is being investigated at ISC in both component and operational scale on-station research Socioeconomic studies at the farm level are also underway to determine the alternate uses and availability of crop residues for improving pearl millet production systems.

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AGRONOMIC TECHNIQUES FOR IMPROVING PRODUCTIVITY OF SORGHUM-BASED SYSTEMS IN THE WEST AFRICAN SEMI-ARID TROPICS

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ABSTRACT

Inspite of the available potential technologies for sorghum production in WASAT region large scale adoption has been negligible. This paper examines various agronomic techniques for bridging the yield gap. Differences in required techniques between the Sudano-Guinean and Sudanian Zones were highlighted.

I. INTRODUCTION

Sorghum (*Sorghum bicolor* [L.] Moench) is one of the major rainfed food crops in the Sudano-Guinea zone of the West African Semi-Arid Tropics (WASAT). It is grown in all the countries stretching from Atlantic ocean in the west to Chad and Central African Republic in the east. It is very important to the caloric food production of Burkina Faso, Nigeria, Cameroon, Mali, Niger, Chad, Gambia, and Senegal.

An examination of the past trends in sorghum production indicates the slow and irregular growth in the WASAT. Total production has essentially remained stagnant with some estimates actually showing a trend of decline in production. It is estimated that since 1961, the land productivity fell at an average annual rate of 1 to 5 percent for sorghum (Matlon, 1985). The poor yield performance has been due to many factors such as erratic rainfall, reducing fallow period and expanding cultivation to lower natural production potential soils. The demographic and ecological factors have resulted in the depletion of nutrients from the soils already chemically poor, and the loss of organic matter and top soil through erosion due to continuous cultivation. Use of inputs on sorghum has not grown fast enough to offset their declining potential nor even to arrest the degradation of the soil base.

Reversing these disturbing trends in sorghum production and productivity to meet the food demand of growing population (at the annual rate of 2.2 percent) necessities technical changes in the production agronomy of the crop. In this paper, an attempt is made to summarize the existing knowledge on the resource base to identify the most limiting constraints and the available production technology to improve the productivity of sorghum-based systems in the WASAT. Research needs in resource management and crop improvement are also highlighted for future consideration.

II. RESOURCE BASE OF SORGHUM SYSTEMS

1. Physical Environment

The two major sources of variation in the production of sorghum in the WASAT are rainfall and soils.

Average rainfall in the WASAT increases from north to south with isohyets more or less parallel to the equator. The distribution of rainfall is erratic with frequent drought spells of 2 weeks or longer being common, particularly in north where the coefficient of variations of total rainfall are also higher. However, in the southern sudano-guinea zone where the total rainfall is higher than 900 mm, the moisture is not a major constraint. Throughout the WASAT the rainfall variability is high during early (planting) and late (flowering and maturity) season. The annual potential evaporation varies between 2 to 4 times the average annual rainfall, highest in May and September, again during planting and grain-filling periods. The risks due to early and late season water stress, therefore, are greater.

Within the rainfall zones, various soil types occur, usually linked to specific position in the topography. Shallow, gravelly soils are associated with upland areas whereas deeper sandy loam or silty loam soils occur in the slopes. Soils of sorghum systems are mostly Alfisols with low clay (mostly kaolinitic type) content whose water holding capacity is low. The soils are highly weathered, with low exchangeable cations - C.E.C. being less than 10 meq/100 g. The soils are poor in inherent fertility and organic matter. They are particularly low in phosphorus and nitrogen. They are structurally inert, tend to restrict water infiltration and are susceptible to compaction, which, when combined with their shallow depth, results in low water holding capacity and poor fertilizer use efficiency. Further, under continuous cultivation, most of these soils are fragile, subject to high risk of acidification, aluminum toxicity and erosion.

Low water holding capacity with irregular rainfall and low soil fertility combine to make sorghum farming risky. Moreover, drought conditions during the last 15 years have accentuated the low soil moisture resulting in poor sorghum production in sudano-sahelian zone. However, because the soil and rainfall constraints are roughly correlated, there is considerably greater technical potential for higher biomass production in the southern sudano-guinea zone.

2. Traditional Varieties and Cropping Systems

Traditional sorghum varieties are tall, late, photoperiod sensitive and have poor harvest indices. Average grain yields in the normal rainfall years range from 400 to 900 kg/ha in drier to wetter areas. In some areas, stovers are used to build fences and roof systems.

Recently, demographic pressures are forcing reduction in fallow periods and sorghum cultivation is expanding to marginal soils that are fragile with low production potential. Labour availability is also decreasing as more labour is attracted to urban areas. In spite of these new trends, traditional low input system continues, resulting in stagnant yield and decline in the aggregate output per capita (Matlon, 1987). Further, this resulted in steady degradation of land and thus the production potential.

III. AGRONOMIC TECHNIQUES

The resource base of sorghum system described above underlines many production constraints, the most limiting being soil water and fertility, sorghum cultivars and socio-economic conditions.

In addition, there are a number of biological stresses - insect pests, diseases and weeds (Including *Striga*) which should be considered in developing alternative cultivars. An important body of agronomic research results are available from various research programs in different countries. Some of these production technologies used to overcome the above constraints in sorghum production are synthesized below:

1. Soil and Water Management

The soil and climatic conditions of the WASAT impair crop root development and thus the water and nutrient uptake. Most soils are prone to degradation resulting in severe erosion and runoff of rain water. The following are some of the soil management techniques which influence the runoff: water infiltration, facilitate use of stored water and storage of water in the soil.

a. **Soil Tillage.** Nicou and Charreau (1985) reviewing the tillage effects in the WASAT concluded that the technique was extremely important to improve soil productivity. Experiments conducted at moderately high fertility have shown that plowing has consistent beneficial effects on crop growth with sorghum yield increases averaging about 25 percent. The effects are attributed to better root growth and development and improved soils porosity and water status. Tillage also improves the structure of the soil, hydric regime, the organic matter and microbial activity and consequently the yield of the crop. It is also known to improve infiltration, water conservation, and stored water uptake (by better root development). End of the season ploughing has also been shown to improve conservation of water during the dry season by reducing evaporation and through the suppression and incorporation of soil surface vegetation (Dancette and Nicou, 1974). Repeated plowings have also been found to accelerate oxidation and mineralization of humus by contributing to microbial activity and biochemical processes. Deep plowing also contributes to improved fertilizer use efficiency (Charreau and Nicou, 1971).

However, at the farmers level, because of many factors such as low soil fertility, lack of animal traction, power limitation, labour constraints, and conflicts with other operations, a small portion of the total sorghum area is plowed before planting and that which is ploughed is generally poorly done, resulting in insignificant yield effects (Matlon, 1984).

b. **Ridging.** The advantages of ridging over flat planting is not clear in the case of sorghum, though ridging is known to trap water, prevent runoff and keep maximum of this water at the disposal of the plant. Research on tied-ridging has also shown inconsistent results depending on environmental and management factors. Yield response is higher under conditions of soil moisture stress and where soil fertility is not limiting. Average increments of up to 950 kg/ha for sorghum have been observed by ICRISAT on research station where medium of high doses of NPK fertilizer have been applied (ICRISAT, 1985). However, IRAT (1984) has not observed any yield increment even under fertilized conditions.

The major bottlenecks in the adoption of tied-ridging by the farmers include labour availability and labour cost and poor response under soil fertility conditions prevailing in the farmers' fields. Additional research is needed to identify constraints for adoption of this technique and develop low-cost animal drawn tied ridging equipment to reduce the labour constraints.

c. **Mulching.** The application of crop residues or free cut straw as a soil cover helps to reduce runoff and erosion, increase infiltration, control weeds improve soil structure and reduce evaporation and soil temperature. It also enhances soil organic matter. However, the current results on the yield effects of mulching are often contradictory (Matlon, 1985; Nicou and Charreau, 1985). These differences may be explained by variation in soil types, topography and rainfall patterns. Though under research station conditions, ICRISAT has observed yield increase varying between 50% and 200% for both local and improved sorghum varieties with rice straw mulching in Burkina Faso, on-farm trails are yet to confirm these results (ICRISAT, 1985). Further, the unavailability of straw and the increasing demand for it as a fuel source seriously challenges mulching as a generalized practice throughout the WASAT.

d. **Strip Cropping.** To reduce erosion on gentle slopes, contour placement of narrow bands of permanent vegetation between cultivated fields is a less demanding method. In Cote d'Ivoire and Niger, this technique has led to significant reduction in soil erosion and runoff under experimental conditions.

e. **Contour Bunds.** Although the construction of dirt contour bunds across field slopes and rock based small-scale water harvesting bund systems in the environmentally degraded areas have recorded some significant effect and success in bringing highly eroded, abandoned fields back into production, their potential in increasing yield on currently cultivated fields has not yet been determined. A combination of such small and large scale bund systems appropriate for specific location can be promising in areas of relatively high population density in minimizing erosion as well as enhancing water harvesting.

It should be noted that no soil management technique is universal and that each of them should be adapted depending on rainfall, soil different soil tillage techniques has different advantages and constraints. Nicou and Charreau (1985) recommended early tillage in low lands, flat tillage before sowing in mid slopes depending on contours and shallow cultivation (after rains) and then tied ridges in areas that could not be tilled before sowing.

2. Soil Fertility Management

Predominant sorghum soils have low natural fertility. Nitrogen and phosphorus are the most limiting nutrients. However, potassium and also minor and trace elements can be limiting under intensive cropping.

Past research has clearly shown that though the response is not as great as for maize, sorghum has shown profitable economic returns to N and P in combination at relatively low rates (Pieri, 1985). In Mali, 19 out of 21 experiments have shown response to added P, leading to the recommendation of 46 kg N and 22 kg P205 to sorghum, per hectare (Traore, 1988). Further, recently improved cultivars have also shown their better responsiveness to added fertility than the local cultivars (Sogodogo *et, al.,* 1988).

However, there is increasing evidence that continuous applications of nitrogenous fertilizers can result in long term reduction in soil fertility. IRAT trials have clearly shown (Pieri, 1985) that chemical fertilizer applications over the long term result in decline in sorghum yields due to soil potassium deficiencies, acidification and aluminum toxicity. Only large applications of transformed organic products such as compost and animal manure was found to counteract these negative effects. Manures combine all the advantages of positive effect on potassium nutrition, suppression of aluminum toxicity and positive effect of nitrogen supply (Pieri, 1985). Mulching, incorporation of organic residues, aerobic and anaerobic composting significantly help in maintaining soil fertility. Cropping systems involving legumes also help in improvement of N-balance. Farming techniques such as tillage, manures, and liming increase N-fixation by legumes.

Because of large scale deposits of rock phosphate, considerable emphasis is now being given to accelerate it's production and distribution. Trials have confirmed significant effects (particularly residual) of granulated rock phosphate. However, they are generally less economical because of transportation costs, and the difficulties encountered in applying, incorporation and delay in realizing full yield benefits. Recent research on acidulated forms of rock phosphate shows promise in overcoming some of these problems.

It is now well known that in the WASAT, fertility maintenance is a prime technique to improve crop productivity. A combination of low rates of mineral fertilizer, recycling of organic residues, application of animal manures, incorporation of legumes in the rotation for biological N-fixation and also optimum use of local mineral sources such as natural phosphates help in long-term maintenance of soil fertility to improve sorghum productivity.

3. Improved Cultivars

The local sorghum cultivars are characterized by good seedling vigor, power to compensate for tillering, rapid root development, photoperiod sensitivity, and resistance to some disease and insect pests. However, they have limited yield potentials with poor harvest index and their response to added inputs are also poor. They are also sensitive to lodging, and breakage occur frequently. Further, their long cycle makes them sensitive to late season droughts which occur frequently since the last two decades. Plant breeders in West Africa have made considerable progress in developing improved cultivars which are higher yielding, better tolerant to physical and biological stresses, respond better to added inputs and tailor well with more productive cropping systems. For example, research by IRAT scientists for drier region (500 - 600 mm zone) resulted in improved cultivars like CE-90 and ISRA-IRAT 204 (Chantereau, 1985). These cultivars have shown their higher yield potential and better response to added inputs and tolerance to stresses. Other early cultivars found promising are Naga White, S35, ICSV1083BF, ICSV111IN, ICSV1078BF, CE180-33, which are under multilocational testing in different countries of the WASAT (Personal Communication with ICRISAT breeders).

Several medium cycle cultivars such as E35-1, ICSV1002BF, S-34, Malisor-1 and Malisor-7, ICSV1089BF, ICSV1063BF, ICSV126IN, were also found to do well in intermediate rainfall zone (600 - 900 mm). However, so far no new cultivars have been recommended for the sudano-guinea zone (900 - 1200 mm) where the traditional long cycle, tall and low-yielding cultivars are extensively being grown.

Breeders, crop protection scientists and physiologists have also made considerate progress in identifying sources of resistance and incorporation of these resistances into agronomically desirable lines. However, much more work in West Africa must be done to systematize the evaluation of breeding materials for drought, grain mold, long smuts, leaf diseases, head bugs, midges, stem borers, and *Striga* resistance.

One of the constraints for large scale adoption of the improved cultivars is their poor food quality. The local guineense grain in typically hard, which is important for food quality as well as other reasons such as storability. Most of the improved cultivars have soft grains which can have 50% bran loss during grain processing and also poor food (to) stability. Soft grain often results from drought stress during grain fill in high-yielding introduced cultivars. Head bug feeding as well as grain molds can also result in soft grain. Breeders have therefore been considering the hard grain trait carefully in selecting improved breeding progenies.

Integration of both improved cultivar and agronomic practices is extremely important in improving the productivity of sorghum in the WASAT. There are clear indications that improved cultivars respond better to crop density and fertility (Sogodogo *et. al.*, 1988; Pieri, 1985), plowing (Nicou and Charreau, 1985) and other soil management practices. Studies integrating different agronomic management practices and varieties have also demonstrated the synergistic effects of various treatments when combined together as against their individual effects. Further, when the improved cultivars are introduced to farmers' conditions, they have failed to exhibit their potential (Matlon, 1985) and they seemed to perform well only under optimum soil and crop management systems. It is therefore necessary to aim at improving soil productivity first and, then, incorporate the improved cultivars in such better resource management systems.

4. Improved Cropping Systems

As indicated earlier, sorghum is widely grown as an intercrop by farmers in the WASAT. Fussell and Serafini (1985) reviewed research on intercropping in West Africa and concluded that this cropping system was an appropriate technology resulting in important yield and socio-economic advantages. Sorghum is usually intercropped with cowpeas, groundnuts and millet. Work done in Nigeria, Niger, Mali and Burkina Faso clearly showed the effectiveness of intercropping in maximizing utilization of resources (soil, water, nutrient, light and labour) and time, and stabilizing yield fluctuations due to climate. Both sorghum/legume and sorghum/cereal intercropping systems were reported to produce 25 - 30% advantage over the sole crop system. Strategies to improve sorghum/cowpea, sorghum/groundnut, and sorghum/millet systems by manipulating management factors such as plant population, spatial arrangement, dates of planting and harvest, fertility conditions, and crop varieties have been studied by various authors and result are well documented (Fussell and

Serafini, 1985; Stoop, 1986; Shetty *et. al.*, 1987). For example, to improve intercrop yields, it is essential that N is added to the system. High intercrop densities are tolerated by sorghum if legumes are planted late or harvested earlier. Improved, shorter cycle and shorter statured sorghums result in better overall performance than the tall, longer cycle, traditional sorghum cultivars.

In Burkina Faso, net returns to labour increased by an average of more than 60% as cowpea density was increased above traditional levels in sorghum/cowpea systems. Increasing sorghum density resulted in improved returns in the case of traditional sorghum/groundnut systems (Matlon, 1984). However, increased sorghum density reduced groundnut production, which is an important cash crop for the farmers in the WASAT. In Mali, a planting pattern of 4 row-groundnut: 1 row-sorghum is being recommended in groundnut-growing areas to optimize the productivity of the system (Shetty *et. al.*, 1987). The incorporation of a commercial crop like groundnut into a low value food crop like sorghum has been considered important to attract the application of inputs as well as improved cultivars into the traditional system. It can also be expected that intensified cereal/legume intercrop would not only fix more nitrogen, but also leave more residual N than that left by the traditional system.

The length of the growing period varies from about 100 days in the north to about 200 days in the south in the sudano-guinea zone (Sivakumar, 1986). While there is little scope for manipulating planting dates in the north, the longer growing season in the higher rainfall southern locations provide greater opportunities for system manipulation with appropriate genotype and management (Shetty, 1988). Multilocational screening trials across the latitudes have enabled us to select appropriate genotypes with the phenology and physiological responses that would place the production of sorghums at the most favorable periods. A number of early and short-statured sorghums such as S-34 and S-35 which combine high yields (exceeding upto 2 - 3 times those of local sorghums) with tolerance to biological stresses were identified through such yield trials across Cameroon, Nigeria, Burkina Faso and Mali. These selected genotypes also responded well to both crop density and added N-fertility. The local sorghums did not only respond poorly to added N, but also suffered heavily from late season droughts, hence their poor grain yields as compared to the selected early genotypes which escape late moisture stress.

The series of agronomic trials conducted to examine the performance of some of these genotypes under commonly practiced mixed and relay systems have also revealed the superiority of these cultivars over the traditional cultivars (ICRISAT, 1984 and 1987). Local cultivars are tall and late-maturing, and offer significantly higher competition to associated crops such as cowpea, groundnut and millet than the selected shorter cycle cultivars (Shetty, 1988). Such short season cultivars also provide increased time and opportunity (competition-free growth period) for the associated crops in the production systems. When introduced into a more assured part of the rainy season, these altered sorghums could bring not only stability of production at higher management levels, but also provide for better resource management through more productive inter-, relay- and sequential cropping systems. The optimum resource use in the sudano-guinea zone can be achieved by designing and introducing alternative cropping systems involving improved sorghum cultivars and tailoring them to existing and improved cropping systems.

IV. SYNTHESIS AND CONCLUSION

An assessment of the available technologies to improve the productivity of sorghum in the WASAT indicates that though potential technologies are available, their large scale adoption has been negligible. Presently, with the available technologies, a yield level of about 3 t/ha has been achieved at research stations. The reasons for nonadoption of the technologies are mainly related to socio-economic situations prevailing in the WASAT such as lack of infrastructure including weak national research and development programmes and unavailability of and cost of inputs. In order to understand the yield gaps between the research stations and the farmers' fields, first recommendation domains must be identified and refined by recognizing key differences in agroclimatic and socio- economic situations. After regional zonification, on-farm diagnostic studies should be conducted to determine important constraints for adoption (physical, biological and socio-economic) and to measure the potential of alternative techniques under on-farm situations. Early on-farm testing is also important to provide feed-back to "fine-tune" the technology, if necessary, before recommending it for large-scale adoption.

Generalization of technologies across the WASAT cannot be done because of diverse sets of sub-regions comprising a range of agroclimatic and demographic conditions with varied technical potentials.

The current available technologies and their prospects for improving sorghum productivity in the two major zones can be summarized as follows:

1. Sudanian Zone

Because of agroclimatic deficiencies, land and water conserving techniques to arrest the degradation of land base (such as anti-erosion and runoff management techniques) and stress reducing technologies (such as short cycle sorghum cultivars resistant to physical and biotic stresses) have shown potential in the northern sudanian zone. Prevention of further decline in productivity while stabilizing production should be the goal in this region. Input responsive and yield increasing techniques (such as the use of input responsive cultivars) should be considered only after major and sustainable improvements in soils base to reduce top soil loss and to conserve nutrient and moisture have been undertaken.

In areas with heavier soils, the potential for gains in productivity through tied-ridging is higher particularly if the farmer has animal traction and owns appropriate equipment. The southern-sudanian zone has higher potential for yield increasing packages because of better resource base. Here, low rates of chemical fertilizer in conjunction with frequent applications of organic matter combined with input responsive and well adapted sorghum cultivars can result in higher productivity gains. In order to avoid risks and improve nutrient use efficiency, soil moisture conserving and runoff management systems should be integrated into this yield increasing package of technologies. Appropriate tillage and tied-ridging are more appropriate means to improve soil base and remove the soil moisture constraint. Animal traction offers considerable advantage in removing labour constraints and also expanding area under cultivation. In addition to animal traction as a power source, more closely integrated crop-livestock systems yield greater long term benefits in terms of biomass recycling (through composting) which is necessary for sustainable improvement of soil base. Further, it is in this zone where the maximum concentration of animal traction has taken place. Alternative technologies, therefore, to improve mechanization (through alternative equipment, improved animal nutrition, etc.) and crop-livestock systems (better composting, more productive forage sorghums and forage/legume intercrop) would be both technically and economically more feasible.

2. Sudano-Guinea Zone

Due to higher and more assured rainfall, a longer cropping season, and better soils, the potential for improving sorghum productivity is greater in this zone. Both yield increasing and labour saving technigues can be profitable because of better resource base. Further, in this zone, the existence of diversified cropping systems and the untapped resources favors the research towards the improvement of the overall productivity of the cropping systems on a year-round basis. One such approach has been described earlier (Shetty, 1988). The possibility of taking two or more crops by intercropping, sequential cropping or rationing is greater through careful manipulation of crop varieties and soil and rainfall management. Further, incorporation of cash crops such as cotton and groundnuts and more productive and input responsive crops such as maize and upland rice into the sorghum systems should be considered to improve the overall productivity on a year-round basis. Incorporation of such higher valued crops stimulates the use of production inputs on component cereal crops. These more productive systems could also attract and support improved management responsive cultivars.

It is expected that the pay-off for the integration of improved physical resource base and the improved cropping systems will be maximum in this particular zone.

In the WASAT, research and development agencies should aim at reversing the decline in small holder production of sorghum for food by aiming at significant increase in productivity of the crop. In the area of research, a farming systems approach is needed to guide the crop improvement process. There should be a close link between resource management research and crop improvement research. It should be underlined that, for more productive and sustainable systems, both improvement and conservation of the physical resource base should go hand-in-hand with the improvement of sorghum varieties. Success could be achieved only if improved agronomic techniques are combined with improved sorghum varieties. Past experience has shown that the recommendation of either agronomic techniques or variety alone would result in limited adoption.

The poor transferability of technologies from research institutions to farmers' fields has further stressed the importance of strengthening the national research programs. The international and regional institutes have a vital role to play not only in conducting basic research, but also in strengthening national research systems by assisting them to develop capability in conducting most of the applied and adaptive research necessary to develop alternative technologies to improve sorghum productivity in the WASAT.

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TECHNOLOGY OPTIONS FOR CROP INTENSIFICATION IN SEMI-ARID GHANA: CASE STUDIES AT NYANKPALA AGRICULTURAL EXPERIMENT STATION

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ABSTRACT

High population densities in the Sudan Savanna Zone and the lack of capital and labour in the sparsely populated Guinea savanna zone of Semi-arid Ghana imply that increase in food production must come from increases in yield per unit area. Research at the Nyankpala Agricultural Experiment Station has focused on cropping systems and practices in northern Ghana with a view to increasing the productivity of the small-scale farmer with a minimum of external agricultural inputs. Crop intensification employing intercropping, crop rotations emphasizing the inclusion of legumes and alley cropping are studied.

Land use efficiency (LER) for sorghum-groundnut intercrop was equal to or higher than for sole crops. Cereal-cereal rotation resulted in depressed yields. A rotation of groundnut (*Arachis hypogea*, L.) - maize (*Zea mays*, L.) - yam (*Dioscorea rotundata*, Poir) - Sorghum (*Sorghum bicolor* (L.) Moench) was found to have positive yields effects on succeeding crops. Inclusion of soybean (*Glycine max*) in the rotation may require P fertilization. Maize and groundnut yields from the alley cropping were higher than the yields from farmers mixed intercropping. In semi-arid Ghana sustainable food production could be obtained through the intensification of existing cropping practices and systems.

I. INTRODUCTION

Semi-arid Ghana extends from latitude 8° N to 11° N and longitude 1° E to 3° W. It covers over 40% of the land area of Ghana and consists of two distinct agroecological zones. The Sudan savanna is to the north and the Guinea savanna is to the south. The two zones receive annual rainfall on the average of 650 and 1000 mm respectively in one rainy season from April to October. Rainfall patterns are erratic and unpredictable. Soils are generally poor in inherent fertility and low in organic matter.

Generally population is dense in the Sudan savanna zone while the Guinea savanna zone is sparsely populated. Population growth rate in these areas is higher (2.7% per annum) than the national average of 2.6% per annum (Seidu and Ziblim, 1988). About 80% of the people depend on agriculture (mixed farming). In both the Sudan and Guinea savanna zones, population pressure on the land is very dissimilar. In the Sudan savanna zone, the population density is very high (87 persons/sq.km - Seidu and Ziblim, 1988). Land available for agricultural activities is fast decreasing because permanent cultivation has replaced the fallow system that rejuvenates soil fertility. Soils are poor and in some places stones have to be gathered in heaps along the contours to bund the slopes before cultivation is possible. In the Sudan savanna zone, therefore, agricultural production can be achieved only through increasing yield per unit area. The Guinea savanna zone is sparsely populated (17 persons/sq.km. Seidu and Ziblim, 1988) and therefore land is available for agricultural production. However, because of lack of capital and labour, farmers are compelled to cultivate only small fields. Increased production must therefore come from increased productivity and not through increase in land area. Consequently, to meet the food requirements of the people, attempts must be made to increase yield per unit area through intensification of cropping in both time and space while maintaining soil productivity.

The Nyankpala Agricultural Experiment Station, NAES, is located in the Guinea Savanna zone of Ghana. It is part of the Crops Research Institute (CRI), one of the 12 institutes within the Council for Scientific and Industrial Research (CSIR), an autonomous organization within the Ministry of Industries, Science and Technology. Financial and technical support to the station is provided by the Federal Republic of Germany through the German Agency for Technical Cooperation, GTZ. It has the overall goal to research into ways of increasing productivity of agricultural food crops and fibre in the areas under discussion. These areas are the major centers for the production of livestock, yams, cereals, grain legumes and cotton. Crop yields in the area are very low. For example, maize yields about 1 t/ha.

At N.A.E.S, our attention has been to assist the small-scale farmer achieve self-sufficiency in food production through:

(a) genetic improvement of crops in regard to yield, adaptation, pest and disease resistance,

(b) identification of cropping systems and practices to ensure high and stable productivity under permanent cultivation with a minimum of external inputs, and

(c) identification of socio-economic constraints that hamper production and evaluation of new technologies under farmers' conditions.

Research findings have gone to farmers through field demonstrations by the Ministry of Agriculture and other extension agencies such as Global 2000 Inc. and IFAD. For example the success of Global 2000 in the Upper West Region is due to the use of the high-yielding sorghum variety, Framida which was tested for several years and released by N.A.E.S.

At this Farming Systems Research Workshop on Appropriate Technologies for Achieving Sustainable food Production Systems in the Semi-Arid Tropics of Africa, we shall limit our discussion to work done at N.A.E.S., in cropping systems and practices that will help achieve the overall goal of the institute and workshop. The systems and practices are multiple cropping, crop rotation and alley cropping which are carried out both on the station and on the farmer's fields.

II. MULTIPLE CROPPING

This system is an intensification of cropping in time and space dimensions in which two or more crops are grown on the same field in a year. Two forms of multiple cropping were described:

a) Sequential cropping-where crop intensification is only in time dimension. For example, in Upper West double cropping is practiced where early cow pea is planted at the onset of the rains in April, harvested in June and is followed by either sorghum or millet.

b) Intercropping: Crop intensification is in both time and space dimensions. In northern Ghana, all forms of intercropping, viz, mixed-, strip-, and relay-cropping are practiced.

1. Intercropping Trials in the Sudan Savanna Zone

In northern Ghana, intercropping is the dominant cropping system (Nabila, 1988). In 1987, a trial was conducted to compare the yield and land use efficiency of row intercropping, intra-row intercropping systems and those of sole cropping systems. The location of the trial was at Manga-Bawku in the Sudan savanna zone where the population density is highest in the country. Factors studied are listed below:

Factor 1. Plant population/ha ('000) **Factor 2.** Pattern of Intercropping

Crop	high	low	
Sorghum	50.0	25.0	A: Inter row
Groundnuts	111.0	55.5	B: Intra row

The experimental design was a randomized complete block design with four replications. Phosphorus was applied at the rate of 20 kg/ha before harrowing and N at rate of 60 kg/ha three weeks after emergence. The trial was planted on 10th June 1987. Groundnut was harvested on 3rd September 1987 and sorghum on 5th November 1987.

Yield assessment was from the three middle rows for sole and intra row cropping, and for the inter-row cropping four middle rows were harvested, two of each crop. All cultural practices were as those employed at the N.A.E.S.

Results: the effects of the various intercropping systems and sole cropping on the yield and land use efficiency as measured by land equivalent ratio (LER) are presented in Table 1.

Table 1: Yield (kg/ha) and land equivalent ratio (LER) of sorghum-groundnut intercropping and sole cropping systems.

Treatment	Sorghum	Groundnut	LER
SH / GH - A	1160	760	1.09
SH / GH - B	1500	740	1.28
SH / GL - A	1050	740	1.03
SH / GL - B	1320	600	1.23
SL / GH - A	1010	830	1.07
SL / GH - B	840	920	1.04
SL / GL - A	710	790	0.90
SL / GL - B	1230	750	1.11
Sorghum sole	1890	-	1.00
Groundnut sole	-	1610	1.00
LSD (5%)	520	270	0.26
CV (%)	30	22	17

S = Sorghum; G = groundnut; H = high density; L = low density; A = inter-row; B = intra-row.

Sorghum grain yields: At the higher plant density, sorghum yielded higher in the intra-row than the yields from inter-row planting.

However, when the sorghum was planted at lower density and groundnut at the higher density the order was reversed. In either of these the yield difference was not significant ($P< 0.05$).

The higher yields of sorghum in the intra-row intercrop could be due to uptake of nitrogen exudated from the groundnut roots. Also the groundnut was harvested two months before the sorghum matured and might have utilized the nitrogen left in the soil by the groundnut which on the average is about 30 kg/ha.

From the data, sorghum grain yield was slightly reduced when the population was reduced from high to low and groundnut population was maintained at the higher density. For sorghum grain yield, it is advisable to plant sorghum and groundnut at their lower densities in intra-row spacings (LER 1.11).

Groundnut yields: Yields of all intercropping were less than sole cropping. There was no difference in yield for either intra and inter-row spacings, and for the higher and lower densities.

LER: The LER for the sorghum and groundnut planted at lower densities in inter-rows was less than 1.0 Highest LER of 1.28 was obtained when sorghum and groundnut were planted in intra-row and at highest densities.

2. Intercropping Trial in the Guinea Savanna Zone

Rainfall in the Guinea Savanna is much more reliable starting in mid April to October. Crop intensification can therefore be achieved by intercropping late-maturing crops or by relaying of two short duration crops. In 1987, a trial was conducted to determine the economic feasibility of relay systems using gross margin as an index.

Materials and methods: The following crop varieties were used. Groundnuts: Chinese (90 days); Relay millet: Manga nara (90 days); Cowpea: Valenga (55 days); Relay maize: TZESR. W (90 days); Relay sorghum: Naga white (90 days); Millet (full season) Local millet; Maize (full season) Dobidi (120 days); Sorghum (full season) Local 29.

The trial was planted on 12th June 1987. The relay crops were planted on 11th August, 1987. Inter-row spacing was o.75 m for crops. Row length was 10 m and plot sizes 52.5 sq. m. The experimental design was a randomized complete block, with four replications.

Grain yields were all adjusted to 12% moisture. Gross margin of output (Gross Income minus cost of production), was computed based on farm gate prices at Nyankpala.

Results: The highest gross margin was obtained from the full season pure maize, followed by cowpea which gave a yield of more than one ton. The yield of the relay maize was so low that the system could not economically out-perform the full season maize (Table 2).

Table 2: Crop yields (kg/ha) and gross margin (US $/ha) from legume/cereal relay systems and their corresponding full season cereals.

Treatments	Legume	Cereal	Gross margin
Groundnut/Millet	1240	150	720
Cowpea/Maize	1360	1470	1231
Groundnut/Sorghum	1170	220	699
Millet (f.s.)	-	1300	566
Maize (f.s.)	-	4120	1733
Sorghum (f.s.)	-	990	379
LSD (5%)			228.6
CV (%)			17.0

f.s. = full season

It can therefore be inferred that based on economic factors alone the relay system is a disadvantage compared to the full season maize crop. But if the value of the farm product is considered in the light of the farmers dietary requirements , the relay system may be desirable, since legumes provide proteins in their diets. It must be emphasized that this work was done for only one year.

In the groundnut/millet and groundnut/sorghum systems, the relay practice is more economically feasible than the full season cereals.

Later, rainfall might have washed off pollen in the early millet. It also encouraged head mould disease in both the early millet and the sorghum (Naga White). Time of planting the relay crops was so late (11th August) that the potential of the relay crops could not be realized.

III. CROP ROTATION TRIALS

In northern Ghana, in particular, the Sudan savanna zone where population density is very high, continuous land cropping is replacing the fallow system in which soil fertility could be restored. Crop rotation may be used to improve or maintain soil productivity, control/suppress pest and weed buildup.

Crop rotation is the system of growing different kinds of crops in recurrent succession on the same piece of land. The practice may be good or bad as measured by its effects on soil productivity or on its economic returns. The practice of crop rotation is not unknown to farmers in the area; nevertheless, it is rarely practiced, or the sequence of crops may not be well-ordered and little information is available about the practice.

1. Crop Sequence

An experiment was initiated in 1981 by Schmidt and Frey (1988), with the objective of identifying the best crop rotation system(s) that would increase crop productivity and improve or maintain soil productivity with addition of small quantities of inorganic fertilizers.

Materials and Methods: In 1981, four sole crops, maize (improved varieties), groundnut (improved), yam (cv Kpune, local) and sorghum (Mankaraga, local), and maize/groundnut intercrop were planted in vertical strips. In 1982, the same crops were planted in horizontal strips so that all possible successions were made. The direction of plant rows and the position of the subplots were maintained. There were four replications. This arrangement was repeated until 1986, which allowed for the alternating horizontal and vertical evaluation of monocropping and crop succession effects on each crop.

Plantings were done at optimum densities. Crop succession plots were subdivided between Zero-N plots and those receiving 60 kg N/ha. Phosphorus was applied annually at the rate of 26 kg/ha, and 50 kg K/ha was applied starting from 1984. Soil and plant analyses for N, P, and K were done from maize plots.

Results: Grain yield data of maize from 1982 to 1986 indicate either positive or negative influence of preceding crops on its performance, whereas positive response to N application was observed (Table 3).

Groundnut or yam as preceding crops had positive effect on maize grain yield while maize or sorghum as preceding crops had detrimental effect on maize grain yield. Groundnut fixed atmospheric N and did not use much of the soil N for its growth. Residual N from groundnut could therefore be available for the succeeding maize crop. Yam has low N requirements, and its cultivation results in rapid decomposition of organic materials because of the high degree of aeration and the hastened soil mineralization.

Data indicate that cereal-cereal crop sequence had detrimental effect on yields of the subsequent crop, especially, when the preceding cereal crop wa sorghum (Table 4). Groundnut yields were little influenced by preceding crops other than groundnut or maize-groundnut intercropping, thus indicating self-intolerance (Table 5). Yam yields were hardly influenced by preceding crops or N fertilization (Table 6). It was concluded that the best rotation was groundnut - maize - yam - sorghum.

Table 3: Influence of preceding crops and nitrogen fertilizer on grain yields of maize, crop sequence trial, 1981-1986, Nyankpala (Schmidt & Frey, 1988).

Preceding crop in rotation (a)	Kg N/ha applied to maize (b)	Maize grain yield (t/ha)				
		1982	1983	1984	1985	1986
Maize	0	1.04	0.38	1.19	1.72	2.35
	60	2.80	1.58	4.72	4.47	3.74
	mean	1.92	0.98	2.96	3.10	3.04
Groundnut	0	2.83	1.66	3.03	3.62	3.35
	60	4.12	3.20	6.36	5.55	4.06
	mean	3.48	2.43	4.69	4.58	3.70
Maize + Groundnut	0	0.94	0.86	1.45	2.64	2.98
	60	2.69	2.08	4.27	4.53	3.83
	mean	1.82	1.47	2.86	3.58	3.40
Yam	0	2.30	0.84	1.66	2.04	2.70
	60	4.18	2.78	5.73	5.62	3.86
	mean	3.24	1.81	3.69	3.83	3.28
Sorghum	0	0.75	0.26	0.58	1.40	2.07
	60	2.03	1.21	3.45	3.80	3.12
	mean	1.39	0.74	2.01	2.60	2.59
Mean	0	1.57	0.80	1.58	2.28	2.69
	60	3.16	2.17	4.91	4.79	3.72
LSD (5%)	(a)	0.64	0.45	0.72	0.45	0.27
	(b)	0.24	0.16	0.34	0.16	0.23
	(b/a)	0.53	0.35	0.76	0.36	0.51
	(ab)	n.s.	0.52	0.90	0.51	n.s.

Table 4: Influence of preceding crops and nitrogen fertilizer on sorghum grain yields, crop sequence trial, 1981-1986, Nyankpala (Schmidt & Frey, 1988).

Preceding crop in rotation (a)	Kg N/ha applied to sorghum (b)	Sorghum grain yield (t/ha)				
		1982	1983	1984	1985	1986
Maize	0	0.90	0.60	0.35	0.98	0.82
	60	1.17	0.45	0.71	1.50	1.27
	mean	1.04	0.52	0.53	1.24	1.05
Groundnut	0	1.18	0.40	0.86	1.53	1.33
	60	1.38	0.38	0.81	2.14	1.43
	mean	1.28	0.39	0.83	1.84	1.38
Maize + Groundnut	0	0.94	0.74	0.66	1.24	1.14
	60	1.42	0.50	0.63	1.77	1.26
	mean	1.18	0.62	0.64	1.50	1.20
Yam	0	1.11	0.62	0.52	1.01	0.89
	60	1.53	0.64	0.72	1.78	1.36
	mean	1.32	0.63	0.62	1.40	1.12
Sorghum	0	1.28	0.50	0.24	0.50	0.62
	60	1.67	0.66	0.56	1.14	0.95
	mean	1.48	0.58	0.40	0.82	0.79
Mean	0	1.08	0.57	0.52	1.05	0.96
	60	1.44	0.53	0.69	1.67	1.25
LSD (5%)	(a)	n.s.	n.s.	0.19	0.25	0.14
	(b)	0.09	n.s.	0.07	0.16	0.10
	(b/a)	0.19	n.s.	0.16	0.36	0.21
	(ab)	n.s.	n.s.	0.22	n.s.	0.20

Table 5: Influence of preceding crops and nitrogen fertilizer on groundnut yields, crop sequence trial, 1981-1986, Nyankpala (Schmidt & Frey, 1988).

Preceding crop in rotation (a)	Kg N/ha applied to groundnut (b)	Groundnut kernels (t/ha)				
		1982	1983	1984	1985	1986
Maize	0	1.26	1.43	1.50	1.04	1.31
	60	1.07	1.17	1.29	0.94	1.14
	mean	1.16	1.30	1.40	0.99	1.22
Groundnut	0	1.14	1.08	1.22	0.83	1.40
	60	1.23	0.95	1.06	0.65	1.22
	mean	1.19	1.01	1.14	0.74	1.31
Maize + Groundnut	0	1.25	1.28	1.34	0.94	1.49
	60	1.16	1.00	1.13	0.78	1.18
	mean	1.20	1.14	1.24	0.86	1.34
Yam	0	0.83	1.36	1.58	1.18	1.40
	60	1.08	1.13	1.48	0.93	1.10
	mean	0.95	1.25	1.53	1.06	1.25
Sorghum	0	1.20	1.54	1.78	1.22	1.17
	60	1.10	1.32	1.39	0.95	1.04
	mean	1.15	1.43	1.58	1.08	1.10
Mean	0	1.14	1.34	1.48	1.04	1.35
	60	1.13	1.11	1.27	0.85	1.14
LSD (5%)	(a)	n.s.	0.18	0.23	0.12	0.17
	(b)	n.s.	0.05	0.07	0.07	0.06
	(b/a)	0.17	0.12	0.16	0.16	0.13
	(ab)	0.22	n.s.	n.s.	n.s.	n.s.

Table 6: Influence of preceding crops and nitrogen fertilizer on yam yields, crop sequence trial, 1981-1986, Nyankpala (Schmidt & Frey, 1988).

Preceding crop in rotation (a)	Kg N/ha applied to yam (b)	Tuber yield of yam (t/ha)				
		1982	1983	1984	1985	1986
Maize	0	19.3	13.1	12.0	16.0	17.2
	60	23.0	12.9	15.0	18.1	18.6
	mean	21.1	13.0	13.5	17.1	17.9
Groundnut	0	21.2	12.6	14.9	15.6	19.4
	60	23.1	12.6	15.1	18.2	20.3
	mean	22.1	12.6	15.0	17.0	19.8
Maize + Groundnut	0	19.7	11.6	15.0	14.0	20.4
	60	23.6	12.3	16.8	17.6	20.0
	mean	21.7	12.0	15.9	15.8	20.2
Yam	0	19.2	10.7	12.2	12.8	16.8
	60	20.2	11.3	13.4	17.0	17.7
	mean	19.7	11.0	12.8	14.9	17.2
Sorghum	0	22.0	11.4	12.8	13.4	17.4
	60	24.4	14.9	17.4	17.2	17.9
	mean	23.2	13.1	15.1	15.3	17.6
Mean	0	20.3	11.9	13.4	14.4	18.2
	60	22.9	12.8	15.5	17.6	18.9
LSD (5%)	(a)	1.5	n.s.	n.s.	n.s.	2.0
	(b)	1.1.	n.s.	1.0	1.4	n.s.
	(b/a)	2.4	n.s.	2.2	3.1	n.s.
	(ab)	n.s.	n.s.	n.s.	n.s.	n.s.

2. Fertilization of Legumes

The importance of legumes in rotations cannot be overemphasized, since they may provide adequate supply of nitrogen to meet the N requirements of non-leguminous crops though they cannot supply other nutrients in which the soil may be deficient. For satisfactory growth of legumes, deficient soils may require application of minerals such as phosphorus and potassium.

In Northern Ghana, the most deficient mineral element is phosphorus. While non-leguminous crops have received attention in regard to P fertilization, this has not been the case with legumes. Soybean (*Glycine max*) production in Ghana is on the increase. An experiment was therefore designed at NAES to determine the response of this crop to N, P, and K.

Materials and Methods: Two soybean genotypes, TGX 306-0360C (nodulating, late maturing - 125 days) and Jupiter (non-nodulating, medium-maturing - 110 days), were planted in 1988. Fertilizer was applied before planting at the following rates: 0 and 60 kg Nitrogen (urea)/ha, 0 and 50 kg P (TSP)/ha, and 0 and 50 kg K (KCl)/ha. The experimental design was a 2 to 4th power factorial within a RCBD, with 3 replications. Data were analyzed as a 2 to 3rd power factorial for each genotype.

Results: Preliminary grain yield data indicate that both soybean genotypes responded to P but not to N or K (Table 7).

Table 7: Effect of N, P, and K on the yield (kg/ha) of two soybean genotypes grown at Nyankpala, 1988.

			GENOTYPES	
N	P	K	TGX 306-0360C	JUPITER
0	0	0	1132 ef*	860 e
	0	50	1030 g	976 cde
	50	0	2128 a	1503 a
	50	50	2087 abc	1562 a
60	0	0	1100 fg	923 de
	0	50	1151 defg	1004 bcde
	50	0	1789 bc	1568 a
	50	50	1728 c	1633 a
	CV (%)		15	21

* : Means with a column followed by the same letter are not different at the 0.05 level of significance, Duncan's Multiple Range Test.

IV. ALLEY CROPPING TRIAL

Alley cropping is a form of agroforestry whereby food crops are grown between rows of fast growing leguminous tree species. These leguminous trees do not only fix nitrogen for the use of food crops, but the prunings also serve as a source of organic matter or are used as mulch. Sticks (wood) from these pruned trees are used either for construction or for fuel. In the South-eastern part of the Guinea savanna zone where wood is scarce, farmers do not stake their yam plants. Maize and sorghum stalks are collected from the fields for fuel and construction.

A trial was started in 1987 to compare the existing farmers' practice with researcher's practice of alley cropping and strip rotation.

Materials and Methods: A two-factor randomized complete block design with six treatments and five replications was established. Planting was done on 13 x 6 m plots, i.e. 12 ridges 1.08 m apart. Crop varieties and plant densities were as follows:

Crop	Variety	High density	Low density
Maize	Dobidi	30303	22727
Sorghum*	Local 29	45454	30681
Groundnut	F-mix	90909	45455
Pigeon pea	Wantugu Pink	6818	6818

*: Sorghum was thinned to these densities.

The cropping patterns were: (a) farmer's practice - groundnuts are planted on the ridge, maize by the side of the ridge and sorghum broadcasted in the maize furrows; (b) strip rotation - consisted of 4 ridges of each sole crop maize and groundnuts with sorghum broadcasted in the maize furrows; (c) alley cropping - similar to the strip rotation but with the 4th, 7th and 11th ridges planted to pigeon pea (*Cajanus cajan*).

There was a basal application of 30:30:30 (N:P205:K20) with a side dressing of 30 kg N/ha to all plots in 1987.

Results: In the first year, cereal yields under farmer's practice were higher than under researcher's practice of alley cropping and strip rotation. Maize grain yields did not differ significantly between the different densities within the cropping patterns, but was reduced in the alley cropping. Groundnut yields were low, due to poor crop establishment. Kernel yields under farmer's practice were significantly lower because of severe competition for light with the intercropped cereals. In the second year, 1988, the order was reversed. Maize and groundnut yields were higher under researcher's practice than under farmer's. Sorghum yields did not show any significant differences between the cropping practices (Table 8).

Table 8: Grain yield (kg/ha) of three cropping patterns at Nakpa, 1987 - 1988.

Cropping Pattern	Population density	Maize		Sorghum		Groundnut	
		1987	1988	1987	1988	1987	1988
Farmer's practice	high	1375	1871	918	746	86	939
	low	1292	1909	1218	1121	136	901
Strip rotation	high	1186	3166	335	898	262	1701
	low	1386	3242	389	1159	261	1879
Alley cropping	high	967	3587	185	1061	257	1950
	low	797	2859	217	1132	250	2172
Overall mean		1167	2273	544	1019	208	1590
LSD (5%)		391	791	236	377	100	477
CV (%)		25	31	33	40	37	32

V. CONCLUSION

The following conclusions may be drawn from our studies:

(1) Land use efficiency can be improved in sorghum/groundnut mixtures, especially in intra-row intercropping, in the Sudan savanna zone;

(2) In the Guinea savanna zone where rainfall is higher, crop intensification in time and space dimensions, such as double and relay cropping, is feasible;

(3) Rotation effect on subsequent crops may be positive or negative depending on the preceding crop(s). The best crop rotation was found to be [grain legume -> cereal -> root crop -> cereal];

(4) Phosphorus may be required to improve the yields of legumes in crop rotations;

(5) Alley cropping in the Guinea Savanna zone can improve soil fertility and crop productivity.

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CROP PRODUCTION TECHNOLOGY DEVELOPMENT AND EVALUATION UNDER LIMITED RESOURCES: THE CASE OF NORTH BENIN

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I. BACKGROUND

This paper reports major research findings on crop technology evaluation by the SAFGRAD/Farming Systems Research (FSR) Project which operated from 1985 - 1988 in Northern Benin. The field objectives of the programme were to conduct baseline surveys, identify major constraints to increased production and carry out on-farm adaptive trials. In the process, the project was to assist the Directorate of Agronomic Research (DRA) of the Government of Benin to improve the national FSR capacity.

The study area covers the two northern provinces of Benin (Borgou and Atacora) with a total area of 82,200 km^2 (72% of the country) and a population of about one million (28%), more than 80% engaged in agriculture. The region stretches across three agro-ecological zones (Fig. 1 a&b): the transition from Sudan to Sahel (long-term average annual rainfall of 900 mm), Sudan Savanna in the mid belt (1100 mm) and Northern Guinea Savanna to the South (1200 mm) (Adam and Boko, 1983).

Over the past 10 - 15 years, however, annual precipitation had declined by 300 - 400 and 200 - 300 mm in the extreme north and to the south of the two provinces, respectively. Rainfall distribution is monomodal, beginning in April - May, peaking in August, dropping sharply in the Sudan-Sahel and gradually in the Northern Guinea zone.

The dominant soil group is the Ferruginous Tropical Soils (Alfisols), covering 85% of the region. These soils are slightly acid and reddish with low levels of phosphorus, remain moderately productive and can support a wide range of crops. In certain parts of Atacora, soils are degraded as a result of continuous cultivation pressure and deforestation. The vegetation of Northern Benin is largely composed of wooded savanna with *Pterocarpus enrinaceus, Afzelia africana, Bombax buenopose, Butyrespermum parkii, Khaya senegalensis and Parkia biglobosa* as the dominant species (Otsyina *et. al.,* 1987).

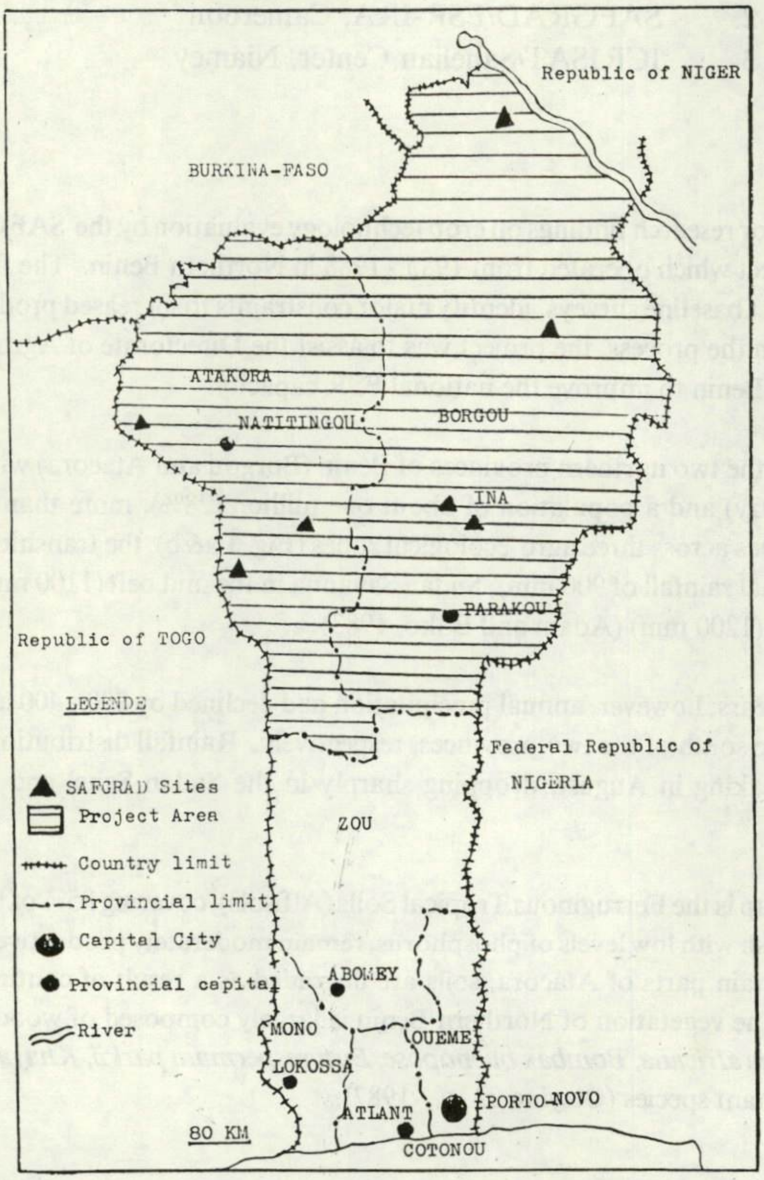


Figure 1a: People's Republic of Benin

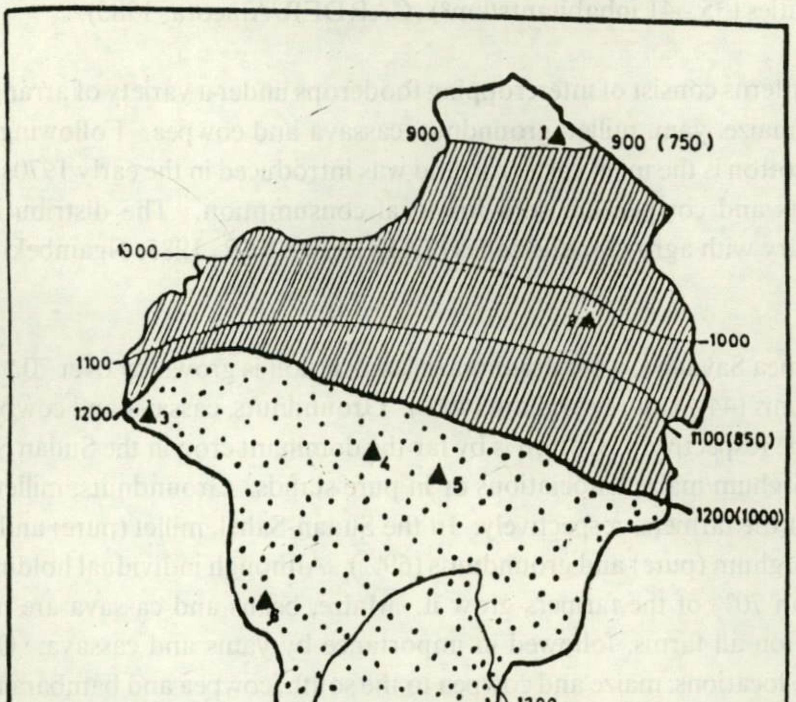


Figure 1b: Agroclimatic zones of northern Benin and location of research sites.

Cropping Systems

Production systems in Northern Benin are predominantly subsistence oriented. Although shifting cultivation is still widely practiced, an increasing fraction of farmers have moved to fallow systems of 3 - 5 years. Permanent cultivation has even evolved in Ouake and Boukoumbe districts of Atacora because of land scarcity due to high population densities (35 - 41 inhabitants/km²) (CARDER/Atacora, 1985).

Existing cropping patterns consist of intercropping foodcrops under a variety of arrangements. Major crops are cotton, sorghum, maize, yam, millet, groundnut, cassava and cowpea. Following the tradition in Francophone West Africa, cotton is the main cash crop and was introduced in the early 1970s as an engine for modernization. Groundnuts and cowpea are sold for local consumption. The distribution and relative importance of these crops vary with agro-climatic zones (SAFGRAD/FSR, 1985; Ngambeki and Ndunguru, 1987).

In the Northern Guinea Savanna, a sorghum/maize association is grown by over 70 % of the farmers, followed by cotton (49%), yams (44%), pure sorghum (40%). Groundnuts, cassava and cowpea are grown by 35,33 and 37% of the farmers, respectively. Cotton is by far the dominant crop in the Sudan Savanna (85% of the farmers), followed by sorghum/maize associations or in pure stands. Groundnuts, millets and beans are grown by 64, 57 and 35 % of the farmers, respectively. In the Sudan-Sahel, millet (pure) and millet/sorghum predominate, followed by sorghum (pure) and groundnuts (69%). Although individual holdings of cotton are small in this zone, more than 70% of the farmers grow it. Maize, beans and cassava are minor crops. In Atacora, sorghum is grown on all farms, followed in importance by yams and cassava. Other crops play significant roles according to locations: maize and cowpea to the south, cowpea and bambara nuts (voandzou) to the west, and groundnuts in the center.

In a typical rotation, yams are often the first crop after the forest or fallow has been cleared. It is followed in successive seasons by cotton or groundnuts (one or two crops), maize or sorghum (pure or associated) and cassava before the land is reverted to fallow (SAFGRAD/FSR, 1988; OAU/STRC-SAFGRAD, 1989).

II. INSTITUTIONAL FRAMEWORK AND STATUS OF CROP RESEARCH

Until the mid 1970s, agricultural research in Benin was under the responsibility of French overseas institutes. Emphasis was on export and industrial crops (cocoa, coffee, oil palm, coconuts, etc.) with only a marginal interest in foodcrops (maize, rice). In its implementation of the first (1977 - 1980) and second (1983 - 1985) Development Plans after the nationalization of agricultural research services (1977), the government of Benin reoriented agricultural policy toward foodcrops research and the attainment of food self-sufficiency (FAO/World Bank, 1986). Among other policy options, increases in foodcrops production were to be achieved through investment in commodity research and the implementation of FSR projects in the country's major agro-ecological zones.

There are 13 *Unites de Recherche et de Production* (URPs) currently under the DRA, eight with straight commodity mandates; the remainder provides supporting services (e.g. soil surveys, mapping and analysis, food technology, animal health, socio-economic studies). However, the geographical distribution of URPs in Benin is biased toward the more densely populated provinces in the south, with Ina as the only foodcrops station for northern provinces - 2/3 of Benin's territory (SAFGRAD/FSR, 1986).

Research infrastructure at Ina is inadequate (Ndunguru and Ngambeki, 1985). Until 1987 the station had no laboratory and lacked basic equipment even those that perform simple soil and plant analysis. Professional staff is limited to 6 national scientists, 4 at the BSc level. The station operates essentially on project funds as the government budgetary allocation dried out in the early 1980s.

In the face of unstable and unreliable resource situation, food-crops research in Northern Benin has generally been weak and thematic in approach. Consequently, limited technologies - a few improved varieties of maize, groundnuts and cowpea - have been developed or adapted and no achievements recorded with such important crops as sorghum and yams (Murinda and Kamuanga, 1988). The following is a brief review of the status of crops research as of 1985 - 1986.

Cotton: Results have been generally good with regard to variety development. Varieties MK73 and L299-75 achieved complete coverage of north and south Borgou, respectively. Although agronomic practices are well defined, no suitable rotation involving cotton has yet been proposed to the farmers.

Maize: The release of TZB maize in 1984 marked a significant headway over previous selections. URP/Ina recently identified a streak resistant variety - TZBSR (URP/Ina, 1985). Improved agronomic practices have also been developed and there is now an acceptable package (*Fiche technique)* available for extension.

Sorghum: Varietal improvement at Ina has so far failed to produce a single variety that is superior to local cultivars with respect either to yield or *Striga* resistance. Two photo-sensitive varieties - IRAT Togo and Ghana 1 - have shown consistently good yields under station conditions. Sorghum is indeed a difficult crop to improve; in the absence of a suitable high fertilizer responsive variety, there is little to be gained from improved agronomic practices.

Groundnuts: Two varieties now recommended - 69101 and RMP91-give fairly good yields, averaging 2.4 t/ha and also show some resistance against rosette virus (Murinda and Kamuanga, 1988). Resistance to rust and the search for short cycle materials for the extreme north are currently receiving priority. The fertilizer recommendation needs to be refined in view of the crop's known response to residual effects of previously applied fertilizer. The role of groundnuts as a forage is also being recognized.

Cowpea: TVX1850-01F has been superior to a host of other cultivars including TN61 which was the recommended variety up to the mid 1980s. As with groundnuts, fertilizer doses need refinement. In 1985-86, no research data was available on the performance of cowpea in intercropped systems as widely practiced in the region.

Yams: No improved material has been released yet. The variety Terikokonou was identified to be well adapted to Northern Benin conditions. Traditional technology has never been surpassed by new production techniques (Dumont, 1976). High fertilizer doses have not resulted in yields higher than those obtained by farmers on freshly cleared land. The real challenge in yam production is to reduce the cost of planting materials and to develop techniques of land preparation which will be less labour demanding.

Research - Extension Linkages

There is a rural development project known as the *Centre d'Action Regionale pour le Developpement Rural* (CARDER) in each province. CARDER/Borgou and Atacora have had the following objectives: (a) to develop and provide infrastructure for agricultural, animal and forestry production; (b) to organize the formation of village cooperatives and mobilize them; (c) to facilitate input and output marketing, and (d) to enhance the efficiency of extension services. Moreover, CARDER/Borgou encourages farmers to increase their holdings of cotton while attempting to strike a balance with foodcrops production.

Benin is unique in that it has a strong, adequately financed and well decentralized extension service reaching practically every village. It is therefore in the dispensing of extension services to promote improved practices for foodcrops that the research-extension links are the weakest (i.e. there is very little technology to extend on the side of foodcrops).

III. FARMERS' PRACTICES AND EVALUATION OF IMPROVED TECHNOLOGIES

1. Approach

Considering the lack of infrastructure and the weak status of foodcrops research, the SAFGRAD/FSR programme in Northern Benin sought to provide a strong applied component to thematic research at Ina, including limited backstop to the station for modest improvements of basic facilities (Ndunguru and Ngambeki, 1985). Following reconnaissance surveys, the content of the programme evolved along the identified major constraints and suggestions for intervention:

- Reduction in rainfall across the region and its erratic distribution has resulted in shorter growing seasons. Karimamma district (extreme north) in particular faced serious drought, pointing to the necessity of introducing suitable varieties as well as water conservation techniques (Fig. 2).

Research has been very much in favour of cotton at the expense of foodcrops. The lack of high-yielding varieties of sorghum and yams was limiting the potential and impact of improved agronomic practices.

- Little or no recommendation tailored to the socio-economic conditions of farmers was available. For example, most foodcrops are grown in association with very little use of fertilizer; yet scanty data existed on the performance of intercropped systems in the region.

- Soil degradation in Ouake and Boukoumbe districts called for the introduction of practices to restore soil fertility (fertilizer, manure, rotation, etc.) as well as improved agro-forestry techniques.

- Labour shortages at peak season (planting, weeding) and the lack of assured market outlets for grain constituted bottlenecks limiting increased productivity. On the other hand, input delivery, seasonal and long-term credit facilities were only extended to cotton farmers. Shortage of cash income to buy oxen and farm equipment and other purchased inputs reduced productivity gains.

Baseline studies were conducted in early 1985, followed in 1986 by a detailed study of farmers' practices. Researcher-managed trials were conducted at five primary sites (Birni-Lafia, Bensekou, Sokka, Ouake and Boukoumbe) representing different agro-ecological zones (Fig. 1b) and at Ina and Sosso stations (Atacora). As part of the design stage, these trials were aimed primarily at generating technologies to be later tested on farmers' fields. In 1987, experiments were researcher/farmer managed with some of the tests completely managed by farmers.

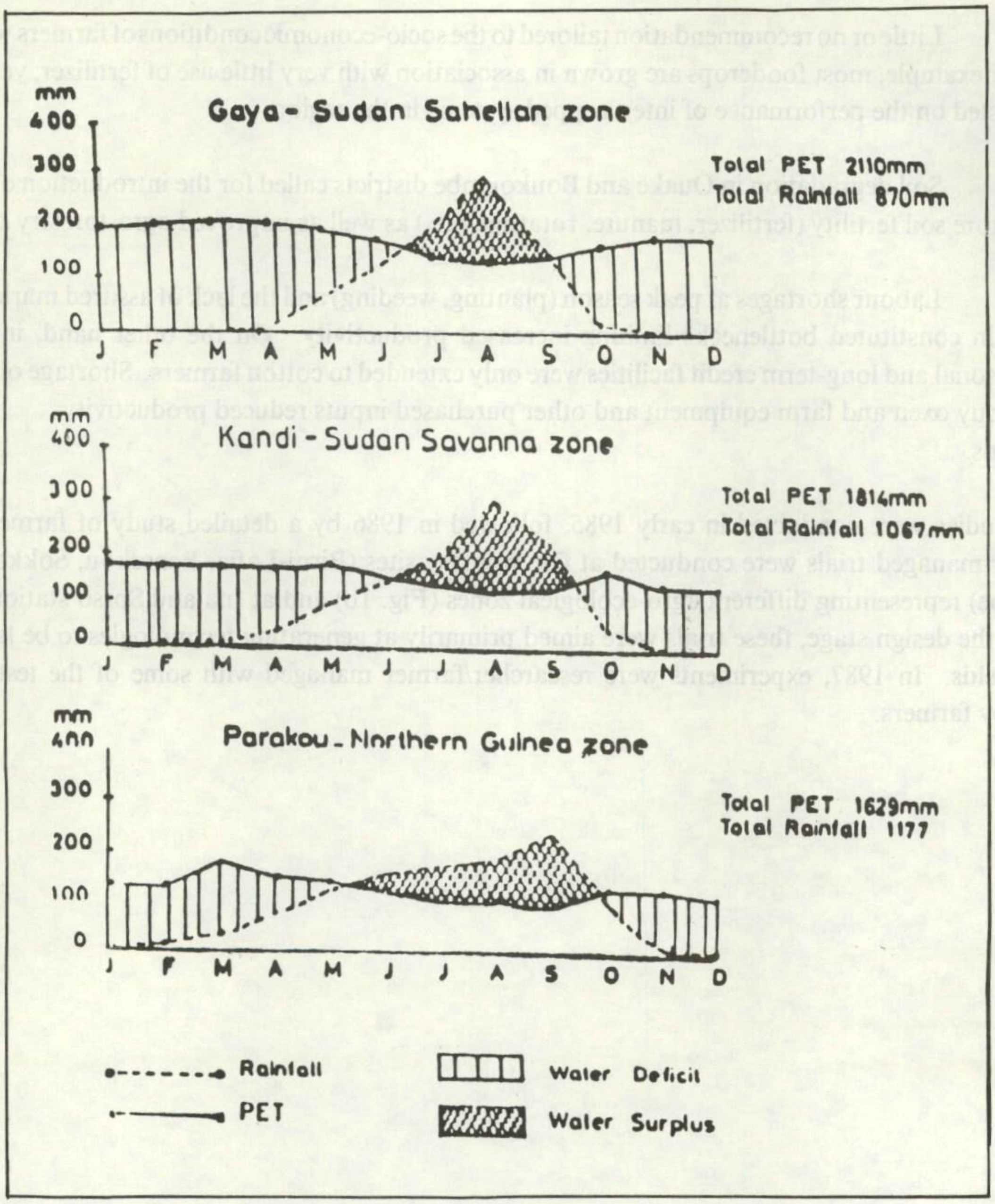


Figure 2: **Precipitation and potential evapotranspiration (PET) at 3 stations in Northern Benin, 1984. (Adapted from Borgou II-World Bank /FAO 1986 Report).**

2. Farm Level Resource Use

Knowledge of farmer's existing resource base, its utilization over the course of the season and the relative importance of enterprises is relevant to the process of developing and adapting new technologies. Table 1 derived from input/output data shows the proportion of total labour use and net incomes between crops, livestock (sedentary management) and on-farm management of economic trees across the three agro-ecological zones.

Labour use on crops absorbs 71% of the total number of man-hours available to the farm, followed by livestock (25%) and trees (3.3%). The same allocational pattern seems to hold for farm expenses. Crops provide 95% of net income, 40% of which is cash. The highest net income per active worker is realized at Bensekou (Sudan Savanna), the lowest at Ina/Sokka (Northern Guinea). Differences in income levels reflect the variation in farm sizes, the size importance of cotton holdings, the extent of animal traction use and the variation in the production potential of each agro-ecological zone. Generally, cotton farmers with animal traction realize the highest incomes because they are able to generate extra income from increased hectarages of food-crops due to animal traction (OAU/STRC-SAFGRAD, 1989).

The pattern of labour use in crop production Table 2 indicates the position of eventual slack period from one agro-climatic zone to another. The highest demand for labour at Birni-Lafia (464-man-hours/farm) is shown to occur in September-October due to weeding and concurrent harvesting operations for millet, sorghum and cotton in October. At Bensekou, land preparation for cotton (on larger holdings), maize/sorghum, and groundnuts requires 824 man-hours per average farm, but much less (388) in November for the harvesting of cereals, cotton and yams. The peak period at Ina/Sokka in December is attributed to the high labour demand for the collection of cotton. On the other hand at Ouake (Atacora), land preparation in May-June is the most labour consuming operation, in part due to the cultivation of a wide range of crops on relatively small-sized farms. In the major cotton-growing zones (Northern Guinea, Sudan Savanna), at least one third of the total labour spent on crops is used up between November and February in land preparation for yams, harvesting and collection of cotton.

Total crop expenses per hectare average 14040 FCFA across the region, with the largest expenditure (22170 FCFA) incurred by the Sudan Savanna farmer. It is interesting to note that more than 70% of crop expenses are made between April and August for land preparation and weeding. These expenses are essentially made for cotton fertilizer, hiring and/or own use of oxen and ploughs, purchase of seeds and small tools.

Table 1. Labour use, cost of production and farm incomes at selected sites in Northern Benin, 1988.

	ZONE (VILLAGE)			
	Northern Guinea (Ina/Sokka)	Sudan Savanna (Bensekou)	Sudan-Sahel (Birni-Lafia)	Atacora (Ouake)
Farm size (ha)	4.5	6.9	5.5	2.8
Labour force (wu)*	6	5	5	4
Labour use				
farm total (man-hrs)**	4397	4067	2829	2746
% Crops	64.2	67.2	82.4	70.0
% Livestock	29.3	25.6	15.6	27.8
% Trees	6.1	5.5	1.0	1.0
Cost of Production				
farm total (FCFA)**	59299	187690	107215	52000
% Crops	87.0	81.5	62.6	62.2
% Livestock	6.6	17.6	34.6	21.4
% Trees	0.5	0.3	0.1	1.0
Net income				
farm total (FCFA)**	576948	640417	198620	281710
% Cash	20.8	70.6	29.6	36.9
% Crops	98.8	95.7	91.0	92.7
% Livestock	0.9	2.8	1.5	6.6
% Trees	1.0	0.3	0.8	3.6
per ha (FCFA)	83766	92814	36113	100611
per worker (FCFA)	62825	128083	66207	70428

* : wu = work unit

** : includes labour or expenses for general farm activities.

Table 2: Monthly labour use per farm (LAB, man-hrs) and crop expenses per hectare (EXP, CFA/ha) at selected sites in Northern Benin, 1988.

MONTH	ZONE (VILLAGE)							
	Northern Guinea (Ina/Sokka)		Sudan Savanna (Bensekou)		Sudan-Sahel (Birni-Lafia)		Atacora (Ouake)	
	LAB	EXP	LAB	EXP	LAB	EXP	LAB	EXP
April	41	369	11	225	-	-	-	-
May	43	1748	47	585	52	-	364	844
June	244	1787	824	5250	95	480	329	384
July	283	1452	270	4774	205	694	167	3505
August	310	1114	281	4753	460	2473	148	4829
September	306	956	256	1869	452	3340	280	1200
October	209	839	166	1747	464	1845	233	800
November	344	829	388	471	348	866	251	293
December	445	432	175	160	210	614	80	-
January	256	50	194	138	15	591	42	-
February	262	487	109	2798	20	902	28	-
March	80	37	12	-	10	206	0	-
Total	2823	10127	2733	22170	2331	12011	1922	11855

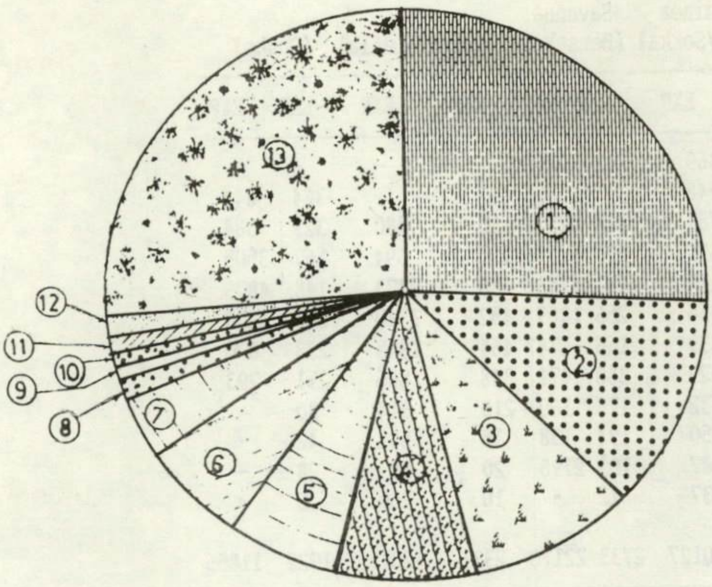
3. Testing and Evaluation of Improved Technologies

In this section, technologies and farm management practices tested over 2-3 years are reviewed and evaluated. Experimental themes covered improved cropping patterns, variety evaluation, soil fertility and soil water conservation, and input use efficiency in yam production.

3.1 Crop Associations

Nearly all foodcrops are grown in associations in Northern Benin. They represent 51% of the total cultivated land outside cotton (Fig. 3). For Borgou province alone, this proportion is above 60% (SAFGRAD/FSR, 1986).

A. Area planted (%)



(B) NUMBER OF MONITORED PLOTS IN 1986

Codes	Crops / Assoc	Total
①	Cotton	102
②	Sorghum / Maize	50
③	Sorghum	42
④	Yams	43
⑤	Millet	40
⑥	Maize	37
⑦	Groundnuts	29
⑧	Yams / cereals	13
⑨	Gdnut / cereals	10
⑩	Cassava	9
⑪	Sorghum/grain leg	7
⑫	Maize/ grain leg.	4
⑬	Others	62
	Total	448

Figure 3: Relative importance of crops and associations in the survey zones.

Economic advantages of crop associations are known to farmers and include minimizing food risks and a more efficient utilization of labour (Norman, 1974). However, in response to our query, farmers did not always articulate well technical reasons for practicing mixed cropping. Only 38% of the farmers interviewed at Bensekou pointed out that intercropping cereals with legumes give good yields and benefits soils. Agronomic advantages of crop associations are known to include increased total output, soil fertility maintenance and minimization of diseases and pests. Differing growth cycles of crops are most apparent technical reasons for growing crop mixtures (Norman *et. al.,* 1982; Fussell and Serafini, 1985). Disadvantages of intercropping include delays in maturity of some of the associated crops and a reduction in yields of individual crops. However, as long as small holder agriculture continues to dominate the semi-arid region of Africa, intercropping is likely to maintain it status as the predominant cropping system for local production (Fussell and Serafini, 1987).

The objective of experiments was to evaluate and improve the performance of common associations in the region. The trials involved growing crops in pure stands and in association, using local and improved varieties at various sites. For cereal/cereal associations, sorghum/maize trials were conducted in Northern Guinea and Sudan Savanna, and sorghum/millet trials in the Sudan-Sahel zone. As to cereal/legume associations, sorghum/cowpea trials were implemented in all three zones in conformity with local practices. Fertilizer, ridging and planting in alternate rows were included as treatments to improve the performance of associations.

Sorghum/Maize Associations

As shown in Table 3, individual crop yields were reduced in the association. Under **low management** (no fertilizer, flat cultivation), the grain yield of local sorghums was not apparently affected by the association as is the case for improved sorghum (Ghana 1) intercropped with both local and improved maize (TZB). Yield reductions were 54% and 39%, respectively. The yield of local maize is largely reduced (-56%) under association with local sorghum, but much less (-7%) with Ghana 1. The reduction of TZB maize yield is the same when grown in association with local and improved sorghum. Under **high management** (fertilizer, ridging), the highest (-53%) and lowest (-23%) yield reductions were recorded with Ghana 1 and local sorghum, respectively, intercropped with TZB.

In terms of total grain, the highest performance (1680 kg/ha) was recorded with TZB/local sorghum under low management. Under high management, the highest yield (2625 kg/ha) was recorded in TZB pure. The coefficients of variation (CVs) were generally lower in the associations as compared to sole cropping at both levels of management.

Table 3: Effects of sorghum/maize association on yield (kg/ha) parameters under two levels of management in Northern Benin*.

Management levels	Pure Stands				Crop Associations								
Parameters	Local Sorgh. S1	Ghanal S2	Local Maize M1	TZB M2	S1	M1	S1	M2	S2	M1	S2	M2	Mean
LOW MANAGEMENT (no fertilizer, on flat)													
.Indiv. yield	659	503	1085	1461	698	477	624	1056	229	1001	307	1036	
.Total grain					1175		1680		1230		1343		
.LER	1.00	1.00	1.00	1.00	1.50		1.67		1.38		1.32		1.47
.% change in yield due to association	-	-	-	-	+6	-56	-5	-28	-54	-7	-39	-29	
.C.V.(%)	17.4	30.4	20.7	31.1	22.4		25.4		18.6		22.5		23.6
.Gross margin (x 1000 FCFA)	51.5	37.8	59.9	81.8	74.6		104.0		76.2		80.6		
HIGH MANAGEMENT (Fertilizer + Ridges)													
.Indiv. yield	309	1250	2192	2625	588	1454	582	1910	767	1154	585	1817	
.Total grain					2042		2492		1621		2402		
.LER	1.00	1.00	1.00	1.00	1.39		1.45		1.14		1.16		1.28
.% change in yield due to association	-	-	-		-27	-34	-28	-23	-39	-47	-53	-31	
.C.V (%)	14.7	34.5	15.0	16.1	13.1		17.4		16.4		19.5		18.4
.Gross margin (x 1000 FCFA)	46.1	82.3	101.5	135.1	111.1		135.5		98.3		126.7		

*. Means of 3 seasons and 3 sites: Sokka, Ina and Benesekou.

The land equivalent ratio (LER) was above one in all associations and the highest under TZB/local sorghum at low management (1.67). Partial budget analysis reveals that gross margins per hectare are generally higher with fertilizer and ridging treatments (except for local sorghum). The highest returns under high management in sole cropping comes from TZB maize (135,100 FCFA/ha). In crop association, the TZB/local sorghum intercrop gives the highest return (135,500 FCFA/ha). The compatibility of TZB and local sorghum is attributed to different growth habits: sorghum with a longer vegetative period (more than 120 days) begins its vigorous growth when TZB maize(55 days) is maturing.

Sorghum/Cowpea Associations

The results reveal substantial reductions in the grain yield of cowpea in association as compared to sole cropping (Table 4). The average reduction across years and sites is estimated at 44.3%, with the highest (-59.9%) recorded at Ina in 1987. However, the grain yield of sorghum was not significantly affected. While its average percent reduction across years and sites is only 9.3, there were instances when sorghum in association yielded higher than in pure stand (i.e. at Ina in 1986 and Sokka in 1987).

Table 4: Grain production (kg/ha) and land equivalent ratios (LER) of cowpea and sorghum grown in pure stand and in association in Northern Benin (INA), Bensekou (BSK), Karimana (KMM), and Sokka (SKA), 1985 - 1987.

Parameters	1985			1986		1987				Gross returns (x 1000
	INA	BSK	KMM	INA	KMM	INA	SKA	X	CV(%)	FCFA)
Cowpea (C)										
pure	1080	913	209	1370	523	905	685	812	16.4	172.8
in assoc.	787	399	135	696	337	363	368	441	17.8	
% reduction	27.1	56.3	35.4	49.2	35.6	59.9	46.3	44.3		
Sorghum (S)										
pure	922	337	529	761	1210	998	753	787	13.0	45.9
in assoc.	589	331	450	910	992	760	823	694	12.3	
% reduction	36.1	1.8	14.9	+19.6	18.0	23.8	+9.3	9.4		
C/S assoc.										
grain yld.	1376	730	585	1606	1329	1123	1191	1134	11.2	135.5
LER	1.37	1.42	1.50	1.70	1.46	1.16	1.63	1.46		

As to total grain yield, sorghum/cowpea associations performed better than either crop in pure stands. This is confirmed by the high value of LER (average 1.46) with the maximum (1.70) recorded at Ina in 1986. The gross return is lower due to the larger share of sorghum in the mixture coupled with its lower market price (87 vs 224 FCFA/Kg in 1987 for sorghum vs cowpea, respectively). The fact that LERs are substantially higher under association compared with pure stands and sorghum yields are unaffected supports farmers' practices and objectives in planting cowpea in association i.e. to produce a secondary crop (cowpea) without either reducing significantly the yield of the main crop (sorghum) or incurring additional labour for land preparation and weeding.

In sum, growing crops in association reduces yields of individual crops, with higher percent reductions noted for legumes associated with cereals. In addition, associations give consistently higher total grain yields (LER > 1) and show more stability (lower CVs) across sites and seasons than sole cropping. Fertilizer application and ridging improve total grain yield, gross returns and the stability of crop associations.

3.2 Variety Improvement

Variety trials for sorghum and millet were conducted in 1986 and 1987 at Birni-Lafia (Sudan-Sahel). The experiments involved 4 local varieties and 4 introductions (IRAT-Togo, 2871, Ghana 1 and Tiermafing for sorghum; ITMV 8001, ITMV 8304, HKP and CIVT for millet). Treatments included early, normal and late sowing dates to expose the varieties to drought spells which often occur early and late in the season. The 1986 experiments could not all be interpreted[1]. In 1987, rains were insufficient and came too late to apply the treatment involving an early date of planting. Nevertheless, an attempt was made to interpret the available data.

Only six sorghum varieties succeeded to maturity (Fig. 4). The highest yield (2033 kg/ha) was recorded in IRAT-Togo and the lowest (200 kg/ha) from Blanc de Baragou (local). The promising finding was that IRAT-Togo outyielded even the best local variety (Blanc de Karimama). All introduced lines of millet outyielded the locals. ITMV 8001, ITMV 8304 and CIVT significantly outyielded the best local variety (Somnon) with increments of 740, 40 and 396 kg/ha, respectively.

The superiority of IRAT-Togo and three improved millet varieties over the local materials provided sufficient ground to the research team to propose their advancement under farmer managed tests in 1988. The next step was to evaluate these varieties for profitability under farmers' conditions in Karimama district.

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[1] Trials partly destroyed by roaming animals.

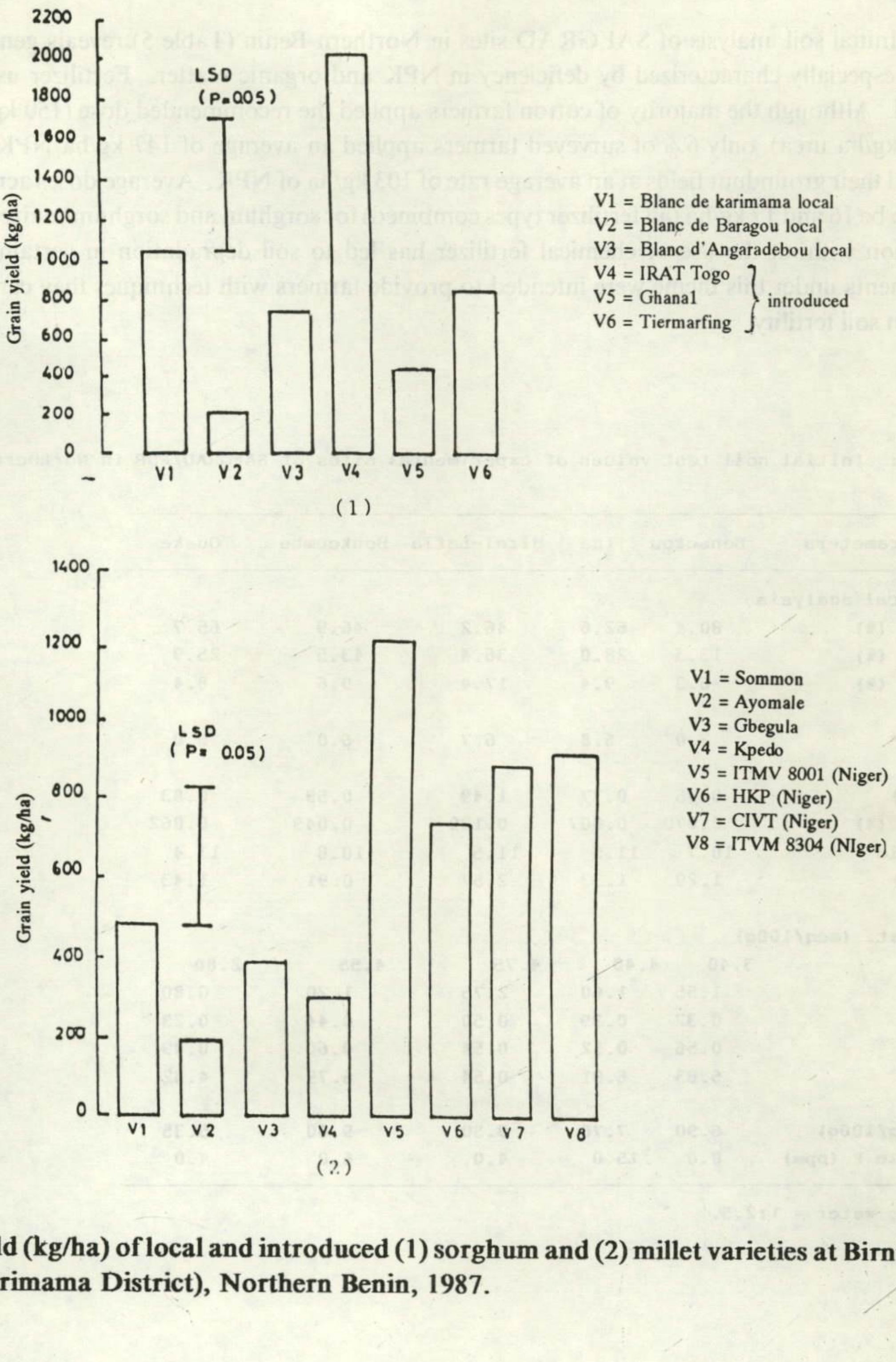

Figure 4: **Yield (kg/ha) of local and introduced (1) sorghum and (2) millet varieties at Birni-Lafia (Karimama District), Northern Benin, 1987.**

3.3 Soil Fertility and Water Conservation Experiments

Initial soil analysis of SAFGRAD sites in Northern Benin (Table 5) reveals generally low levels of fertility especially characterized by deficiency in NPK and organic matter. Fertilizer use outside cotton is minimal. Although the majority of cotton farmers applied the recommended dose (150 kg/ha NPK 20:10:10 and 50 kg/ha urea), only 6% of surveyed farmers applied an average of 147 kg/ha NPK on maize and 2% fertilized their groundnut fields at an average rate of 103 kg/ha of NPK. Average doses across the region were found to be 16 and 17 kg/ha (all fertilizer types combined) for sorghum and sorghum/maize fields. Continuous cultivation without the use of chemical fertilizer has led to soil degradation in certain parts of Atacora. Experiments under this theme were intended to provide farmers with techniques they can afford in order to maintain soil fertility.

Table 5: Initial soil test values of experimental sites of SAFGRAD/FSR in Northern Benin, 1986.

Soil Parameters	Bensekou	Ina	Birni-Lafia	Boukoumbe	Ouake
Mechanical analysis					
Sand (%)	80.4	62.6	46.2	46.9	65.7
Silt (%)	13.3	28.0	36.4	43.5	25.9
Clay (%)	6.3	9.4	17.4	9.6	8.4
Soil pH*	7.0	6.8	6.7	6.0	6.0
O.C. (%)	0.75	0.77	1.49	0.59	0.83
Total N (%)	0.070	0.007	0.129	0.049	0.062
C/N ratio	10.7	11.5	11.5	10.8	13.4
O.M. (%)	1.29	1.33	2.57	0.91	1.43
Exch. cat. (meq/100g)					
Ca	3.40	4.40	4.75	4.55	2.80
Mg	1.55	1.60	2.75	1.20	0.80
K	0.32	0.39	0.50	0.44	0.23
Na	0.56	0.52	0.54	0.60	0.49
Total	5.83	6.91	0.54	6.79	4.32
CEC (meq/100g)	6.90	7.70	9.50	9.60	5.35
Available P (ppm)	8.0	15.0	4.0	6.0	4.0

*: Soil: water = 1:2.5.

Evaluation of Fertilizer x Variety x Land Preparation

The experiment (23 factorial) was conducted at three sites over three years. The objective was to evaluate fertilizer response in local and improved maize (TZB) under different land preparation methods (flat vs ridges). Cotton fertilizer was applied and plant density was maintained at 62,500 plants/ha.

Ridging had very little significant effect on the yield of maize (Table 6). Fertilizer, on the other hand, significantly increased the yield of maize in 9 and 3 out of 12 cases for TZB and local maize, respectively. The response of TZB maize to fertilizer application is consistent; nearly 4 t/ha was achieved at Sokka in 1987. From these results the following observations were made:

> There is no advantage to planting maize on ridges in Northern Guinea zone; instead ridges should be made after last weeding to incorporate fertilizer and guard against lodging.
>
> Since TZB maize has been widely adopted, farmers should be encouraged to apply fertilizer in order to realize the full potential of the variety even under association with sorghum.

On-Farm Maize Fertilizer X Variety Trials

a. **Farmer-Managed Trials:** The objective was to provide researchers with an opportunity to assess factors determining the yield gap between that station and farmers' circumstances and conduct simple benefit-cost analysis of fertilizer use to guide policy makers.

The trial involved comparing TZB and local maize, without and with fertilizer (60 kg/ha N) and was conducted at Ina, Sokka and Bensekou by 5 farmers from each village. The farmers provided 0.25 ha of land divided into four equal parts for the respective treatments and in turn received fertilizer and seeds free of charge. Labour allocation conflicts with cotton at planting and weeding precluded farmers from properly tending the trials.

TZB maize responded positively to fertilizer but overall yields were low (less than 2 t/ha) due to low management. Data from successful farmers at Ina and Sokka were pooled; in this zone, yield increases due to fertilizer were estimated at 45 and 71% for the local and TZB maize, respectively. At Bensekou, increases of 141 and 134% were recorded. The highest benefit-cost ratio (3.42) was recorded at Bensekou (Sudan Savanna) for TZB maize and the lowest (0.81) at Ina-Sokka (Northern Guinea) for local maize.

Table 6: Effect of fertilizer application and land preparation on yield (kg/ha) of local maize and TZB in Northern Benin, 1985 and 1987.

			Local Maize		TZB		
Year	Site	Land preparation	without fertil.	with fertil.	without fertil.	with fertlil.	C.V (%)
1985	Ina	Flat	1278 b*	2142 ab (68) **	1353 b	2892 a (109)	16.5
		Ridge	1676 b	1934 ab (15)	1277 b	2938 a (130)	
	Sokka	Flat	910 b	898 b (-1)	769 b	1873 a (144)	12.7
		Ridge	855 b	1005 b (18)	879 b	1531 ab (74)	
	Bensekou	Flat	306 d	557 b (82)	475 c	759 a (60)	16.4
		Ridge	465 a	647 ab (39)	439 c	636 ab (45)	
1987	Ina	Flat	1230 bc	1618 bc (32)	2375 ab	3463 a (46)	28.4
		Ridge	740 c	2318 ab (213)	2015 bc	2418 ab (20)	
	Sokka	Flat	1593 c	2090 c (31)	2740 c	3940 c (44)	11.1
		Ridge	1835 c	1838 c (-1)	2093 c	3013 b (44)	
	Bensekou	Flat	695 b	940 b (35)	893 b	1710 a (91)	25.5
		Ridge	680 b	983 b (45)	1008 b	1700 a (69)	

* : Means followed by the same letter are not significantly (P = 0.05) different.

**: Figures in parentheses represent % increase due to fertilization.

b. Researcher/Farmer - Managed Trials: A different objective was pursued under this experiment, i.e. to evaluate the station recommended dose of 60 kg/ha and test whether small doses of N fertilizer which farmers can afford have any economic significance. Five farmers were selected at Birni-Lafia, Bensekou and Ouake to run the experiment using five levels of N fertilizer. TZB maize could not be used at Birni-Lafia as the season is shorter there.

As illustrated in Figure 5, a small does (15 kg/ha) of Nitrogen at Ouake more than doubled the yield of maize (497 to 1087kg/ha). This was attributed to the relatively low fertility levels and sufficient rainfall as compared to other sites. On the other hand, the very low response to fertilizer at Birnin-Lafia was attributed to low moisture availability which is characteristic of Sudan-Sahel Savanna. At Bensekou, TZB had a better response to fertilizer than local maize; consequently, to increase fertilizer use efficiency, TZB maize should be recommended under such conditions.

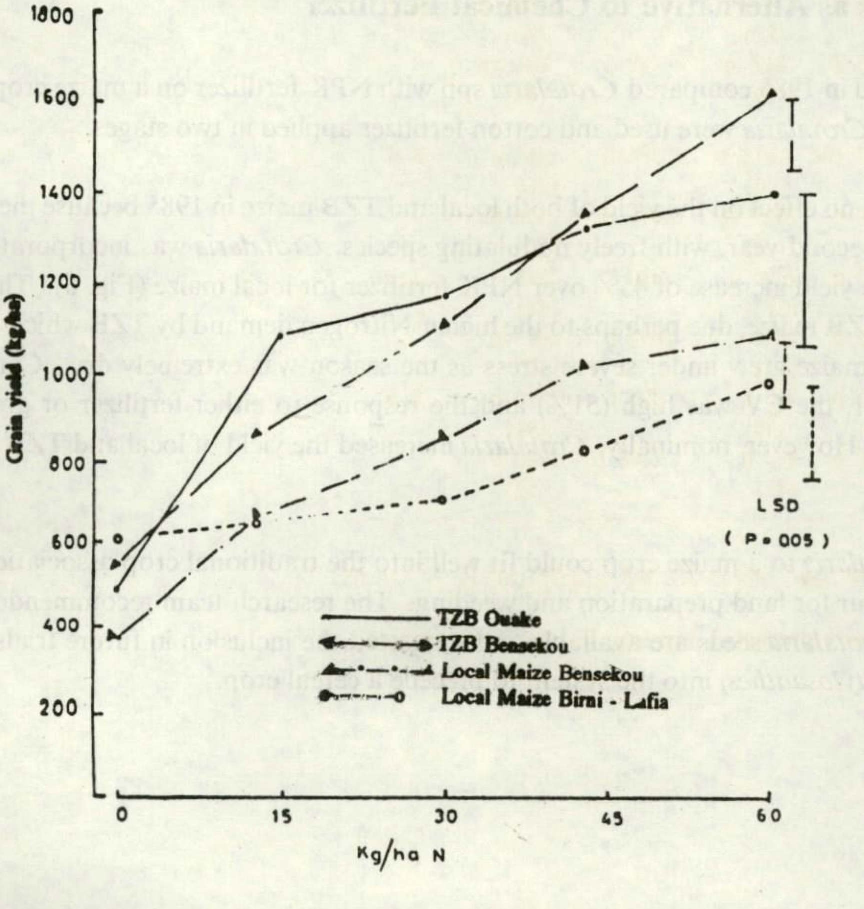

Figure 5: Yield (kg/ha) of maize at varying levels of N-fertilizer at different locations in Northern Benin (on-farm trial), 1987.

From the partial budgets results for TZB maize at Ouake and Bensekou and for local maize at Bensekou the following observations were made (Table 7):

- The treatment resulting in the highest yield (60 kg/ha N) was not the most profitable.

- For local maize, the highest marginal rate of returns (MRR) was 125% at Bensekou for 15 kg/ha N.

- For TZB maize, the highest MRR was secured by application of 30 kg/ha N, although at still higher rates (45 and 60 kg/ha N) MRR was only slightly lower (122 and 120%, respectively). The most profitable dose at Ouake occurred at 15 kg/ha N as the physical yield doubled.

Leguminous Herbs as Alternative to Chemical Fertilizer

A trial initiated in 1985 compared *Crotalaria* spp with NPK fertilizer on a maize crop. In 1986, more nodulating species of *Crotalaria* were used and cotton fertilizer applied in two stages.

Crotalaria had no effect on the yield of both local and TZB maize in 1985 because the species used did not nodulate. In the second year, with freely nodulating species, *Crotalaria* was incorporated at the second weeding, resulting in a yield increase of 45% over NPK fertilizer for local maize (Fig. 6). The fertilizer effect was much higher on TZB maize, due perhaps to the higher Nitrogen demand by TZB which *Crotalaria* could not supply. In 1987, maize grew under severe stress as the season was extremely dry. Consequently, yield performance was poor, the CV was high (51%) and the response to either fertilizer or green manure non significant ($P = 0.05$). However, nominally, *Crotalaria* increased the yield of local and TZB maize by 25 and 13%, respectively.

Adding *Crotalaria* to a maize crop could fit well into the traditional crop association practices as it requires no extra labour for land preparation and weeding. The research team recommended more on-farm tests provided that *Crotalaria* seeds are available and suggested the inclusion in future trials of fast growing forage legumes (e.g. *Stylosanthes*) into the system to precede a cereal crop.

Table 7: Partial budget (x 1000 FCFA) of fertilizer application to local and TZB maize, on-farm experiment, at Bensekou and Ouake, 1987.

Treatment	Yield (kg/ha)	Gross Revenue	Total Var. Cost	Net Benefit	Marg. Rate of return (%)
Bensekou (Local Maize)					
T0*	370	222	0	222	-
T1	670	402	80	322	125
T2	860	516	142	374	84
T3	1040	624	201	423	83
T4	1110	666	263	403	d**
Bensekou (TZB Maize)					
T0	550	330	0	330	-
T1	870	522	89	433	116
T2	1130	678	158	520	127
T3	1380	828	225	603	122
T4	1640	984	296	688	120
Ouake (TZB Maize)					
T0	495	297	0	297	-
T1	1097	658	95	563	280
T2	1190	714	158	556	d
T3	1350	810	225	585	42
T4	1433	860	287	573	d

* : Fertilizer rates in kg N/ha: T0=0, T1=15, T2=30, T3=45, T4=60.

** : d= dominated treatment.

Evaluation of Organic Manure on Sorghum Yield in Atacora

This initial trial (1987) of a planned multiyear experiment* at Ouake and Boukoumbe was intended to evaluate the effects of alternative sources of fertilizer in an area marked by severe soil degradation. The treatments included chemical fertilizer (30 and 60 N), animal manure (5 and 10 t/ha), green manure *(Mucuna)* and crop residues (5 t/ha). There were applied singly and in various combinations, bringing the total number of treatments to eight.

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* Project funding was terminated before the onset of the 1988 - 89 season.

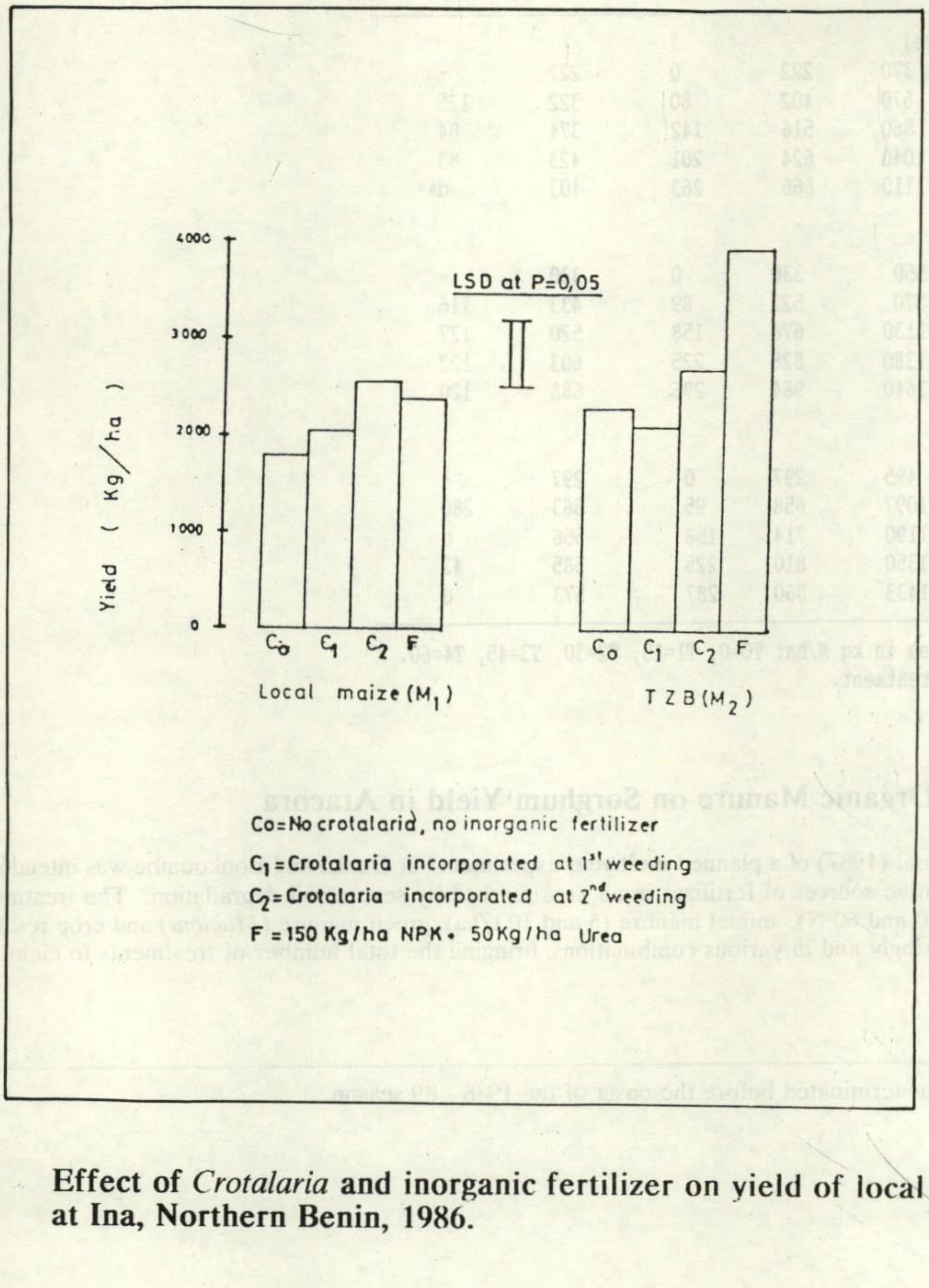

Figure 6: **Effect of *Crotalaria* and inorganic fertilizer on yield of local and TZB maize at Ina, Northern Benin, 1986.**

The most important finding was that at both sites the application of 10 t/ha of animal manure increased sorghum yields by more than 100%. It was also revealed that combining 30 kg/ha N and 5 t/ha of animal manure was as good as the application of 60 kg/ha N. The high response to animal manure needs to be emphasized given the low organic matter content of soils in the area and the farmers' practice of continuous removal of ground cover without returning crop residues into the soils.

The real problem with animal manure is its limited supply. Available quantities are used by farmers on a still limited scale to fertilize the major foodcrop - sorghum. In addition, there is no market for dung in the area, thus making any benefit-cost evaluation at the farm level open to bias, because valuing manure would only be based on the opportunity cost of collecting it. Future research is indeed needed on the economics of manure and soil fertility study for the region.

3.4 Input Use Efficiency in Yam Production

Labour is the major constraint in yam production. Yams are traditionally grown in mounds 0.6 - 1.3 m high and 0.9 - 1.3 m apart and require from 150 - 250 man-days per hectare. Making mounds is time consuming and no equipment has yet been devised to ease the task. On the other hand, if yams could be planted on ridges using animal traction, additional labour could be freed and reinvested in other farm operations thus increasing overall system productivity.

In this respect, trials were conducted at Ina and Sosso stations to compare yields of yams planted on ridges vs mounds. Under **researcher-managed trials** (1986) at two treatments (73. and 7.5 t/ha at Sosso, 11.9 and 11.5 t/ha at Ina). Under **farmer-managed trials** (1987), labour use was monitored on 0.25 ha of land provided by each of the participating farmers who in turn received seeds free of charge. As shown in Table 8, very little variation was recorded in the labour required by operation, which resulted in virtually the same number of man-hours/ha in total labour. The yield of yams on mounds and ridges were, however, largely different - 8.6 and 3.9 t/ha, respectively.

The lower yield under ridging could be explained by the bias introduced by participating farmers in the execution of the test. For example, farmers were convinced beyond doubt that mounding was a better cultural practice than ridging; consequently, plots with ridges were planted and weeded 2 to 3 weeks later. Had the farmers not been biased against ridging, yields under the two treatments might have been the same as suggested by the results from on-station trials in 1986. With this assumption plus the fact that labour to make mounds and ridges was the same, logically economic returns to labour can only be secured if animal traction is used. The research team recommended animal traction to be included in future on-farm tests.

Table 8: Labour requirement (man-hours/ha) for yam production on mounds and ridges, Sosso, 1987.

Operation	Mounds	Ridges	S.E.	CV(%)
1. Land preparation	186.0	180.0	23.1	20.0
2. Planting	117.5	107.5	9.0	12.7
3. Weeding	363.0	379.0	38.9	16.6
4. Harvesting	121.0	119.0	6.4	8.3
Total	787.5	785.5	54.6	11.0

The quantity of yams used as seed under traditional techniques is quite large, sometimes as high as 50% of the farmer's total harvest. In another trial (researcher managed) at Ina, Alafiarou and Sosso (1986 and 1987), the technique developed at IITA as an economic source of yam seeds was tested. Results revealed no significant difference in yields of yams from varying tuber sizes (75, 100, 125 and 150 g/tuber), thus suggesting that smaller cuts can be used without affecting production. On-farm tests were recommended to confirm the results and evaluate profitability.

PROSPECTS FOR INCREASED CROP PRODUCTION AND INCOMES UNDER IMPROVED TECHNICAL OPTIONS

Compared to the southern and most of the central parts of Benin, the northern region has a relatively abundant land resource. It is estimated that only 11 and 7% of total arable land is under cultivation each year in Atacora and Borgou provinces, respectively (CARDER, 1986). Thus in theory it is possible to increase foodcrop production in Northern Benin by bringing more land into cultivation. However, this is not quite simple. Production levels have remained low due to climatic, edaphic and socio-economic constraints discussed earlier. Moreover, improved techniques are needed to open up more land and weed the planted crops.

Production potentials across the three agro-economical zones vary. Northern Guinea Savanna has the highest potential as a result of higher rainfall, a longer growing season and reasonable soil fertility level. However, high labour consuming crops such as yam result in reduced labour productivity. Good soil properties are also noted in the Sudan Savanna where, however, reduced rainfall has become a limiting factor. It is conceivable in these two zones to increase the production of sorghum, yam, maize, groundnut and cowpea (singly or in association) by raising yields per hectare with improved varieties, fertilizer and increased use of animal traction leading to an efficient utilization of family labour. Increases in foodcrop production can be generated without competing with cotton for land, though some competition can be expected for labour.

The shorter growing season, low and erratic rainfall in the Sudan-Sahel result in reduced crop growth, unreliable yields and lower demand for labour. As discussed earlier, technological options in this area include the introduction of drought-tolerant, early-maturing varieties of sorghum, millet and maize, and the adoption of water conservation techniques such as tied-ridging. High population density and continuous cropping which have accentuated soil degradation in Ouake and Boukoumbe call for practices that could improve and maintain soil fertility, in particular, fertilizer and an integrated livestock/animal manure/forage system.

In order to adapt viable options for increasing farmers' crop revenues to varying farming situation, an operational typology of farms was developed. This was based on the SAFGRAD project survey data and the CARDER/Borgou farm monitoring studies (1985 - 87) carried out on a random sample of about 1600 farms. The farm types and their expected changes in incomes for the short-to medium-term are shown in Table 9. The types described are representative only in that they provide modal values of parameters characterizing major cropping systems. They do not indicate in any way the range and multiplicity of crop associations and practices that exist among farmers in the region.

The financial results shown in Table 9 were derived from detailed farm budgets constructed for each farm type. Expected percentage increases in yields are based on results from station and on-farm trials; the change in area planted to main crops was estimated on the basis of the available labour force, adoption or increased use of animal traction and "reasonable expectations". The proposed scenarii assume that the extension services will successfully promote profitable technical packages for food crops as that for cotton is already well established. The four major farm types are briefly enumerated below.

Type I: This category (24% of the farmers south of Borgou) does not grow cotton and uses no animal traction. Farmers are expected to moderately increase maize production (area and yields) through the use of improved seeds, fertilizer and better cultural practices. TZB maize planted in association with local sorghum will increase total grain production. Current levels of net incomes and returns per man-day are expected to increase by 35 and 17%, respectively.

Type II (a,b): The largest category of farmers - (a) - in the south (40%) are manual cotton producers. Improving this system depends heavily on the adoption of animal traction and increased use of fertilizer, improved seeds and better crop association practices. Ridging of yam fields would free significant amounts of labour given their larger holdings of yams. Total net income is expected to rise by 35% and labour productivity by 10%. The remaining 30% of farmers (Type IIb) in the Northern Guinea zone are already using animal traction and planting an average of 1.5 ha to cotton. Following the same trend increase in production will come from expanding maize area.

Type III: This category represents the most successful group of farmers (84% in the Sudan Savanna) with more than 5 ha of cropped land, half of which under cotton. Animal traction has long been adopted, allowing them further increases in areas planted to food crops. Moderate increases in area planted to maize and groundnuts are also expected. Yield increases are expected to follow as farmers invest in additional equipment (oxen-drawn weeders, carts and seeders) and extend the application of cotton fertilizer to cereals. Improved intercropping practices - e.g. TZB + local sorghum - can also be adopted. Total net income and net income per man-day increased by 40 and 17%, respectively.

Type IV: Seventy percent of farmers in the extreme north use animal traction but allocate only 0.6 ha of their total cropped land (4.5 ha) to cotton. This is the poorest area of Northern Benin where farm incomes are generally the lowest. Technical options open to this group include the use of early-maturing, drought-tolerant varieties of sorghum, millet and maize. Tied-ridging and tree/crop associations (alley cropping), although not yet tested on farm represent viable alternative options. As their incomes increase additional traction equipment are purchased leading to further increase in productivity. With these developments, areas under maize, groundnuts and cowpea will increase probably at the expense of sorghum and millet. Expected income increases are, however, small (15 and 10% for total net income and labour productivity).

A comparison of the four types of farms suggests that development efforts should be selectively targeted at farmers comprising types I, IIa and IV. Animal traction and cotton cultivation are highly correlated with higher levels of incomes under the current situation. Indeed, from survey results, the highest proportion of cash income (71%) was generated at Bensekou (Sudan Savanna), where type III farmers are numerically superior. As market conditions for cotton are at present bleak, improving market prospects for cereals and grain legumes in Northern Benin is one of the options available to policy makers.

TABLE 9: EXPECTED INCOME CHANGE IN THE SHORT TO MEDIUM TERM

CHARACTERISTICS	TYPE I Foodcrops, Manual without Cotton	TYPE IIa, IIb* Foodcrops, Manual with Cotton	TYPE III Foodcrops, Animal Tr. with Cotton	TYPE IV Foodcrops, Animal Tr. with Cotton
Agro-ecolog. location	Northern Guinea	Northern Guinea	Sudan Savanna	Sudan-Sahel
% Farms in the zone	24	40	84	73
Total cropped area (ha)	2.8	4.6	5.3	4.3
Labour Force (w.u.)	5.0	6.0	5.0	4.0
Cropping pattern	sorgh/maize (0.9 ha) maize/cassava (0.5 ha) yam (0.9 ha) cassava (0.5 ha)	cotton (1.3 ha) sorghum/maize (1.7 ha) yam (0.6 ha) maize/sorgh/cowpea (0.4 ha) groundnut/maize (0.2 ha)	cotton (2.5 ha) groundnut (0.3 ha) maize pure (0.1 ha) maize/sorgh (0.6 ha) sorgh/cowpea (0.6 ha) sorghum pure (0.6 ha) yam/cowpea (0.3 ha)	sorgh pure (0.4 ha) sorgh/millet (1.2 ha) sorgh/maize (0.4 ha) millet/cowpea (0.1 ha) ground. pure (0.4 ha) cotton (0.6 ha)
Direction of change and** avail, techn. options	-maize area (+25%) -improved seeds, Assoc. TZB + Local Sorghum; fertilizer.	-adoption AT, cotton area (+20%) -yams on ridges (+/-) -improved seeds -fertilizer, TZB	-maize area (+30%) -groundnut area (24%) - new AT.equip.(weeding) -improved seeds, fertilizer TZB + local sorghum.	-maize, groundn. area (+ 15%) -short cycle varieties -tied ridging -new AT equip. (weeding) - agroforestry
Current yields (kg/ha) Expected % Increase	-maize 1015 82% -sorgh. 710 15%	-cotton 1200 20% -maize 1500 20% -cowpea 250 10%	-cotton 2500 10% -maize 1300 54% -cowpea 250 60% -groundnut 20%	-groundnut 600 20% -maize 550 30% -cowpea 150 20%
Current Income (FCFA) Expected % Increase				
- Total net income	198,500 35%	340,000 35%	456,700 40%	145,300 15%
-Income/man-day	615 17%	680 10%	650 17%	480 10%

Notes:* :Type IIb as Type IIa + animal traction; cropped area of 5.3 ha (1.5 ha for cotton). Increases are expected in area of maize and in yield of cotton. They represent 30% of farmers.

**: + = expected increase: +/- = uncertain outcome.

SUMMARY AND PERSPECTIVES

Except for cotton, cropping systems in Northern Benin are predominantly subsistence oriented. Shifting cultivation is still practiced, although large sections of farmers have moved to fallow systems of 3 - 5 years. Permanent cultivation resulting from higher demographic pressure and deforestation has evolved in Ouake and Boukoumbe districts of Atacora.

Major foodcrops in the region are sorghum, yam, maize, groundnuts, cowpea, cassava, millet and beans. More than 50% of the cropped land is under associations. Constraints limiting production include shortage of rainfall and its erratic distribution, particularly in the extreme north, low soil fertility, lack of improved varieties, little or not use of modern inputs and lack of assured market channels for grains.

Unlike most developing countries where research is stronger than extension, the reverse is true for Benin. It was therefore logical for the SAFGRAD research team to focus on researcher-managed trials in 1985 and 1986 in order to generate technologies to be later tested on farmers' fields. Unfortunately, this important phase in FSR development could only be implemented for one year due to lack of resources and the short duration of the project. Nevertheless, there were promising findings and indications are that the following results should be further tested on farm and in pre-extension trials in Northern Benin:

Improved white grain maize (TZB) fits well in the sorghum/maize intercrop when associated with local sorghum. The two crops have compatible growth habits and their total grain yield is higher.

- Ridging and fertilizer application increase the grain yield of sorghum/cowpea association by more than 30%.

- *Crotalaria* spp planted as green manure improves the yield of maize by 45% when incorporated into the soil at the second weeding.

- On poor, degraded soils (Ouake), one fourth to half of the recommended cotton fertilizer boosts yields of maize substantially when rainfall is relatively higher (800 - 1000 mm). A combination of smaller doses of chemical fertilizer (e.g. 30 kg/ha N) with 5 t/ha of animal manure is as good as 60 kg/ha N applied to sorghum.

There is no difference in labour required to plant yams on ridges as opposed to mounds. Using animal traction to construct ridges should reduce labour demand and increase productivity.

The major constraint to increased research output in Northern Benin is the lack of infrastructure and trained personnel at Ina station whose mandate is to serve nearly two thirds of the country's territory. Since important advances in agriculture have to come first from thematic/ commodity research, clear priorities need to be set. The limited research resources should be efficiently utilized by concentrating on relevant themes and a few important crops. For example, for sorghum, bulk selection of local materials and a vigorous effort to introduce a wide range of improved lines for local adaptation; proposals recently made to pursue a programme for creating synthetic varieties by tissue culture are obviously farfetched and unrealistic. Refinement of fertilizer doses for legumes, continued search for improved, early-maturing varieties for the extreme north and intensification of crop associations are among feasible priorities for Ina station. Research on maize could well fit in the mandate of the southern foodcrops station (Niaouli). Production techniques for yams to increase labour use efficiency should also be higher on the agenda because Ina is within the West Africa yam belt and yam is an important stable food in the region.

Since cropping systems are diverse in Northern Benin, stratification of the farming population into foodcrops, animal traction, cotton cultivation groups as suggested above is useful in that it can permit a selective and efficient approach in dispensing development and extension efforts by targeting the most disadvantaged groups (non-cotton, manual farmers in Northern Guinea zone and the majority of small farmers in the extreme north). With gloomy prospects in the international markets, the after cotton era needs to be prepared now by redirecting efforts to the improvement of market infrastructure for cereals and grain legumes.

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PART III

LIVESTOCK AND AGROFORESTRY IN FARMING SYSTEMS

THE ROLE OF LIVESTOCK - BASED SYSTEMS FOR DEVELOPING SUSTAINABLE FOOD PRODUCTION IN THE SUBHUMID ZONE OF AFRICA

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ABSTRACT

The poor quality of the available feed has been identified as the main constraint on ruminant productivity in the subhumid zone. The origin of the inadequate nutrition is the poor nature of the prevailing soils which is felt equallly by arable farmers. Since it is the farmers and not the livestock owners who own the land no intervention will be widely effective for sustained livestock production if it is not mutually beneficial to cropping. The International Livestock Centre for Africa (ILCA), in collaboration with national research and development agencies, has conducted research on introducing forage legumes into the traditional farming and the livestock hushandry systems so as to improve the quality of the feed available to ruminants and promote sustainable improvements in crop yields. The impact of forage legume technology on ruminant productivity, crop yields and crop-livestock interactions are highlighted.

Although most of the research used as a basis for this paper was conducted in the subhmid zone of Nigeria the concepts could be applied to the semi-arid tropics with little or no modification.

INTRODUCTION

Livestock-based systems contribute directly or indirectly to food production and income generation. Meat and milk are taken directly as food while manure and traction play a vital role in sustaining the ecosystem on which future production depends. ILCA's task is to increase the outputs of these commodities so as to improve the quality of life of the people in Sub-Saharan Africa (ILCA, 1987).

As long as national food production is dependent on traditional peasant type agriculture the growing demands of increasing human populations can only be met by expanding the area under cultivation and increasing the number of livestock. In Nigeria, despite very intensive cultivation in the North and South there are still vast areas in the subhumid zone that are under-exploited. This is because of the low quality of the soil and vegetation, leading to poor returns to labour from cropping and low levels of ruminant productivity. The prevalence of trypanosomiasis also affected animal health. This situation is now changing as farmers and cattle owners are rapidly occupying the zone because of the rapid decline in tsetse challenge (Bourn, 1983).

In the long term such immigration and expansion of local populations will lead to competition for resources between cultivators and herders because they belong to different ethnic groups and their systems of production are not presently well integrated. Certainly, the cattle graze the crop residues after harvesting and deposit some manure; the cultivators buy meat and milk products from the herders. These interactions do not, however, constitute truly integrated systems and there are negative trends. The farmers are expanding maize production which, because it matures early and deteriorates fast, has a negative effect on the quality of crop residues available for grazing. There is a tendency to prefer chemical fertilizer because there is a limited quantity of manure; also the manure imports weed seeds to the fields and trampling by cattle tends to produce surface capping of the soils (Powell, 1986).

Even when cultivators own cattle they tend to run the enterprises entirely separately (Kjenstad, 1987); there is no animal traction and no deliberate effort has been made to produce forages.

In this situation there are two prerequisites to sustainable systems that will meet the growing food demands: increased animal productivity and increased mutuality between livestock and cropping systems.

II. LIVESTOCK SYSTEMS RESEARCH CASE STUDY

In order to promote sustainable enterprises ILCA is conducting research in a systems context with the objective of encouraging the integration of crop-livestock systems.

A multidisciplinary team of scientists was established in the subhumid zone of Nigeria in 1978 and encompassed the three phases of Livestock Systems Research (von Kaufmann, 1987). These are:

1) Description of farming systems and diagnosis of the problems.

2) Development of appropriate techniques through on-station and on-farm trials to alleviate constraints.

3) Extension of results and monitoring of impact.

In compliance with the above steps, ILCA'S research commenced with ground surveys, descriptive studies on crop/livestock systems and a state of knowledge symposium (ILCA, 1979). Results from all these approaches showed that disease, poor nutrition and land tenure were the main constraints affecting the livestock industry in the subhumid zone. The most serious cattle diseases such as rinderpest and contagious bovine pleuro-pneumonia can be fairly well controlled with available techniques. The land tenure issues tend to be site specific and highly political and therefore, not appropriate for an international research organization. ILCA therefore considered maluntrition especially in the dry season as the most appropriate topic for research.

Productivity monitoring of traditionally managed herds in the drastic weight losses (15-20%), high calf mortalities (30%) and low fecundity (Mani *et al.*, 1988). The natural vegetation has an inadequate crude protein content for most of the year. During the six months dry period it averages 3% crude protein.

The poor quality of the herbage stems from the poor nature of the ferruginous tropical soils which cover 50% of the subhumid region. They have low cation exchange capacity, poor water retention and low nutrient reserves. They are also short of soil organic matter and are prone to compaction and accelerated erosion (Adeoye *et al.,* 1988). The presence of a hard pan in the subsoil restricts root development and encourages waterlogging (Tarawali and Mohamed-Saleem, 1987). These features force the farmers to grow crops on laboriously prepared ridges so that plant roots are not exposed to water logging. The yields per ha and per man hour are very low. For instance average grain yield of crops recorded from farmers fields were 1,800, 1,420 and 700 kg/ha for maize, sorghum and millet respectively (Powell, 1984).

Although this workshop is directed to the semi-arid tropics, most of the results that will be presented in this paper are derived from research conducted in the subhumid zone of Nigeria. The authors believe, on evidence from Australia and else where, that most of the principles should be applicable with little modification to the semi-arid zone.

The subhumid zone site is based at Kaduna, Nigeria and is characterized by 900-1,500 mm annual rainfall and a growing period of 180- 270 days. The subhumid zone occupies 22% of sub-saharan Africa and has almost 60 million people and 70 million ruminant livestock.

III. INTRODUCTION OF FORAGE LEGUMES

The introduction of forage legumes (*Stylosanthes* pastures) into the cropping and fallow systems was considered the best option for increasing the nutritive value of the available herbage and for improving soil fertility thereby promoting mutuality between livestock keeping and cropping. This is because leguminous plants such as *stylosanthes* can maintain a crude protein content of over 8% in the dry season and the associated rhizobia can fix soil nitrogen.

Since at the present time, labour and not land is the primary limiting constraint, the adoptability of the intervention depends on minimzing the labour requirements for the establishment, management and utilization of these improved pastures. It is also necessary to avoid dependence on machinery that is not available to the vast majority of small scale farmers and herders. Various low input techniques have therefore been developed for establishing small strategic pastures (fodder banks for dry season feed supplementation; these techniques are described below (Otsyina *et al.* 1987):

(1) Select a fallow area (4 ha or more) close to the homestead

(2) Prepare seedbed by confining herd overnight.

(3) Broadcast scarified seeds mixed with single superphosphate (150kg/ha).

(4) Control fast growing grasses by early season grazing.

(5) Leave the forage to bulk up until the dry season.

(6) Select 15-20 pregnant or lactating cows to graze fodder bank for 2-3 hours a day.

(7) Enhance stylo regeneration in the following season by ensuring sufficient seed drop and adequate stubble.

Another method of establishing a fodder bank by undersowing cereal crops is described by Mohamed-Saleem (1985). This exploits the land preparation done for cropping in the years of rotations before the land is left fallow. When undersowing sorghum with *stylosanthes* it is necessary to sow the legume between 3 to 6 weeks after planting the sorghum in order to reduce competition between the two species. Maize is less susceptible to competition because of its rapid growth so the present deleterious effect on livestock production by expanded maize acreages could be turned to good advantage. The under-storey of stylo will increase the quality of the succeeding crop residue and will also improve soil fertility faster than a natural fallow.

The fodder bank and undersowing concepts have been tested under on- station and on-farm conditions by ILCA and have now been taken up by Nigeria national development agencies for further testing and extension to livestock owners.

IV. IMPACT OF FORAGE LEGUMES ON LIVESTOCK PRODUCTIVITY

On-farm trials conducted to study the performance of agro-pastoral herds with and without access to fodder showed that herds with access to fodder banks were more productive, particularly due to increased calf survival (Table 1: Mani *et al.*, 1988).

Table 1. Performance of herds with and without access to fodder banks.

Character	Non Suspplemented	Supplemented	Improvement (%)
Cow survival (%)	92.2	96.0	4.1
Calving percentage (%)	53.8	58.1	8.0
Calf survival (%)	71.8	86.3	20.2
Calf weight at 1 yr (kg)	98.1	103.4	5.4
Lactation milked out yield (kg)	300.2	312.5	4.1
Productivity index* per Cow per year (kg)	51.5	69.1	34.2

*: Total of 1 year old calf plus liveweight equivalent of milk produced.

Similarly, in comparing the liveweight changes of adult goats tethered on fallow land with those grazed on fenced natural pasture or fenced forage legumes pastures (mini fodder banks) it was concluded that goats allowed to graze forage legumes performed better than those tethered or grazing freely on natural pasture (des Bordes *et. al.*, unpublished). The superior performance of the animals on the fodder banks is attributed to the higher nutritive value of the forage legume (Figure 1).

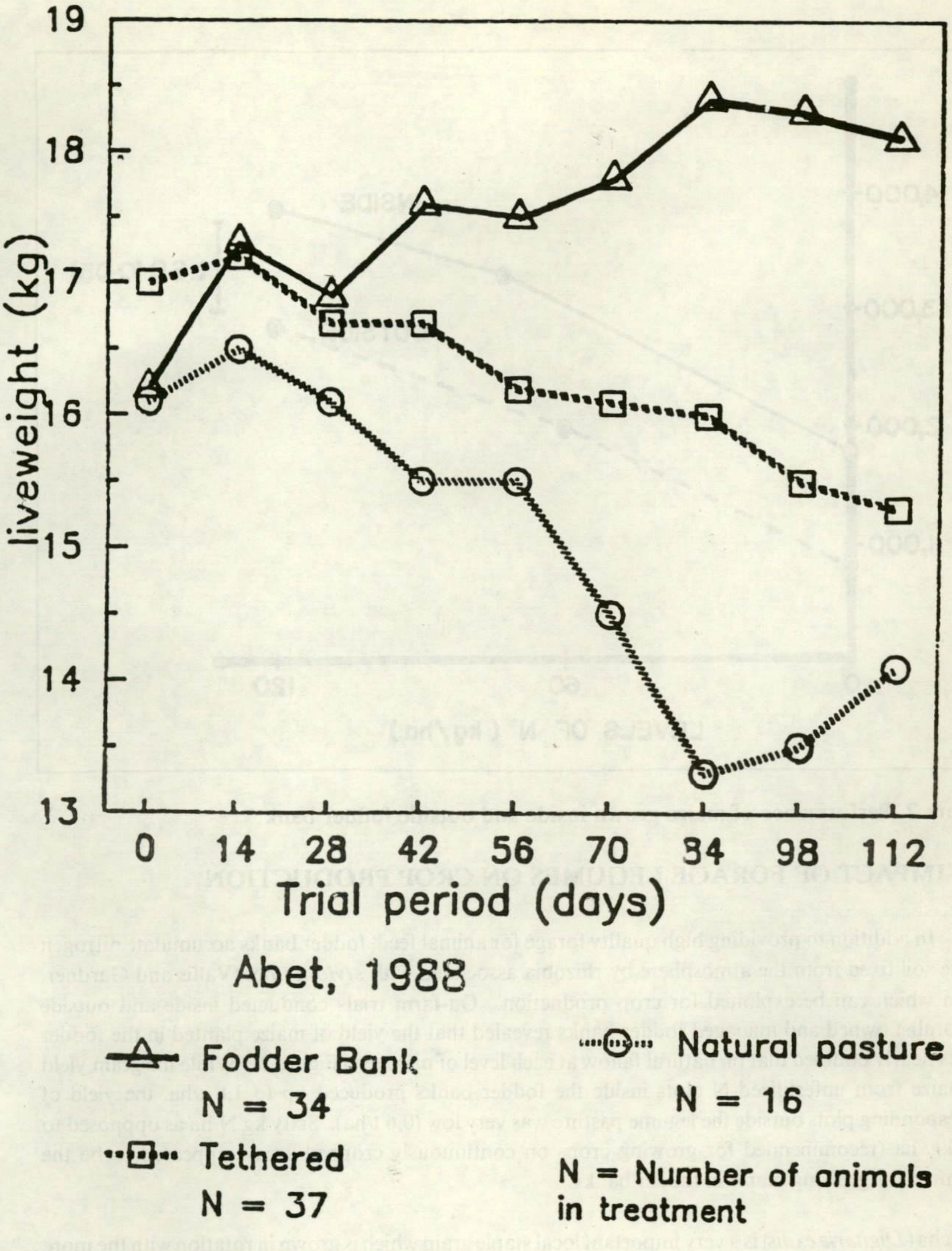


Figure 1. A comparison of weight changes of adult goats under different management conditions. Abet, 1988.

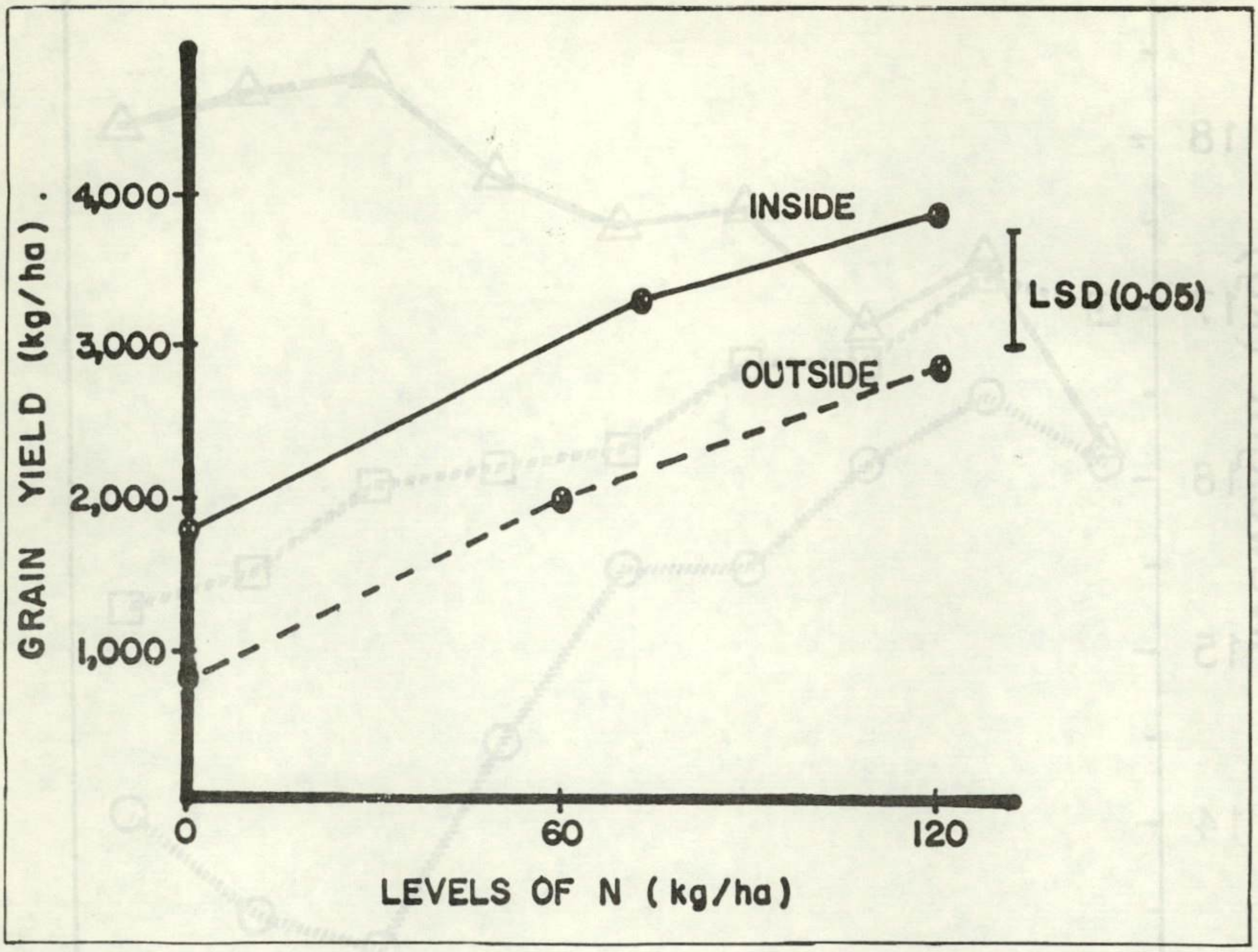


Figure 2. Performance of maize grown inside and outside fodder bank.

V. IMPACT OF FORAGE LEGUMES ON CROP PRODUCTION

In addition to providing high quality forage for animal feed, fodder banks accumulate nitrogen in the soil fixed from the atmosphere by rhizobia associated with *stylosanthes* (Vallis and Gardner, 1984) which can be exploited for crop production. On-farm trials conducted inside and outside pastoralist owned and managed fodder banks revealed that the yield of maize planted in the fodder banks nearly doubled that on natural fallow at each level of nitrogen (Figure 2). While the grain yield of maize from unfertilized-N plots inside the fodder banks produced up to 1.8 t/ha, the yield of corresponding plots outside the legume pasture was very low (0.6 t/ha). Sixty kg N/ha as oppposed to 120 kg//ha (recommended for growing crops on continuously cropped areas) appeared to be the optimum for growing maize in fodder banks.

Acha (*Digitaria exilis*) is a very important local staple grain which is grown in rotation with the more demanding cereals because of its low requirement for mineral nutrients. The highest grain yields for this crop have been achieved inside fodder banks with no N applied at all whereas 40- 60 kg N/ha was required to produce a reasonable yield of acha outside the stylo area (Figure 3).

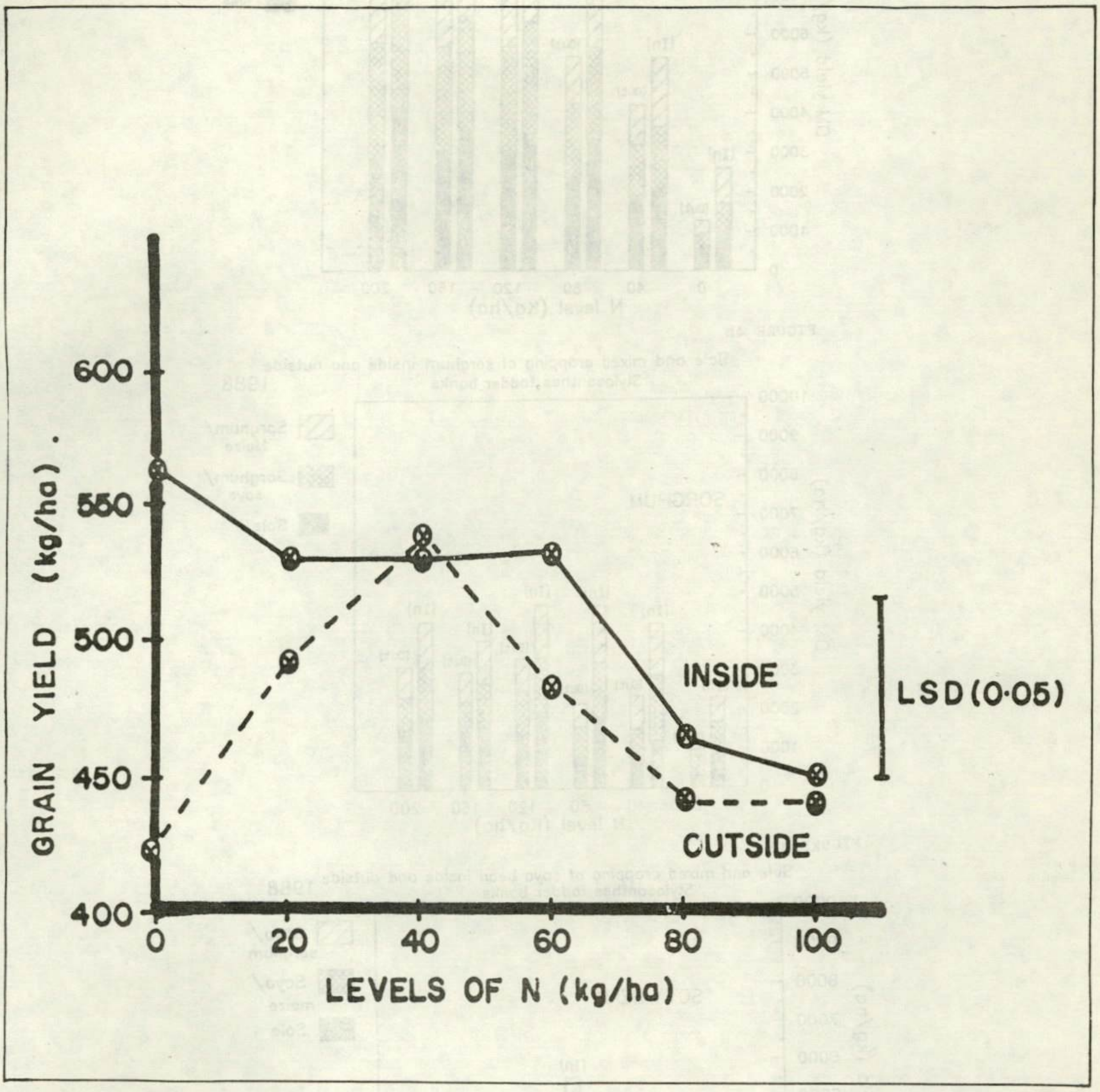
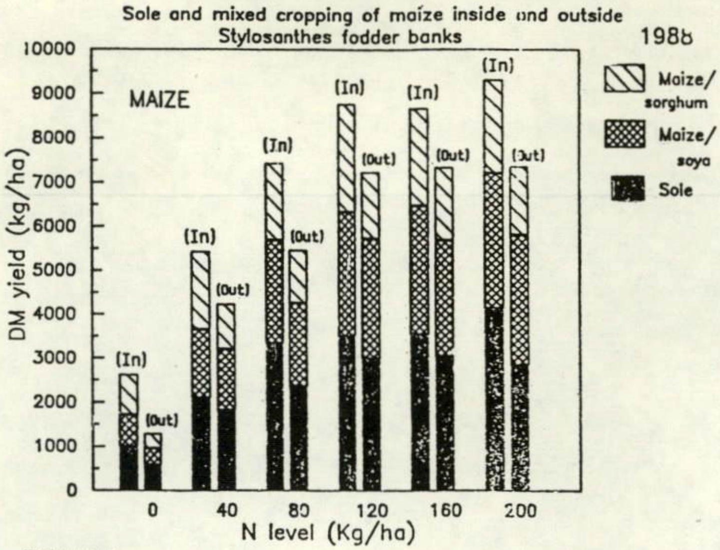


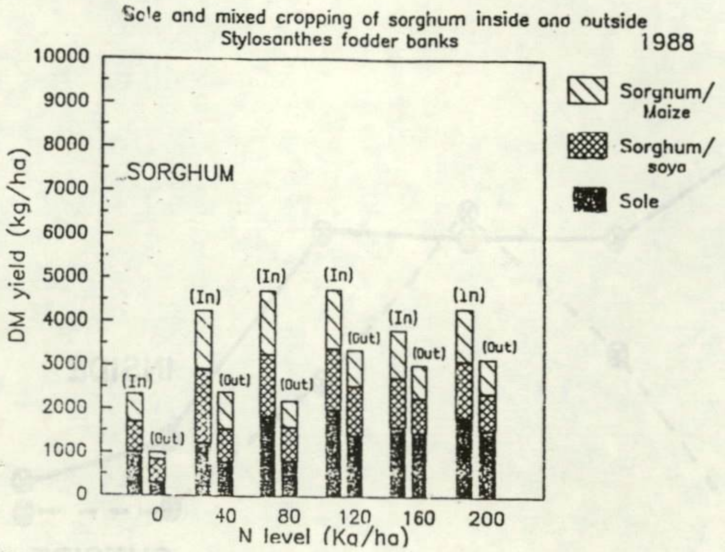
Figure 3. Performance of acha grown inside and outside fodder bank.

The three main crops of the region (maize, sorghum and soyabean) were tested inside and outside *Stylosanthes* pasturres using various crop combinations and levels of nitrogen. The crops sown in fodder banks outyielded those on natural fallow (Figures 4a, 4b and 4c).



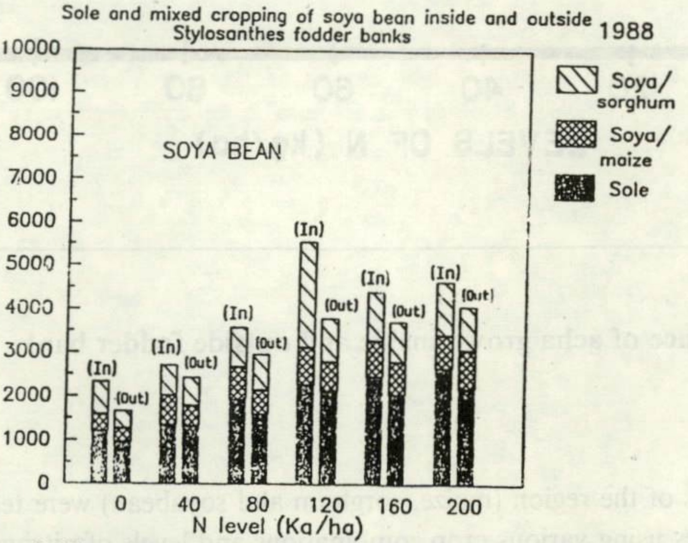
Sole and mixed cropping of maize inside and outside Stylosanthes fodder banks

FIGURE 4b



Sole and mixed cropping of sorghum inside and outside Stylosanthes fodder banks

FIGURE 4c



Sole and mixed cropping of soya bean inside and outside Stylosanthes fodder banks

Figure 4. **Dry matter yields of (a) maize, (b) sorghum and (c) soyabean grown in sole and mixed cropping inside and outside *Stylosanthes* fodder banks.**

Maize depressed soyabean growth far more than sorghum indicating that soyabean/sorghum is the most compatible mixture for inter -croppin. In the maize/sorghum combination, the individual yield of each cereal was reduced, mainly due to a reduction in total plant popuation and competition between the two species. This effect was,however, moderate in the crops planted inside the fodder banks. Maize was the most responsive crop to soil N and soyabean, being a legume, naturally the least.

The superior yield of the crops grown inside the stylo-based pasture over those planted on natural vegetation is due not only to the increased N but also to improved physical and chemical characteristics of the soil such as reduced bulk density, improved water infiltration rates, increased organic matter and cation exchange capacity, etc. (Mohamed-Saleem and Otsyina, 1986).

VI. FURTHER RESEARCH

The above set of techniques is by no means the final package and research is continuing particularly on problems revealed as the innovation is adopted by farmers with different production systems and in different ecological circumstances. Feedback from the extension services is a vital ingredient in this process.

1. Labour Requirements for Cropping Fodder Banks

In introducing legume-based cropping to the farming systems, some of the participants recruited for the trials predicted that stylo soil would be more difficult to till than land that had been under natural vegetation.

Informal surveys revealed that the cultivators were referring to stylo that had been used for soil reclamation and was allowed to become woody. In order to clarify this allegation, component research was carried out to determine the labour requirement for cropping maize inside and outside fodder banks. Results (Figure 5) showed that land that had been under the legume was easier to ridge (Tarawali *et al.*, 1987). The total time taken to cultivate stylo-based soils was, however, higher than that for non-styl soils but this was due to extra time spent in harvesting the extra grain yield from the crop inside the fodder banks.

2. Nitrophilous Grasses and Termite Infestation

The high level of soil N and organic matter typically found in 2- 3 year old stylo pastures attract nitrophilous grasses and termites. These intruders reduce forage quality, soil N, organic matter and even stylo productivity. In order to examine the extent of the damage caused by the weeds a study was conducted to determine the effect of grass density on the performance of stylo. It was shown that increasing grass population from 0 -100% decreased stylo productivity, N-contributed by the legume and the grain yieldof a subsequent maize crop (Table 2). In order to flush out excess nitrogen and destroy termite mounds, agropastoralists are advised to crop part of their fodder banks periodically (rotational cropping). This will discourage the growth of nitrophilous grasses in favour of the legume.

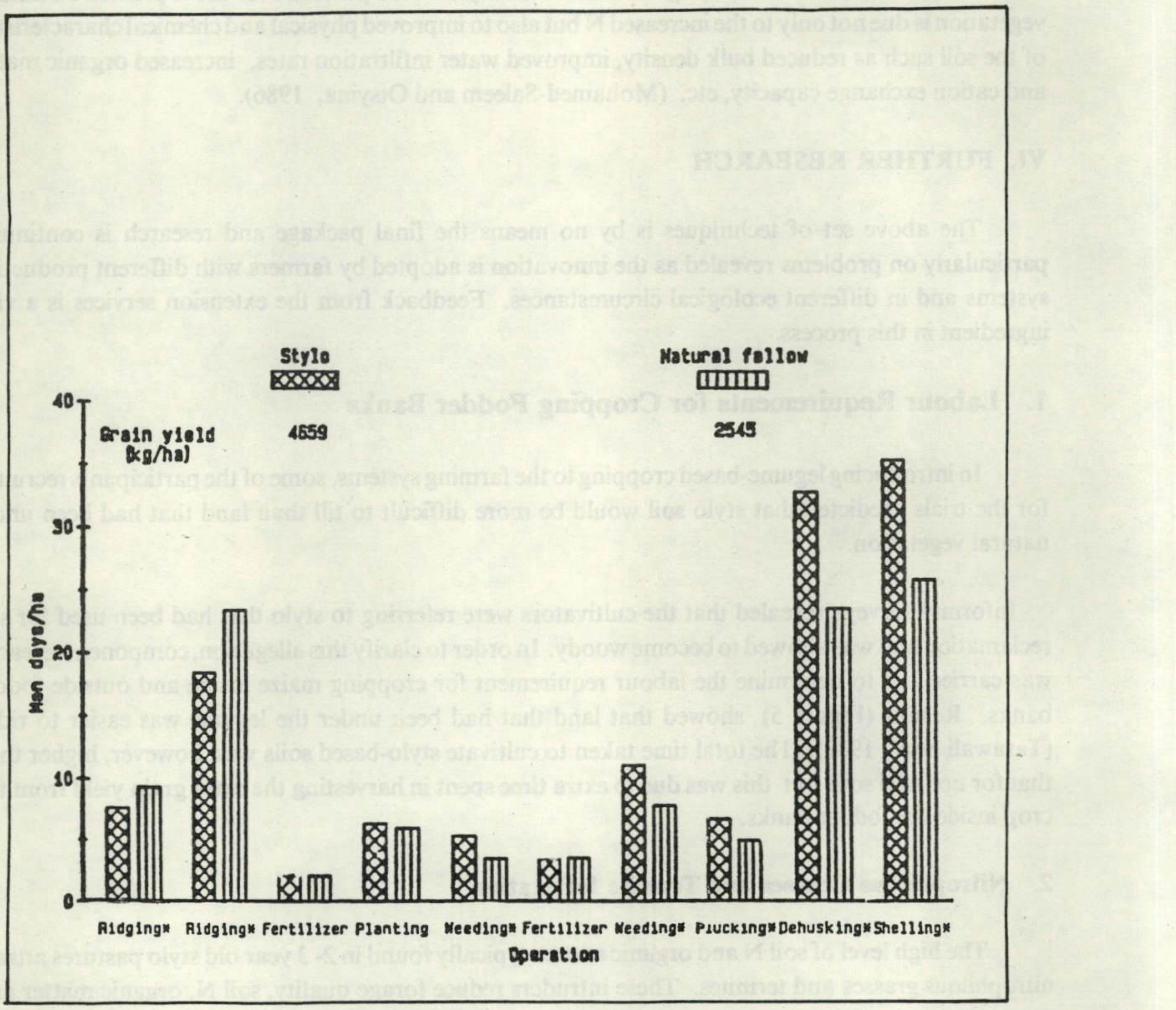


Figure 5. Labour requirement for cropping maize on stylo and natural fallow soil.

Table 2. Effect of grass density on stylo productivity, soil N and grain yield of subsequent maize crop.

Grass Density (%)	Stylo Productivity (Kg/ha)	Soil N (%)	Grain Yield (Kg/ha)
0	8549 a	0.0702 a	1387 a
25	5120 b	0.0660 ab	1058 b
50	4220 b	0.0647 a	775 bc
75	2423 c	0.0630 b	661 d
100	-	0.0570 c	220 d

Means followed by the same letter do not differ significantly (P <0.05). Source: G. Tarawali, unpublished.

3. Stylo Regeneration in Cropped Areas Within Fodder Banks

Farmers were concerned that practicing rotational cropping within fodder banks would affect stylo regeneration. A study conducted to determine the effect of cropping on stylo productivity, seedling population and botanical composition showed that cultivating soil preceded by *Stylosanthes* pastures led to a decline in legume seedlings. However, this did not affect the productivity of the succeeding herbage (Table 3). Cropping stylo-based pasture also increased the legume component in the sward whereas in the uncropped portion stylo was generally being replaced by grasses.

Table 3. Effect of cropping on stylo productivity, seedling population and botanical composition of fodder banks.

Land History	Stylo Seedlings per m2	Productivity of Sward (Kg/ha)	Crude Protein (Kg/ha)	Botanical Composition Stylo (%)	Grasses (%)	Forbs (%)
Uncropped	106 a	5567 a	260.4 b	43.0	39.0	18.0
Cropped for One year	75 a	5452 a	385.2 ab	58.0	23.0	19.0
Cropped for Two years	67 a	6182 a	417.6 a	56.0	26.0	18.0

Means followed by the same letter do not differ significantly (P<0.05). Source: G.Tarawali, unpublished.

4. Land Tenure

In most of Nigeria, cattle owners do not have land rights. The land belongs to arable farmers who have no interest in cattle production (only small ruminants) and are sometimes very reluctant in giving their unused fallow land to pastoralists for pasture development. This land tenure constraint affected the rate of adoption of fodder banks and for the intervention to continue to expand, it must, therefore, also be beneficial to arable farmers. To encourage this, field days demonstrating the beneficial effects of legume-based cropping and the use of *Stylosanthes* pastures for small ruminant and cattle production were organized for both arable farmers and agro-pastoralists. These demonstrations led to spontaneous adoption of the fodder bank intervention by farmers (landowners) in order to improve the soil fertility in their fallow areas and the quality of feed for small ruminants.

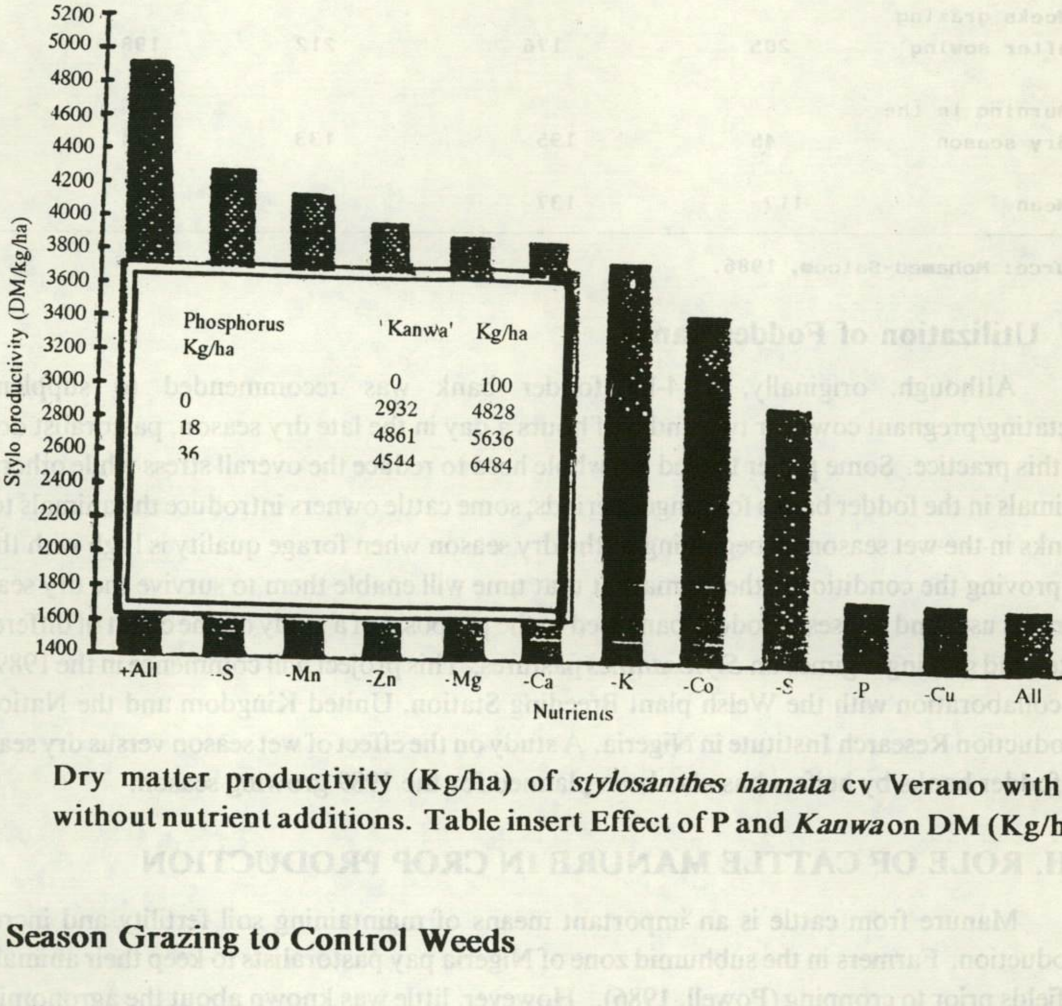
5. Greater Choice of Forage Species

Originally, three stylo species (*S. gamata* cv Verano, *S. guianensis* cv cook and *S. guianensis* cv Schofield) were used in fodder banks. Cook and particularly Schofield are susceptible to anthracnose (a disease caused by a fungus of the genus *Colletotrichum*) meaning that the fodder bank intervention is now virtually relying on one species, Verano (Tarawali, 1989). However, screening trials in various ecological zones have identified other species that may be used in place of Verano.

The best accessions in dry areas such as Maiduguri, 453 mm rainfall, are *Centrosoma pascuorum, Cassia rotundifolia* and *Lablab purpureus.* For wetter areas such as Jos and Makurdi, 1300 mm rainfall, *Stylosanthes scabra* and *Centrosoma brasilianum* are the most promising. Verano grew best at Bauchi, 780 mm (S.A. Tarawali, unpublished).

6. Increasing Herbage Productivity of *S. hamata* in Subhumid zone

The dry matter yield of Verano used in fodder banks is very low (4-5t/ha) compared to other places of similar climatic conditions (7-10 t/ha). A nutrient omission trial conducted on soils from different locations has shown that P an Cu are frequently deficient and this restricts the growth of the legume (Mohamed-Saleem *et al.,* 1986; Figure 6). This can be combated by the appropriate minerals with N-P-K fertilizer. An indication of the potential effects was shown in ILCA trials with *Kanwa* (a locally mined evaporite, usually used as a salt stick for cattle and containing a wide range of mineral elements). This salt increased the yield of stylo (Mohamed-Saleem and Otsyina, 1987) and the response was attributed to the minerals in *Kanwa,* mainly calcium and minor elements such as copper, iron, manganese and zinc.



Phosphorus Kg/ha	'Kanwa' Kg/ha 0	100
0	2932	4828
18	4861	5636
36	4544	6484

Figure 6. Dry matter productivity (Kg/ha) of *stylosanthes hamata* cv Verano with or without nutrient additions. Table insert Effect of P and *Kanwa* on DM (Kg/ha).

7. Early Season Grazing to Control Weeds

Pastoralists have objected to allowing their cattle to graze grasses where animals have been corralled for fear of worm infestation from the dung. The need to corral the animals to prepare seed bed can be circumvented by various land preparation techniques for the establishment of fodder banks (Table 4). It is possible to protect the stylo seed from insect damage or being washed away by coating in slurry or insecticide. Treating the grazing for 2 weeks after sowing enhanced seedling establishment.

Table 4. Effect of land preparation and seed dressing on stylo seedlings (6 weeks after planting).

Method of land preparation	Seed treatments (seedling/m2)			
	Mixed with Sand	Mixed with dung slurry	Insecticide dressing	Mean
1 Week overnight Confinement of herd	150	76	167	131
2 Weeks grazing before sowing	69	99	67	78
2 Weeks grazing after sowing	205	176	212	198
Burning in the dry season	45	195	133	124
Mean	117	137	145	-

Source: Mohamed-Saleem, 1986.

8. Utilization of Fodder Banks

Although, originally, a 4-ha fodder bank was recommended to supplement 15-20 lactating/pregnant cows for two and half hours a day in the late dry season, pastoralist do not adhere to this practice. Some prefer to feed the whole herd to reduce the overall stress while others leave their animals in the fodder banks for longer periods; some cattle owners introduce the animals to the fodder banks in the wet season or beginning of the dry season when forage quality is high with the hope that improving the condition ofthe animals at that time will enable them to survive the dry season. These various uses and abuses of fodder banks led to the proposal of a study on the effect of different stocking rates and grazing regimes on *Stylosanthes* pastures. This project will commence in the 1989 wet season in collaboration with the Welsh plant Breeding Station, United Kingdom and the National Animal Production Research Institute in Nigeria. A study on the effect of wet season versus dry season grazing of fodder banks by heifers has also been planned for the 1989 growing season.

VII. ROLE OF CATTLE MANURE IN CROP PRODUCTION

Manure from cattle is an important means of maintaining soil fertility and increasing crop production. Farmers in the subhumid zone of Nigeria pay pastoralists to keep their animals overnight in fields prior to cropping (Powell, 1986). However, little was known about the agronomic aspects of manure in traditional farming systems. On-farm trials were therefore conducted to determine the contribution of manure to cereal production and soil properties and to identify problems associated with its use. Results have shown that maize grown on manured plots at various levels of N outyielded that on non-manured plots (Figure 7). In Abet, one of ILCA's case study areas in the subhumid zone of Nigeria, manured plots are usually used for ginger cultivation (a major cash crop) and sales from this crop usually brings a high rate of return to farmers (Table 5, based on 1985 data). The yield superiority shown by crops planted on manured plots was attributed to the fact that manuring improved soil properties (Table 6).

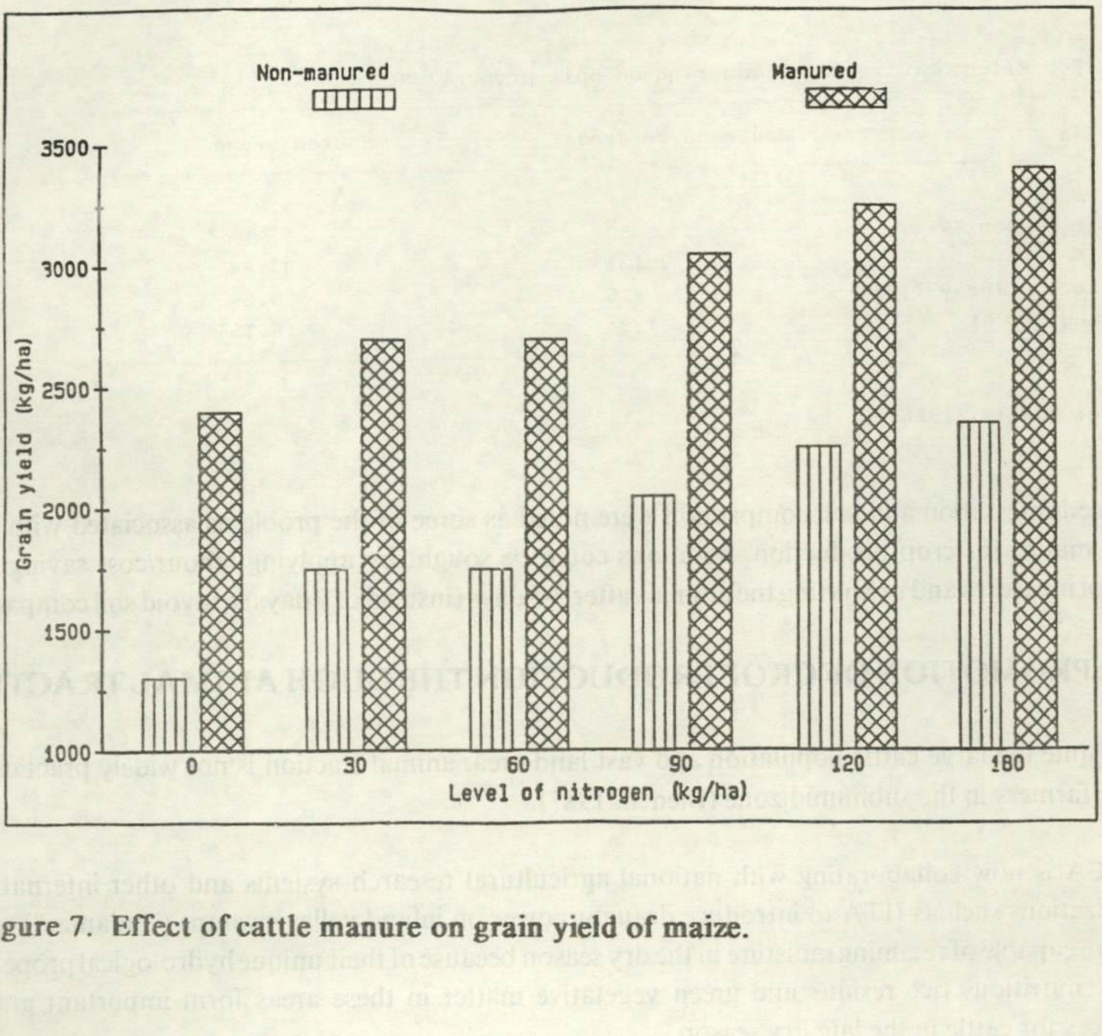


Figure 7. Effect of cattle manure on grain yield of maize.

Table 5: Manured areas, payments made and cash derived from manuring in Abet (n= 8 farmers).

Factor	Mean	Standard Deviation	Range
Plot size (ha)	0.08	0.04	0.04 - 0.16
Payment (Naira)	34	30	18 - 170
Gineger sales (Naira)	920	610	540 - 2400

One Naira = 1.33 dollars (1985). Source: Powell, 1986.

Table 6: Effect of overnight manuring on soil properties

Property	Non-manured areas	Manured areas
pH	5.1	5.8
Organic carbon (%)	5.50	1.91
Total N (%)	0.131	0.164
Available P (Bray-1,ppm)	4.6	9.6
CEC (meq/100 g)	4.34	6.15

Source: Powell, 1986.

Weed infestation and soil compaction were noted as some of the problems associated with using cattle maure for crop production. Solutions could be sought by applying labour/cost saving weed control measures and by shifting the animals after 2-3 days (instead of 7 days) to avoid soil compaction.

VIII. PROMOTION OF CROP PRODUCTION THROUGH ANIMAL TRACTION

Despite the large cattle population and vast land area, animal traction is not widely practiced by arable farmers in the subhumid zone (Blench, 1987).

ILCA is now collaborating with national agricultural research systems and other international organizations such as IITA to introduce draught power on inland valley swamps ("fadamas") where soils are capable of retaining moisture in the dry season because of their unique hydrological properties. Highly nutritious rice residue and green vegetative matter in these areas form important grazing resources for cattle in the late dry season.

"Fadamas" are under-utilized in the subhumid zone mainly because of labour shortage. Priority given to time-bound operations for upland crops at the beginning of the rainy season (April/May) gives very little time for manual land preparation in "fadamas" before the rice crop is planted in June. If the labour constraint could be overcome by using draught animals two crops (instead of one) could be grown annually. Also forage legumes could be grown in association with the second rice crop to increase the quality of the succeeding crop residue.

IX. CONCLUSION

Research in a livestock systems perspective has led to the development of appropriate technologies through careful consideration of the needs of farmers. Demonstration of the mutuality for livestock and crop production through forage legumes is vital in enhancing the incorporation of legumes into the farming systems.

A preliminary assesssment of potential fodder production and animal support capacities in 10 West African countries by Mohamed-Saleem, *et al.* (1988) has indicated that stylo production on 3% of the suitable land of the subhumid and 35% of the semi-arid zones would provide adequate dry season supplementation for all the cattle in the respective zones. While they acknowledge a wide concern about misuse and over exploitation of land resources they are worried that opportunities to reverse the trends are not widely understood. They cite "an inability to match the land resources with the requirements of food and fodder" as major source of misuse. This paper has examined some opportunities for tackling such problems of land misuse using sustainable systems of crop and livestock production.

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THE ROLE OF FORAGE AND DUAL PURPOSE LEGUMES IN LINKING RUMINANT ANIMAL AND CROP PRODUCTION SYSTEMS

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ABSTRACT

The coexistence and interrelated functions of crop and animal systems have allowed continuity of relatively stable production in the sudanian zone. Many constraints are involved in the production systems. Only those constraints associated with the physical, chemical and biological functions of the soil-crop-animal systems are discussed and these are the low availability of: (a) soil moisture, (b) soil nutrients, and (c) feed nutrients.

In view of the dwindling resources to overcome these constraints the search for the conditions that will increase the availability of resources not from outside but within the system is an urgent task. Nitrogen being the most limiting nutrient involved in the biological functions of soil microbes, crops and ruminant animals it is considered to be the common constituent that could link the above components. Forage or dual purpose legumes could make substantial contribution towards this, and strengthening of the integration of crops and ruminants, leading to intensification of the production system.

This paper is divided into two general sections. Section one attempts to pull together available information on the contribution of legumes towards increasing and maintaining soil and crop productivity. Section two deals with the potential of the legumes in increasing the supply of ruminants under the nutritional conditions of the sudanian zone.

1. INTRODUCTION

In Burkina Faso, crop and animal production systems are not mutually exclusive but intimately bound, with the degree of emphasis on each component varying according to the climatic zone. The share of livestock in agriculture amounts to 49.2% of the total export of the country (ECA,1985), indicating the equally important role ruminant animals play in the livelihood of the people.

The overall productivity of cereals, although appears to show some stability in yield, is very low being in the order of 300 to 350 kg grain/ha (Van Staveren and Stoop, 1985). Due to this low productivity in yield per unit area accompanied by progressively increasing requirement for food grain, the farmers are cultivating more land at the expense of fallowing and grazing pasture to ruminant animals.

Besides the generally increasing trend in the population of ruminants there seems to be a shift in their distribution too, with heavy concentration being observed in the heavily cropped sudanian Sahel, and may be looked at in relation to the practice of transhumance. However, the heavy concentration of ruminants in the sudanian zone appears to be linked to the availability of cereal crop residues which have become partial substitute for natural pasture. This probably is also coupled with the availability of water catchments, the majority of which are in the sudanian zone (OECD/CILSS, 1986). Over all, the pressure of agriculture on the Sudanian zone becoming very intense is visible.

As a result of this, the two biological functions, crop and animal production, in the main appear to manifest a certain degree of conflict for both required land, manpower and other resources. On the other hand, it is also clearly manifested that the two systems are promoting each other. It is this latter aspect that needs to be seized if the fulfillment of the objectives is to be achieved. This paper attempts to show the technical opportunities that exist to attain effective integration of crops and ruminants through forage or dual purpose legumes.

II. FORAGE/DUAL PURPOSE LEGUMES FOR PARTIAL ALLEVIATION OF THE BIOLOGICAL CONSTRAINTS OF CROP - ANIMAL PRODUCTION SYSTEMS

Recognizing the existence of many and various forms of connections in the soil-crop-animal system, only those that are directly or indirectly linked to the following three major constraints will be considered in the discussion. The availability of:

1. Low soil moisture
2. Low soil nutrients
3. Low feed nutrients

In the attempt to alleviate, partially or wholly, a particular constraint, considering its all round connection with the other constraints is essential. In so doing, it is also of paramount importance that the key link in the inter-relationships or interconnections of the constraints is identified. For example, nitrogen is the most limiting in the nutrition of soil microbes, plants and ruminant animals in the sudanian zone. Under such conditions, nitrogen could be taken as the common nutrient involved in the biological functions of the soil-crop-animal system. Identification of a source of nitrogen that could fit into the objective conditions of the production system, therefore, becomes a necessity. Thus, the reason for considering forage or dual purpose legumes as the key link in the alleviation, at least partially, of the above three constraints.

1. Forage/Dual Purpose Legumes in Soil-Crop Component

1.1. Soil Nitrogen Status

With the price of chemical fertilizers continuously and rapidly escalating while the purchasing power of the target farmers is rapidly declining, the increasing reliance on nitrogen fixation by legumes is a necessity.

Substantial amount of nitrogen is known to be fixed by tropical legumes and many of them nodulate without inoculation (Haque and Jutzi, 1985). Forage and dual-purpose legumes planted on degraded soils at various sites in the sudanian zone of Burkina Faso were able to nodulate without inoculation but differed in the number, size and colour of nodules (Table 1). Observations were made at flowering and the possible differences in the onset and termination of nodulation were not ruled out. However, amongst the legumes tried, cowpea cultivars performed better in all aspects of nodulation for they are probably the best host plants to the indigenous strains of Rhizobia. Cowpea Rhizobia from hot and dry regions are known to be more tolerant to high temperatures and drought than those strains from cooler and more humid regions in both sandy and other soils (Mulongoy, 1985).

Table 1. Performance of forage and dual-purpose legumes in nodulation at flowering at two sites in the sudanian zone.

Species	Plants w/nodule (%)a		Average no. of nod. /plt		Diameter of nodules (mm)		Nodules w/ red cross sect. (%)	
	KBb	KS	KB	KS	KB	KS	KB	KS
L. purpureus	58	14	8.3	0.6	5.1	4.5	28	0
V. unguiculata								
- cv KN-1	72	14	16.5	19.5	4.1	5.1	73	45
- cv Koakin loc.	78	47	12.8	10.6	4.1	3.6	90	25
- cv Ouahigouya loc.	75	47	14.0	15.8	3.8	6.5	85	25
- cv Kaya local	–	47	–	21.2	–	5.6	–	10
- cv Suvita-2	77	–	12.3	–	4.1	–	58	–
P. aureus	75	42	4.5	0.3	3.2	2.2	33	13
M. atropurpurium	18	–	0.8	–	2.5	–	13	–
S. hamata	27	–	76.0	–	1.0	–	–	–
LSD 0.05	–	–	12.52	8.06	0.087	NS	0.224	0.257
CV (%)	–	–	66.6	48.7	25.3	39.0	39.5	99.0

a: sample number = 10 plants; b: KB = Kamboinse, KS = Kamsi

Cowpea is traditionally grown as an intercrop mainly with millet on the uplands and upper slopes for its grain and the haulms for forage. Most local cowpea cultivars seem to be photoperiod sensitive and mature late. There are indications as shown in Table 2 that late-maturing cowpeas tend to fix more nitrogen than those maturing early thus, encouraging the use of such cultivars to increase the nitrogen status of upland soil. Since photoperiod sensitivity is associated with long vegetative growth period and delayed onset of flowering, it is a characteristic suited for forage production too.

The possibility of genetic improvement of legumes through breeding and selection for increased symbiotic nitrogen fixation exists (Coale *et al.*, 1985). Considering the importance of cowpea in the zone and its nitrogen fixing potential, the research institutions in the country need to consciously lend their effort to improve the capacity of the crop in atmospheric nitrogen fixation.

Cowpea and other forage legumes such as *Lablab purpureus* could be incorporated into the cropping system as intercrops or in rotation with cereals on the arable or fallow land to improve the nitrogen status of soil.

Table 2. Effects of cropping system on cowpea nitrogen fixation (Mulongoy, 1986).

Cowpea cultivar	Maturity age (days)	Nitrogen Fixed Monocrop kg/ha	Monocrop % fixed	Intercrop kg/ha	Intercrop % fixed
IT82 D-789	52 - 55	19.6	73	10.4	73
IT82 D-889	52 - 55	16.4	69	7.7	67
IT82 E-9	60 - 65	13.2	64	12.7	77
IT82 E-60	60 - 65	29.3	80	11.9	76
TVX 3236	80 - 85	31.9	79	19.6	81
VITA 5	> 90	30.0	78	27.5	76

Intercropping with Cereals: For many legumes, the transfer of nitrogen from the legume is usually a slow process involving ageing or damage to the plant (Postgate, 1982) indicating that no direct transfer of symbiotically fixed nitrogen takes place between the legume and the cereal. However, some evidence is emerging (Eagleshan *et. al.*, 1981; Elmore and Jacobs, 1986; Patra *et. al.*, 1985) that legumes can directly transfer substantial amount of the fixed nitrogen to associated crop (Table 3). This direct transfer might depend on the proximity of the two crops as observed in soybean-sorghum intercropping (Elmore and Jacobs, 1986) or in forage legumes and grass association (Brophy *et. al.*, 1987). The transfer to the associated crop appears to be effective only in conditions of low soil mineral nitrogen status and not when mineral nitrogen is plentiful (Eagleshan *et al.*, 1981).

The large increase in millet grain straw yield due to millet/legume intercropping as compared to monocropping in the sudanian and sudano-sahelian zones of Burkina Faso (Table 3) probably was associated with the transfer of nitrogen from the legume directly or from decomposition of nodulated roots since the legumes used (*Phaseolus aureus* and cowpea cv Suvita-2) were of short cycle type.

Table 3: Effects of legume intercroping on associated crop in terms of build-up of nitrogen ions in the rhizosphere, nitrogen uptake and grain yield.

Source of data	Crop combination	Concentration of N ions in the rhizosphere (ppm)		contribution of fixed N (%)	Grain yield (kg/ha)
		NO-3	NH+4		
Singh *et.* al. (1986)	Maize sole	29.9	5.3	-	2135
	Maize + soybean	40.5	6.3	14.0	2415
	Maize+groundnut	31.1	5.8	7.0	2200
	Maize+blackgram	37.9	5.8	15.3	2440
Patra *et.* al. (1985)	Maize + cowpea			27.6	
Patra *et.* al., (1986)	Maize + cowpea			28.0	
Kibreab	Millet sole				
	- without fertilizer				400
	- with fertilizer				479
	Millet + cowpea (Suvita-2)				
	- without fertilizer				744
	- with fertilizer				856
	Millet + greengram				
	- without fertilizer				712
	- with fertilizer				1063

Rotation with Cereals: The value of legumes in their contribution of nitrogen to subsequent crop in a rotation system is well known. Research data on the management of legumes and cereals in rotation in Burkina Faso is limited. However, the findings of Stoop and Van Staveren (1982) indicate that, without fertilization, sorghum following cowpea yielded an average of 315 kg grain/ha more than when it followed millet. In areas where prolonged fallowing cannot be practiced due to shortage of land, suitable annual forage or dual purpose legumes could be planted to be harvested for conservation as hay, and the re-growth (root and shoot) organic matter yield (5287, 3654 and 4301 kg/ha) and nitrogen yield (158, 84 and 94 kg/ha) of cowpea cv KN-1, *L. purpureus* and *P. aureus*, respectively, after harvest for soil conservation as hay indicate the potentials that exist to improve soil structure and fertility. Replacement of fallow with annually sown forage legumes help reduce the fallow period and encourage forage legume/cereal rotation system. Long-term investigation is required on this aspect.

In areas where prolonged fallowing is practiced as a means of restoring soil fertility, better and quicker regeneration of soil may also be possible through the use of perennial legumes. As a result of the increment in soil nitrogen after different lengths of cropping of *Stylosanthes* species, significant increases have been observed in the yield of subsequent cereal crops (ILCA, 1983).

1.2 Soil Cover and Organic Matter Status

Due to their spreading nature, a number of local cowpea cultivars are noted for their efficiency in providing good soil cover (Muleba, 1983) reducing soil erosion and runoff. However, the introduction of deep-rooted forage legumes, particularly in the upland soils where compaction is a common phenomenon, may provide a better alternative for the amelioration of soil conditions.

Forage legumes such as *Macropitulum atropurpurium, M. lathyroides* and *L. purpureus* on moderately eroded Alfisol as cover crops resulted in increased levels of soil organic matter, carbon, C:N ratio and exchangeable potassium, higher infiltration rates, greater proportion of macropores and higher subsoil root growth (Hulugalle, 1987). This was followed with higher grain and dry matter yield of maize in subsequent year (Table 4).

Table 4: Effects of some preceding legume cover crops on infiltration rate at 2 h after commencement of infiltration, and oven dry grain and dry matter yield of maize in subsequent year (Hulugalle, 1987).

	Infiltration rate (mm/h)		Maize yield (kg/ha)	
Preceding cover crop	January 1987	October 1987	Grain DM	Total DM
Zea mays	76.0	46.7	200	1100
Bare fallow	15.2	15.0	0.007	200
Vigna unguiculata	80.0	72.8	200	1600
Cajanus cajan	63.9	54.5	1	600
Macropitulum atropurpurium	156.0	35.6	2200	4300
M. locthyroides	123.9	154.5	2400	5000
Lablab purpureus	167.7	117.7	800	3200

Considering the objective conditions, organic manuring is the only means that is relatively easily available to the farmer to increase and maintain soil fertility. It is an indispensable resource but with limited availability. Studies conducted in Burkina Faso clearly demonstrated that the efficiency of utilization of mineral fertilizer too could be increased when combined with organic manure (M. Sedogo, cit. Pieri, 1985).

The production and conservation of forage dual-purpose legumes and the practice of cut and carry feeding system from browses alley cropped on the wet lowlands could encourage farmers to feed their animals in enclosures all year round. This could allow the collection of manure and feed refusals and other farm wastes for compost making (Table 5). With the traditional practice of piling manure in many small heaps in the field, there could always be loss of nutrients, particularly nitrogen, to the atmosphere. There is evidence that manure stored in a pit has a better nutrient keeping quality. Kwaykye (1980) reported a difference of 108% in nitrogen, 20% in phosphorus, and 62% in potassium content when manure was buried as compared to storing loosely.

Table 5. Estimated quantity of dry matter (DM), organic matter (OM), nitrogen (N), phosphorus (P) and potash (K2O) in feed refusals and faeces of sheep* fed with sorghum supplemented with cowpea hay and cottonseed cake.

Source of data	Supplement (g/kg diet DM)	Feed refusals (kg/hd/yr) DM	OM	N	Faecal output (kg/hd/yr) DM	OM	N	P	K2O
Yilala	Cowpea hay								
(1988b)	0	69	62	0.5	153	130	2.1	0.23	1.2
	200	93	74	0.7	152	112	3.0	0.27	1.3
	400	94	75	0.7	140	119	3.0	0.28	1.5
Yilala	Cottonseed cake								
(1988c)	0	62	54	0.5	130	111	1.9	0.19	0.59
	60	91	78	1.9	127	109	2.1	0.90	2.26
	120	82	68	2.4	160	137	2.4	1.49	3.00

* : Bali Bali sheep with average live weight of 45.2 kg during the experimental period.

1.3 Soil Phosphorus Status.

While the deficiency of soil nitrogen can be partially corrected by legumes, the deficiency of soil phosphorus requires application of fertilizer. Even to exploit the potential of legumes in biological nitrogen fixation and obtain optimal growth, the adequate supply of phosphorus is a necessity (Haque and Jutzi, 1985: Mulongoy, 1986).

Legumes, besides harbouring nodules, can also have mycorrhizal hyphae (Lynch, 1983). Mulongoy (1985) reported that cowpeas grown on poor soils at Maradi, northern Nigeria, fertilized with single superphosphate (30 kg/ha) were heavily infected with vesicular arbuscular mycorrhyzae (VAM) fungi and resulted in superior increases in shoot weight and grain yield. He noted a great variability among the cowpea cultivars in VAM infection.

In studies involving phosphorus uptake by cowpea in Burkina Faso, unfertilized photoperiod sensitive local varieties maintained high levels of soil available phosphorus in their plots and gave high grain yield equal to those superphosphate fertilized improved photoperiod insensitive cultivars (Muleba, 1984). Whether this performance of the local cultivars is associated or not with the harbouring of VAM fungi needs to be investigated.

The cheapest source of phosphorus in Burkina Faso is the local rock phosphate. This source of phosphate was unable to show improvement in the agronomic performance of cereals during the first year of application because of its low phosphorus solubility (Kibreab, 1986). There is a widely accepted view that residual effects of rock phosphate might be greater than initial effects. However, cowpea responded to Burkina rock phosphate application in the first year (Table 6). There is an indication that greater numbers of phosphate solubilizing bacteria exist in the rhizosphere of cowpeas than in cereals (Odunfa and Oso, 1978).

Table 6: Effects of different sources of phosphorus on dry matter (DM, air-dried) yield of cowpea (CV KN-1) at different growth stages.

Stage of Cutting	Phosphorus source (1)				
	Without phosphate	Single Super phosphate	Rock uncomposted	Rock composted(2) Low	Rock composted(2) High
	kg/ha				
At 1st flowering	1619	3063	2313	2900	2965
AT 50% flowering	2858	5850	3875	4313	7751
At podding	4376	7104	5185	5726	8561

(1): Application of phosphate: single super - 100 kg/ha; Burkina rock uncomposted = 400 kg/ha; Burkina rock composted: Low - 200 kg/ha High - 400 kg/ha.

(2): Chemical composition of compost (% DM): Organic matter = 38.0; Carbon = 22.0; Total N = 1.45; Total P = 0.65; Available P = 0.05: Potash = 0.5 and pH = 7.4

The residual effects of rock phosphate showed increases in grain and straw yield of both legumes and cereal in the subsequent year (Yilala and Kibreab, unpublished). These in general might suggest that the gradual replacement of fallow or upland soils by forage or dual-purpose cowpea/cereal rotation might improve the effectiveness of Burkina rock phosphate.

The major part of soluble phosphorus available to plant usually arise from the microbial transformation of organic phosphorus, and composting might provide such benefits to the crops (Lynch, 1983). Composting Burkina rock phosphate with cereal residues and applied at the rate of 10 t/ha gave equally high sorghum grain yield as that fertilized with NPK (Bado, unpublished). The application of compost (at 10 t/ha) containing rock phosphate, feed refusals and sheep faeces resulted in higher cowpea dry matter yield than those fertilized with uncomposted rock phosphate and single super phosphate (Table 6). The effect of the compost might also be associated with the other substrates such as nitrogen, organic matter, potassium, etc. contained in it (Yilala, 1988a).

2. Forage Legumes in Ruminant Animal Component

2.1 Source of Nitrogen

The native pasture in Burkina Faso is usually exposed to short rainy season accompanied with high evapotranspiration and high temperature. This could result in rapid metabolic activity in the pasture, leading to a rapid decrease in the pool size of protein and soluble carbohydrates in the cellular contents to be transformed into structural cell wall components (Van Soest, 1982). Thus, the reason for the rapid decline in nitrogen and increase in the neutral and acid detergent fibre components as the native pasture matures rapidly (Fig. 1). In terms of chemical entities, the same holds true for cereal crop residues, the other locally available major feed resource.

The degradation of the abundant energy components, cellulose and hemi-cellulose, is highly dependant on the fermentative activity of the microbes in the rumen. These microbes, in turn, are dependant on the presence of adequate amount of ammonia for their cellular nitrogen requirements. The increase in microbial production leads to increased rate of cellulose digestion and voluntary intake.

The supplementation of native pasture hay and sorghum stover with different sources of nitrogen such as cowpea hay, pigeon pea (fresh), and cottonseed cake has markedly increased digestibility and voluntary intake (Table 7). It is, therefore, possible to alleviate the constraint of nitrogen availability, for improved utilization of the fibrous diets, through the production of forage legumes and browses.

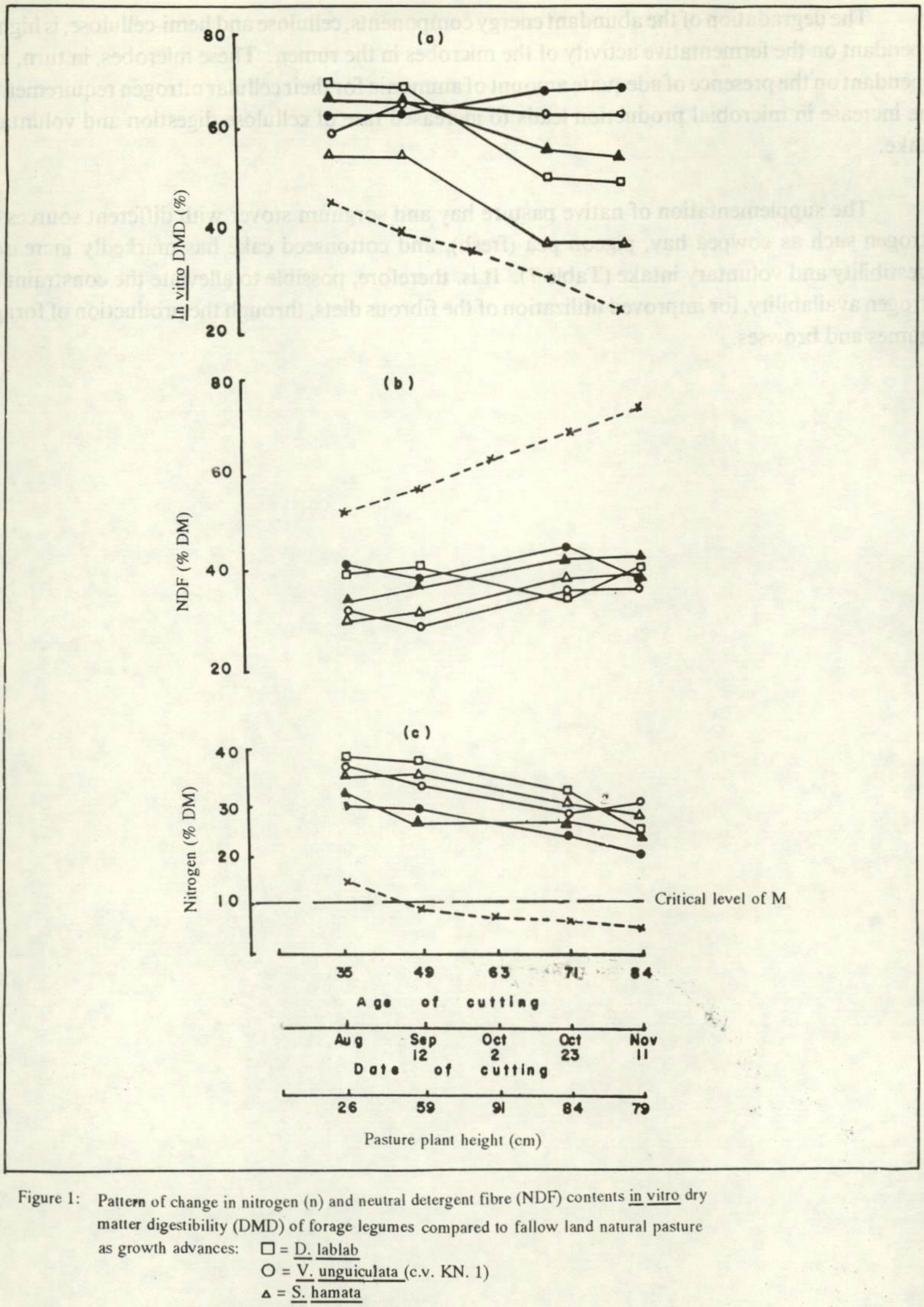

Figure 1: Pattern of change in nitrogen (n) and neutral detergent fibre (NDF) contents in vitro dry matter digestibility (DMD) of forage legumes compared to fallow land natural pasture as growth advances:

□ = D. lablab
○ = V. unguiculata (c.v. KN. 1)
△ = S. hamata
▲ = M. atropurpurium
● = P. aureus
X = natural pasture

Several forage and dual-purpose legumes were assessed in their agronomic and nodulation performance and nutritive value for ruminant animals. All the legumes had nitrogen well above the critical level at all stages of growth (Fig. 1). Biodegradability of the nitrogen component in the rumen was also one of the parameters used in the evaluation of their nutritive value. The crops varied in the rate and pattern of degradation of nitrogen in the rumen. Amongst the legumes, long duration cowpea cultivars and *L. purpureus* were chosen for production and conservation as hay, and *S. hamata* for oversowing into fallow pasture *L. purpureus* (cv Highworth) being photoperiod sensitive failed to reach the flowering stage on the upper slopes but was able to set seeds on the lowland in November/December due to the possible effect of residual moisture. The self reliance on the source of seeds is of paramount importance to guarantee the continuity of forage production. *L. purpureus* has good drought tolerance and vigorous vegetative growth, and may also contribute to the improvement of soil physical structure. Farmers may, therefore, need to reserve small areas in the lower slope where residual moisture may be guaranteed for seed production for use in subsequent year.

Table 7: Effects of supplements of different sources and levels of nitrogen on apparent dry matter (DM) digestibility and voluntary intake of native pasture hay and sorghum stover by Bali Bali sheep.

Source of data	Basal diet	Nitrogen supplement	D M digestibility (%)	Daily DM intake Total (g/day)	Daily DM intake Roughage (g/day)	Rate of change in roughage intake
Yilala (1988b)	**Sorghum stover**	**Cowpea hay (g/kg diet DM)**				
		0	**59.1**	**1135**	**1135**	**0**
		200	**67.1**	**1350**	**1190**	**+0.10**
		400	**71.2**	**1536**	**1149**	**-0.25**
Yilala (1988a)	**Sorghum stover**	**Cottonseed cake (g/kg diet DM)**				
		0	**59.2**	**964**	**964**	**0**
		60	**72.5**	**1410**	**1278**	**+2.78**
		120	**71.2**	**1265**	**1001**	**+1.14**
Yilala (1989)	**Native pasture hay (*)**	**Pigeon pea (fresh)**				
		0	**64.0**	**1022**	**1022**	**0**
		200	**70.3**	**1332**	**1074**	**+0.26**

(*): Predominantly *Pennisetum pedicellatum* species.

As a tradition, crop cowpea seeds are saved for subsequent planting. Until other sources of forage seeds become easily available at the farm level, cowpea forage could serve as the major source of nitrogen for ruminant animals. This might indicate the importance of identification or development of dual purpose cowpea cultivars.

Both cowpea and *L. purpureus* manifested rapid disappearance of nitrogen when tested *in vitro* and *in sacco*. About 70% of their nitrogen is degraded in the first few hours of incubation in the rumen. This rapid disappearance of nitrogen in the rumen could pose a problem of excessive loss of nitrogen in the urine if its release is not synchronized with the release with energy, from fibrous basal diets, to capture it (Fig. 2). Under such conditions, it would be necessary to incorporate in the diet feed ingredients with high contents of water soluble carbohydrates which are known for their rapid disappearance in the rumen. *Andropogon gayanus* and *Pennisetum pedicellatum* harvested at young age or sweet potato vines and cassava leaves grown on the wet lowlands during the dry season might contribute to the supply of water soluble carbohydrates (Table 8).

Table 8: Contents (% DM) of water soluble carbohydrates and nitrogen of native grass species, sweet potato vine and cereal crop residues.

Source	Water soluble Carbohydrates	Nitrogen
Andropogon gayanus		
- young	12.90	1.00
- mature	8.88	0.37
Pennisetum pedicellatum		
-before heading	12.99	0.96
Sweet potato vine	12.85	2.51
Sorghum stover	5.10	0.74
Millet stover	4.80	0.79

The other alternative could be to reduce the quantity of rapidly degrading nitrogen supplement in the ration and incorporate those sources of nitrogen with low degradability. This will allow an increased supply of dietary amino acids that could be absorbed from the small intestine. Under small-scale farm conditions in the sudanian zone, introducing browses with desired contents of condensed tannins might be helpful. Condensed tannins could protect protein from microbial degradation in the rumen and release in the abomassum, and enable increased absorption of dietary amino acids in the small intenstine. The variation in the contents of tannins of introduced browses and existing tree legumes in one of the village sites is given in Table 9. These materials were not tested on animals. However, the potential of using these forage materials as supplements to increase rumen undegradable protein exists.

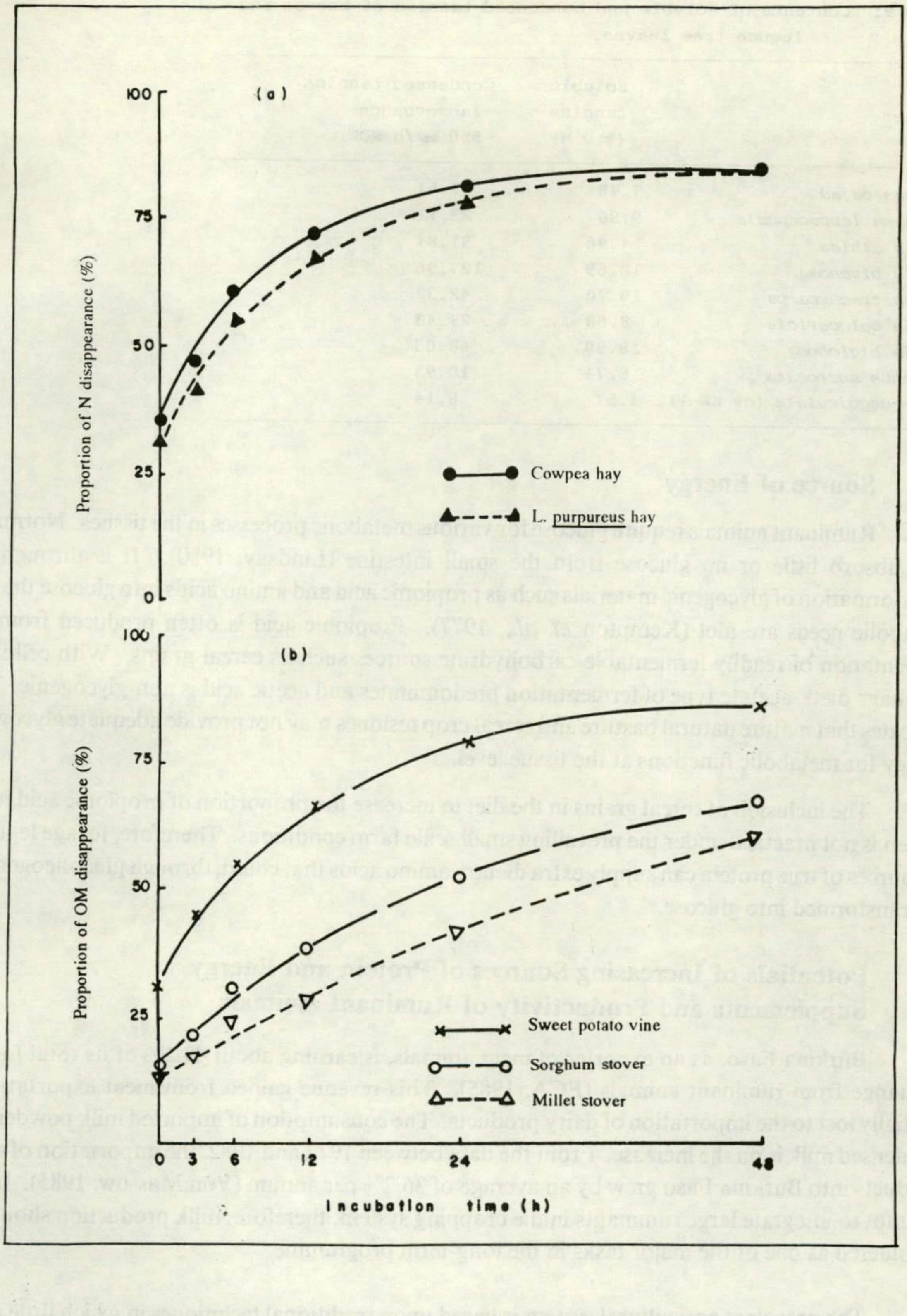

Figure 2: In socco disappearance of Nitrogen of cowpea and L. purpureus (a) and Organic matter of sweet potato vine, sorghum stover and millet stover (b) in the rumen.

Table 9: Contents of soluble and condensed tannins of browse and legume tree leaves.

Species	Soluble tannins (% D M)	Condensed tannins (absorbance 550 mm/g NDF)
Cajanus cajan	7.48	37.51
Leucaena leucocephala	9.96	23.11
Acacia albida	14.96	31.84
Acacia bivenosa	12.69	127.96
Acacia trachycarpa	19.70	42.32
Acacia holocericia	8.58	29.43
Parkia biglobosa	18.90	68.03
Ziziphus mucronata	8.74	10.93
Vigna unguiculata (cv KN-1)	4.57	8.14

2.2 Source of Energy

Ruminant animals require glucose for various metabolic processes in the tissues. Normally, they absorb little or no glucose from the small intestine (Lindsay, 1980). It is through the transformation of glycogenic materials such as propionic acid and amino acids into glucose that the metabolic needs are met (Kempton *et. al.,* 1977). Propionic acid is often produced from the fermentation of readily fermentable carbohydrate sources such as cereal grains. With cellulosic roughage diets, acetate type of fermentation predominates and acetic acid is non-glycogenic. This indicates that mature natural pasture and cereal crop residues may not provide adequate glycogenic energy for metabolic functions at the tissue level.

The inclusion of cereal grains in the diet to increase the proportion of propionic acid in the rumen is not practical under the prevailing small scale farm conditions. Therefore, forage legumes as sources of true protein can supply extra dietary amino acids that could, through gluconeogenesis, be transformed into glucose.

3. Potentials of Increasing Sources of Protein and Energy Supplements and Productivity of Ruminant Animals

Burkina Faso, as an exporter of meat animals, is earning about 49.2% of its total foreign exchange from ruminant animals (ECA, 1985). This revenue gained from meat exportation is partially lost to the importation of dairy products. The consumption of imported milk powder and condensed milk is on the increase. From the data between 1972 and 1982, the importation of dairy products into Burkina Faso grew by an average of 36.2% per annum (Von Massow, 1985). In the attempt to integrate large ruminants in the cropping system, therefore, milk production should be considered as one of the major tasks in the long-term programme.

The prevalent agricultural system is based upon traditional techniques in which little or no draught power is used. Utilization of draught power is unavoidable for the existing stage of development. It will not only reduce the drudgery of labour, but will also allow intensification of the production system through increased efficiency of use of labour. Draught power is required for

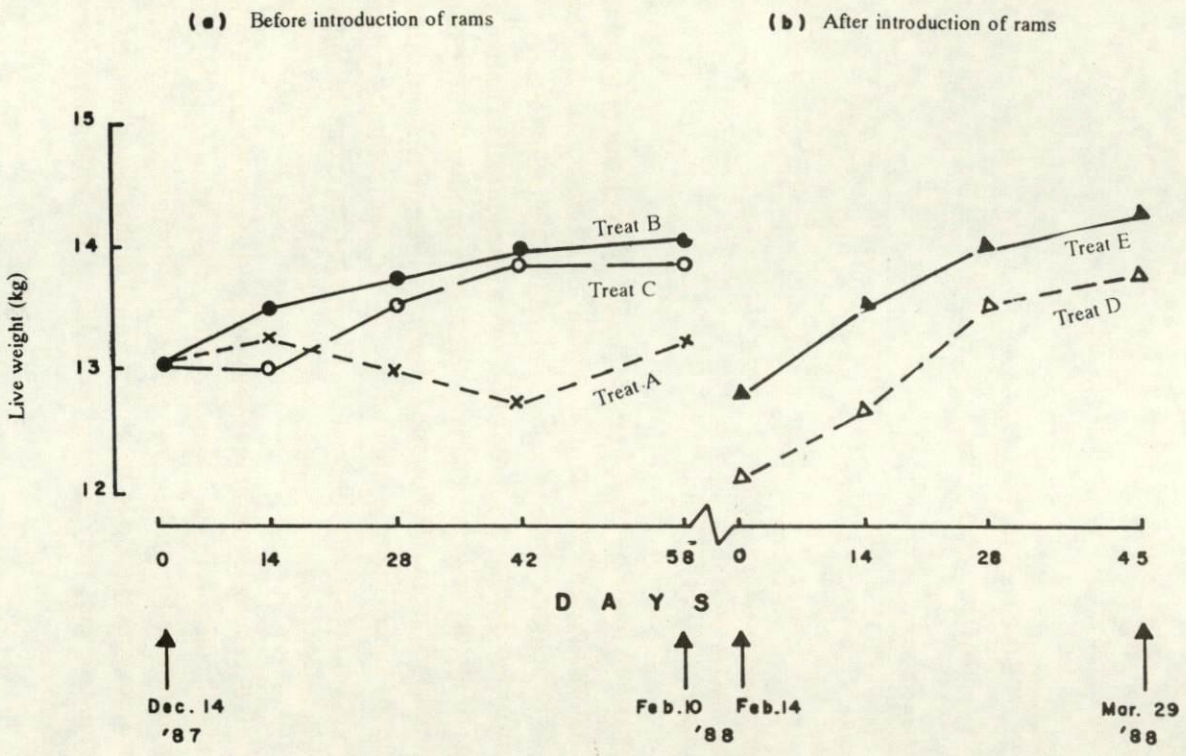

Figure 3: Pattern of live weight change of ewe lambs fed grass hay *ad libitum* supplemented with a) cowpea hay before introduction of rams, and (b) cottonseed cake after introduction of rams. (Treats A, B and C = 0, 100 and 200g cowpea hay/hd/day; D and E = 75 and 125g cottonseed cake/hd/day respectively).

Table 10: Effects of supplements of different sources of nitrogen on live weight change of sheep fed on basal diets of native hay and sorghum stover.

Source of data	Basal diet	Nitrogen supplement (g/kg diet DM)	Live weight Init. (kg)	Live weight Final (kg)	Live weight Gain (g/day)	Supplement cost CFA/hd /day	Supplement cost CFA/100 gLWG*
Yilala& Zoundi (1987b)[+](1)	Native hay	Cowpea hay					
		0	11.7	12.0	4.1		
		150	11.2	13.8	29.2		
		300	11.5	12.5	11.4		
		L. purpureus					
		150	11.4	12.0	13.0		
		300	11.3	12.6	11.1		
Yilala (1988d)[++]	Sorghum stover	Cottonseed cake					
		30	47.5	48.8	23.8	1.9	8.1
		60	46.7	49.7	53.6	3.7	6.9
		120	45.3	48.7	60.7	5.6	9.0

+: Type of sheep used: Djallonke.

++: Type of sheep used: Bali Bali.

*: LWG = Live weight gain.

The limited observations made on pigeon pea *(C. cajan)*planted on contour bunds indicated that it could be established and provide substantial amount of biomass. It was observed to stay green until at least end of December, three months after end of the rainy season. The prunings could be conserved as hay or fed fresh as a source of nitrogen supplement to native pasture hay or cereal residue during part of the dry season. Pruning before or immediately after cereal harvest is necessary so that it could be saved from free ranging ruminants. Pigeon pea and other fast growing browses could be introduced successfully as alley crops on the wet lowlands where farmers use residual moisture and irrigation, from hand dug water wells, for garden crops during the dry season. The Browses could serve at least as partial supplement in a cut-and-carry feeding system (Table 7).

The leaves and fruits of certain leguminous trees such as *Acacia albida* are traditionally used as protein supplements mainly during the dry season. Thus, the reason for the concentration of animals under such trees at times of fruiting. The collection and storage of fruits of such species could be considered as protein concentrate to be incorporated in the diet in limited quantity. The advantages of *Acacia* fruits are that they become available at the time when the deficiency of nitrogen is of serious concern.

Cotton being the principal export crop in Burkina Faso, its byproducts, cottonseed and cottonseed cake, are the cheapest amongst the purchasable sources of energy and nitrogen and could be complementary to forage legume supplements (Yilala, 1988c). The benefits of inclusion of cottonseed cake in sorghum based diet on live weight gain (Table 10) was accompanied by an increase in the contents of phosphorus in the faeces of sheep (Table 5). The latter is of paramount importance in the sudanian zone of Burkina Faso.

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L'ELEVAGE DANS LES SYSTEMES AGROPASTORAUX DU SENEGAL - CAS DE LA HAUTE CASAMANCE -

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RESUME

Cétte étude réalise une description détaillée du secteur de l'élévage dans le sytème agropastoral de la Haute Casamance (Sénégal) en soulignant ses articulations avec les productions végétales. L'analyse des paramètres conceptuels, des facteurs exogènes, des variables controlables, des fonctions du système d'élevage ainsi que des objectifs des différents participants a permis de formuler les principales contraintes qui font obstacle au développement des productions animales dans cette zone. Les solutions de rechange déjà testées et celles envisagées par les organismes de recherche ou de développement et concernant l'alimentation des animaux, le travail animal, la gestion des paturages, la couverture de fumier sont discutées. Les expériences de liason recherche/développement (R/D) capitalisées fournissent de riches enseignements sur les systèmes agropastoraux existants. L'approache de la R/D adoptée se base sur la traduction des besoins exprimés par les organismes de développment en opération de recherche exécutées par l'organisme chargé des investigations sur les productions animales.

Mots Clés: système agropastoral, élévage, Recherche/Développement

I. INTRODUCTION

C'est en 1921, avec la création dela station expérimentale de l'arachide à Bambey que fut initiée la recherche sur les productions animales comme composante d'un système agropastoral au Sénégal. L'objectif de développement de la production arachidiére par le biais de la traction animale (bovine, équine et asine) détermina alors l'orientation des efforts de recherche qui se sont essentiellement focalisés dur l'utilisation des produ;its animaux (travail, fumier) comme intrants aux cultures. L'amélioration génétique due gabarit et de l'aptitude à la traction de la Ndama dans le sud du Bassin Arachidier, les conditions d'alimentation, d'habitat et de soins des animaux ont été ainsi des champs privilégiés de recherche.

Avec l'avènement des "Unités Expérimentales" du Sine Saloum en 1967 sera adoptée l'approche systèmatique comme base méthodologique pour la recherche et la vulgarisation agricoles. Les investigations sur les productions animales revêtront une place importante dans ce processus de recherche attestée par les études menées sur différents aspects de l'élévage des bovins, petits ruminants, équins, asins et volailles. Les pratiques d'élévage, la gestion, la dynamique et la productivité des troupeaux, l'alimentation des animaux et la gestion des espaces pâturés, la situation sanitaire ainsi que l'utilisation des animaux pour la traction ont bénéficié d'efforts de recherche appréciables. L'entrée par le foncier en vue de son amélioration (labour en fin de cycle avec enfouissement de la paille, maintien de la fertilité des sols par l'apport de fumier, entre autres) a permis de mieux percevoir les articulations entre productions végétales et animale et à ainsi justifié l'amphase portée aux études sur la traction animale dans les "Unités Experimentales".

L'extension de l'utilisation de l'approche systèmique ne sera initiée qu'au début des années 80 d'autres zones agropastorales du Sénégal, notamment dans les régions de Ziguinchor, Fleuve et Kolda.

II. METHODOLOGIE

Le cadre conceptuel de l'approche systèmique dans sa phase de diagnostic a été utilisé pour mener cette étude. Les données secondaires concernant la situation actuelle du système agraire (typologie et taux d'occupation des sols) ont été tirées de la littérature existante. Des enquêtes informelles, puis formelles ont été menées pour collecter les données de base relatives aux interactions agriculture-élévage, à la situation des ressources de base, aux institutions, à l'utilisation de l'espace, à l'organisation de la production, à la conduite et la productivité des troupeaux. Les enquêtes ont porté sur plusieurs niveaux d'échelle: village, troupeau, exploitation et cheptel. Un échantillon de 13 villages, 34 troupeaux et 75 exploitations a ete choisi de maniere raisonnee au sein de 7 "Petites Régions Agropastorales" qui ressortent du zonage de la Haute Casamance réalisé par la SODEFITEX (1986).

1. Caractérisation du systèmes d'élévage

Selon la classification de Ruthenberg reprise par SOMIVAC (1978), le système agraire de la Haute Casamance est défini comme système sédentaire à jachère (fallow system) avec "riziculture". Il conviendrait mieux de parler de système agrpastoral sedentaire avec riziculture et "élevage" afin de faire ressortir l'important rôle qu'y jouent les productions animales. En effet la fertilité des sols est entretenue non seulement par la pratique de la jachère, mais aussi par la mise en contribution des animaux que sont des vecteurs de transfert de la fertilité des sols des paturages de plateau vers les zones de culture, autorisant ainsi la mise en culture permanente des champs de case.

L'élevage en Haute Casamance se caractérise essentiellement par:

i) La multiplicité des espèces élévées: bovins, petits ruminants, équins, asins, volailles et abeilles;

ii) un mode de production sédentaire et extensif avec en général un mouvement des animaux dans les limites d'un espace paturé contigu au village;

iii) une appropriation individuelle des animaux ayant accès à des pâturages communs;

iv) les fonctions multiples des animaux élévés: producteurs de lait, viande, revenus monétaires, fumier, travail;

v) une association intime entre productions vegetale et animale reflétée par l'utilisation des mêmes terres, l'exploitation des produits animaux (travail, fumier) pour les cultures et la valorisation des sous-produits de recolte par les animaux.

2. Paramètres Conceptuels du Système d'Elévage

Les paramètres conceptuels servent à spécifier la structure de système etudié. Ils sont de caractère relativement "fixes" mais peuvent cependant être l'objet de changement afin d'améliorer la performance du système. Ces changements s'accompagnent en général d'une mobilisation importante de ressources mais deviennent nécessaires lorsque des mutations s'opèrent dans l'environnement du sytème (Manetsch, 1977). Les paramètres les plus importants que peuvent entrer en jeu sont: i) la terre, ii) les espèces animales, iii) la taille, la structure et la composition des troupeaux à différents niveaux d'échelle (région, troupeau, exploitation).

2.1 La Terre: L'abondance des réserves foncières et par conséquent le potentiel d'extension des surfaces cultivées singularise le paysage agraire de la Haute Casamance. Le taux d'occupation des sols (TOS), est relativement faible (24%). Cette région est aussi relativement sous peuplée avec en moyenne 25 habitants au km^2. La charge animale s'élève à 17.8 UBT/km^2. De grandes variations zonales peuvent être repérées selon les paramètres mentionnés ci-dessus. Les arrondissements de Dioulacolon, Kounkane et Pakour sont densement exploités avec des TOS supérieurs à 40% tandis que la mise en valeur des terres demeure faible dans le Médina Yoro Fouka et Boncoto (TOS < 15%).

Les modes spatial et temporel d'exploitation des terres permettent une cohabitation des activités pastorales (perpetuées dans le temps) et celles agricoles (de nature saisonnière). Trois grands ensembles se distinguent au niveau du terrioir villageois: les zones de résidence, les zones de culture et les paturages de plateau. Les zones de culture se retrouvent aussi bien sur le plateau que dans les vallées où est pratiquée la riziculture. Les champs disposés en auréoles autour des concessions comportent plusieurs types de sols selon leur localisation et l'ancienneté de la défriche. Les champs de case, contigus aux concessions et lieu de parcage de saison séche, sont utilisés pour les cultures de maïs, manioc, gombo, courge, patate douce en culture pure ou en association. Les champs permanents font suite aux champs de case. L'apport de fumure minérale n'est pas systématique mais leur distance limitée par rapport au village explique leur utilisation permanente. Les champs de brousse constituent la dernière zone de culture sur le plateau donnant accès à la forêt qui est regulièrement rongée par les nouvelles défriches ou "séguéli". Ces terres sont mises au repos "soindé" après une exploitation de durée variable (3 à 8 ans). Elles deviennent des "pangassi" lors de leur reprise. Le sorgho, le mil, l'arachide et le coton sont cultivés dans les champs permanents et les champs brousse.

Les lieux de parcage et les parcours des animaux varient selon la saison. Durant la saison des cultures, les animaux sont parqués à la lisière des forêts et les paturages de plateau servent de source alimentaire pour les bovins tandis que les petits ruminants et les équidés exploitent les jachères qui sont d'excellents paturages. A partir de Septembre, les petits ruminants et les équidés sont les premiers à envahir les champs de céréales récoltés où les repousses et les feuiles sont consummées. Ils y seront rejoints par les bovins vers décembre. Durant la saison sèche chaude, les animaux sont attrirés par les repousses des sols hydromorphes des vallées ou les pailles de riz ont déjà été consummées sur pied.

2.2 Les Espèces Animales: Les ruminants domestiques qui peuplent la Haute Casamance sont le taurin Ndama et les moutons et chèvres Djallonké réputés pour leur trypanotolérance. Toutefois, on assiste à une augmentation importante des effectifs de chevaux et d'ânes dans la zone malgré leur sensibilité à la trypanosomiase.

3.1 Paramètres climatiques: Le plus important est la pluviométrie qui connu une chute substancielle au cours des anneés de sécheresse (de 1250 à 1018 en moyenne). Cette réduction du régime pluviométrique se traduit pour les productions animales d'une part par les difficultés accrues liées à l'abreuvement des animaux en saison sèche et d'autre part par la présence d'un important effectif d'ânes et de chevaux trypanosensibles. Ce phénomène serait la résultante d'une réduction du risque de trypanosomiase.

3.2 Ressources en eau: Le disponible potentiel en eau est élevé. Il est composé des eaux pluviales, des écoulements de surface et des eaux souterraines. La nappe phréatique, exploitée pour l'abreuvement des animaux en saison sèche, est très sensible aux variations de la pluvimétrie. Actuellement la corvée de l'eau, par ses exigences élévées en main d'oeuvre est devenue l'une des plus serieuses contraintes de l'élévage.

3.3 Resources alimentaires: elles sont constituées par les paturages naturels et les sous-produits de récolte essentiellement.

3.4 Politique de l'élévage: l'objectif national de promouvoir le secteur de l'élévage se traduit par une série de mesures déterminant les circonstances de productions. Fiscalité, fixation des prix des intrants et des produits animaux, système de tenure foncière, conception de modèle et de stratégies de devoloppement sont des variables de decision externes qui jouent un rôle déterminant dans la dynamique du système d'élévage. L'application de la Nouvelle Politique Agricole (NPA) au Sénégal va opérer des mutations profondes dans le secteur de l'élévage. Elle est soustendue par la libéralisation des prix des intrants et des produits animaux (viande, cuir etc.) l'organisation des éléveurs en groupement d'interêt économique pour leur faciliter l'accès au crédit agricole. Le plan d'action pour l'élévage qui constitue le cadre conceptuel pour la promotion des productions animales envisage pour la Haute Casamance la réalisation de la filière bovine complète (naissage, réélevage, embouche).

La hausse des prix des engrais consecutive à l'application de la NPA a entraîné une augmentation de la valeur de la fumure animale dans les systèmes agropastoraux.

4. Facteurs Internes Controlables

Ce sont aussi des variables de décision qui contrairement à celles exogènes sont sous le contrôle d'opérateurs intervenant directement dans le processus de production. La modicité des intrants caractérise le syèteme d'élévage étudié. Le niveau de supplémentation des animaux est faible et les soins sanitaries qui leur sont apportés sont dominés par la propylaxie contre les maladies infectieuses majeures qui du reste n'est pas systématique.

III. FONCTIONS DE L'ELEVAGE ET OBJECTIFS DES PARTICIPANTS AU SYSTEME D'ELEVAGE

Les anixaux remplissent les fonctions suivantes dans le système de production agricole de la Haute Casamance:

- Formation de revenus monétaires et contribution à la "sécurité alimentaire" des agropasteurs
- Autoconcommation de produits animaux
- Accumulation du capital et épargne
- Intrants aux cultures (travail, fumier, recrutement de main d'oeuvre)
- Approvisionnement en viande de centres urbains
- Rentrée de devises par l'exportation de bétail trypanotolérant.

Les différentes personnes impliquées dans ce système d'élévage privilégient une ou deux des fonctions précises citées dessus.

Au niveau national, les préoccupations des pouvoirs publics tournent autour de l'améioration de la situation nutritionnelle des populations en augmentant la consommation en viande et l'équilibre de la balance des paiements par une réduction des importations des produits animaux. Ils sont ainsi intéressés au premier chef par les deux dernières fonctions citées.

Les agropasteurs affichent des perspectives plus variées pour l'utilisation des ressources animales dont ils disposent. Le cheptel constitue un élément central de leur capacité de subsistance et d'épanouissement materiel et moral. Sécurité alimentaire, revenus monétaires, minimisation du risque dans un environnement à fort degré d'incertitude, accumulation du capital, épargne et couverture sanitaire sont autant d'objectifs réalisés par les agropasteurs grâce a l'élévage d'animaux domestiques.

IV. PERFORMANCES DU SYSTEME D'ELEVAGE

1. Productivité du Troupeau

La lecture du tableau 3 indique les faibles performances de reproduction réalisées. Les femelles manque de précocité. Elles mettent bas pour la première fois à 4 ans d'age. Les écarts entre deux vélages successifs sont importants (21 mois). Les mortalités sont aussi élevées. Le poids adulte est atteint à un age avancé et la production laitière est à des niveaux bas.

Tableau 3. Productivité du troupeau

Reproduction	
Age au premier vêlage	50 mois
Intervalle entre vêlages	21 mois (12-37)
Durée de vie productive de vaches	7.5 ans
Mortalité	
0 - 1 an	14%
> 1 an	5%
Poids adulte	230 kg
Production laitière	313 kg (10 mois de lactation)

2. Travail Animal

L'évolution dynamique de la culture attelée en Haute Casamance s'explique par la longue tradition des paysans à élever des animaux et des boeufs de trait pouvant être facilement tirés du troupeau. L'abondance des terres autorisait l'extension des surfaces cultivées induite par l'adoption massive de cette technologie. En outre, l'introduction et le développement de la culture du coton comme culture de rente avait facilité l'accès au matériel agricole.

La disponibilité en animaux de trait et leur force de traction sont deux indicateurs de la contribution des animaux à la realisation des tâches culturales.

Au niveau régional le cheptel bovin de la Haute Casamance peut théoriquement fournir 25000 mâles de trois ans d'âge chaque année ce qui est de loin supérieur aux exigences de renouvellement les boeufs de trait estimées à 9000 animaux à dresser annuellement.

A l'échelle de l'exploitation, la taille et la structure du cheptel familial et les possibilitiés financières sont déterminantes pour la disponibilité d'animaux derait. Les exploitants non détenteurs d'animaux et ceux à cheptel réduit sont confrontés à des difficultés d'acquisition d'animaux de trait ou pour en extraire de leur troupeau. La location journalière ou saisonniere de boeuf et/ou de matériel est un recours courant. l'utilisation de femelle de trait apparait alors comme une alternative de choix pour ces exploitation.

Malgre son petit format, la Ndama a prouvé ses aptitudes à la traction (Munzinger, 1982; Starkey, 1981; CEEMAT, 1975). En rapport avec leur format, leur puissance de traction est élevés et peut jusqu'à 14% de leur poids corporel. L'utilisation optimale de ces animaux est actuellement limitée par les défaillances de leur conduite alimentaire.

3. Production de Fumier

Le systeme tradtionnel de restitution de ia matière organique se base sur une rotation du parcage des bovins sur les champs de cultures. Il est reconnu que c'est la composante minérale de la fumure qui y jouerait un rôle préponderant; le potentiel fertilisant des déjections animales étant réduit par la déperdition de la matière organique à cause du soleil et des termites. D'importantes quantités de fumier sont ainsi perdues.

V. CONTRAINTES DU SYSTEME D'ELEVAGE-SOLUTIONS ALTERNATIVES

1. Le Système Alimentaire

Le caractère saisonnier de la quantité et de la qualité (faibles proportions d'énergie et de matières azotées digestibles et par conséquent digestibilité faible) des ressources alimentaires disponibles constitue une contrainte majeure de l'élevage se traduisant par la modicité des performances animales observées.

Le volet de la **"SOCIETE POUR LE DEVELOPPMENT DES FIBRES TEXTILES: SODEFITEX)** volgarise une série de techniques destinées à lever cette contrainte en adoptant une stratégie de supplementation sélective des catégories animales les plus productives (mâles et femelles de trait, vaches laitières). L'utilisation de la graine de coton et la conservation des fourrages par le séchage et l'ensilage constituent les actions principales. Le traitement des pailles par l'urée est aussi envisagé.

La supplémentation avec la graine de coton a connu une diffusion plus large que les autres techniques proposées à cause des facteurs favorables à son utilisation. C'est un produit de haute valeur nutritive prêt a être consummé et dont l'utilisation engage peu de main d'oeuvre. Il est en outre rétrocédé par la SODEFITEX à des prix subventionnes à cause de son coût d'opportunité élévé (huilèrie). La conservation des fourrages suppose la fauche et le séchage ou la mise en silo de l'herbe en des périodes de l'année ou la réalisation de ces opérations entre en compétition avec l'exécution des autres tâches agricoles pour l'utilisation de la main d'oeuvre disponible créant ainsi des difficultés d'insertion de ces innovations dans le calendrier de travail de l'agropasteur.

Vu les dimensions de la contrainte alimentaire, des actions de recherches ont été menées par le 'CENTRE DE RECHERCHES ZOOTECHNIQUES DE KOLDA" (CRZ/KOLDA) afin d'y des apporter des remèdes. Le comportement et la., productivité de plusieurs légumineuses (*Stylosanthes)* et de graminées (*Panicum, Brachiara, Andropogon)* fourragèeres ont été testés en station. Seul le *Stylosanthes gracilis* à connu des ebauches de volgarisation par les sociétés de développement qui s'approvisionnaient en sémence auprès du CRZ/KOLDA. L'emergence de l'anthracnose à mis fin a ce programme. La culture de niébé à double fin (graine et fourrage) a prouvé sa viabilité etson haut potentiel d'adaptabilité en milieu paysan comme attestée par l'angouement que manifestent les paysans qui l'ont testée. Le parasitisme demeure l'obstacle majeur au développement de cette culture.

La valorisation des sous-produits de récolte ainsi que la détermination de la charge des paturages constituent aussi des actions de recherches menées actuellement au CRZ/KOLDA.

2. Gestion des Paturages

Malgre l'abondance des terres et la symboise entre activités pastorale et culturale, la gestion de l'espace pose cependant problème. La nouvelle législation foncière dont l'application échoit au conseil rural sous la surveillance de l'administration locale comporte des implications non favourables pour l'élévage. Les parcours du bétail - terres non aménagées - ne font l'objet d'aucune protection. La non mise en valeur d'une terre, materialisée par l'inexistence d'aménagement, favorise la colonisation abusive des parcours du bétail par les cultures. Des confits fréquents sont ainsi générés par la divagation des animaux sur les terrains de culture. De tels problèmes peuvent prendre de l'ampleur dans l'avenir vu les perspectives de développement agricole dans cette zone.

3. Exhaure de l'Eau

L'usage de pompes manuelles et des manèges à traction animale est actuellement vulgarisé pour augmenter les capacités d'exhaure des exploitations. Les petites motopompes sont aussi bien prisées par certains exploitants.

4. Travail Animal

L'utilisation efficiente de l'énergie animale pour la traction est limitée à la gestion défectueuse des animaux de trait. Ils sont dressés à des poids faibles et la durée de leur carrière (3 ans en moyenne) n'autorise pas la retention d'animaux performants dans l'exploitation. En outre, ils souffrent autant que les autres catégories d'animaux du stress alimentaire de la saison séche. A l'installation de la saison des pluies, aù moment où la demande en énergie est à son pic, ces animaux se trouvent dans des conditions non compatibles avec le développement de force de traction exigé.

Pour apporter des solutions, la SODEFITEX organise des centres de dressage et vulgarise un plan de gestion de ces animaux dans le cadre des étables fumières. Nous y reviendrons.

La traction équine est en expansion en Haute Casamance. Les agropasteurs persistent à obtenir des chevaux malgré leur prix d'achat élevé et les difficultés liées à leur entretien (mortalité importante). La rapidité du travail de cette espèce expliquerait cette attitude. Il n'existe aucune activité de recherche ni de developpement (même pas de couverture sanitaire) concernant ces animaux. Pourtant ils méritent une attention particulière à cause de leur potentiel intrinsèque (mécanisation du semis, transport d'intrants, de récolte et de personnes) et de ses implications sur l'utilisation des bovins.

5. Contraintes Sanitaries

La lutte prophylactique contre les maladies infectueuses majeures s'est révélée efficace. Les maladies telluriques (charbons symptomatique et bactéridien) ainsi que la pasteurellose demeurent meurtrières. Chez les petits ruminants, la peste reste sevère en mortalité. La lymphangite epizootique fait des ravages chez les chevaux. La patholgie parasitaire est dominée par les strongyloses gastrointestinales. La trypanosomiase et l'anaplasmose constituent de sérieuses causes de morbidité et de mortalié. Les difficultés d'accès aux produits véterinaires et le manque d'assistance technique aux éléveurs constituent des facteurs limitant une bonne couverture sanitaire du cheptel. Le volet élévage de la SODEFITEX fournit des efforts remarquables pour lever cette contrainte par la redynamisation du service traditionnel de l'élévage (dotation de moyens logistiques, de produits véterinaires) et par une amélioration des infrastructures existentes. La formation d'auxiliaries d'élévage" choisis parmi les éléveurs est aussi encouragée par cet organisme pour l'execution de pratiques véterinaires élémentaires (vaccination, deparasitage, dressage des boeufs de labour, etc...).

6. Restitution de la Matière Organique

Le parc amélioré qui est une variante du système traditionnel de parcage avec la clôture du lieu de parcage et l'apport de fumier ainsi que la confection d'étables fumières sont les deux techniques qui sont proposées en vue de promouvoir la fabrication d'un fumier de quantité et de qualité supérieures.

La mise en stabulation des vaches laitières, des animaux de trait et parfois des bêtes à emboucher, au dela de la fabrication d'un meilleur fumier, constitute un important thème féderateur pour l'intensification et l'amélioration des différentes productions animales dans un système agropastoral. La discussion de ce thème nous donne une opportunité d'illustrer les liaisons recherche/développement pour l'élévage dans un système agropastoral.

VI. CADRE INSTITUTIONNEL DE LA RECHERCHE/ DEVELOPPEMENT

Le CRZ/KOLDA et la SODEFITEX sont dans l'ordre les deux principaux organismes de recherches et de développement qui interviennent dans la zone. Le CRZ/KOLDA est un sous-établissment de l'INSTITUT SENEGALAIS DE RECHERCHE AGRICOLE (ISRA) sous la tutelle de la Direction des Recherches sur les Productions et Santé Animales. Sa vocation est de mener des investigations afin d'apporter des solutions aux différentes contraintes rencontrées par l'élévage dans cette région qui est aussi la zone d'intervention de la SODEFITEX. Cette dernière est une société de développement essentiellement orientée vers la filière coton mais dont les activités connaissent actuellement, une diversification dans le cadre du Project de Développement Rural du Sénégal Oriental comportant un volet élévage.

Des rencontres fréquentes entre les agents de ces deux organismes ont servi de cadre d'échange informel mais très riche ayant permis au CRZ/KOLDA de s'informer des préoccupations de la SODEFITEX et à cette derniere d'être au courant des actions et des acquis de la recherche. Cette liaison CRZ/KOLDA-SODEFITEX évolue favourablement vers la mise au point d'un cadre structure de collaboration.

La SODEFITEX a identifié trois principaux axes de recherche/ developpement pour les productions animales en Haute Casamance. Il s'agit de: i) la stabulation des animaux dans les étables fumières, ii) l'amélioration de l'alimentation du bétail par la conservation des fourrages et iii) le suivi des élévages villageois afin de disposer d'indicateurs de l'évolution de la productivité des troupeaux sous l'impact des innovations introduites.

Ces thèmes qui correspondent en général aux axes de recherche définis par le CRZ/KOLDA dans le cadre de la réstructuration et l'élargissement de ses domaines d'intervention, ont été immédiatement traduits en actions de recherche et aussitôt mises en oeuvre par une conjugaison des efforts de part et d'autre.

La mise en stabulation des animaux de trait, des vaches laitières et dans certains cas d'animaux en embouche dans des habitats appropriés sous forme d'étable fumière a été vite perçue autant par le CRZ que par la SODEFITEX, comme un passage incontournable pour l'intensification des productions animales. Elle s'offre comme une technique de choix dont l'adoption permet à l'exploitant de produire plus et mieux de fumier, d'augmenter la production laitière des vaches, d'avoir des animaux de trait plus performants et d'accroître l'output en viande de son exploitation sans computer ses effets favourables sur la fertilité des femelles et la croissance des veaux. Cette technique constitue ainsi une porte d'entrée ideale menant vers l'élaboration d'un cadre formel de recherche/développement.

A l'issue de l'identification des besoins de la SODEFITEX par le CRZ, ce dernier établit un plan de recherche en deux phases. Il fallait au cours d'une première étape évaluer les niveaux d'adoption de cette innovation et par le même biais identifier les differents obstacles à sa large diffusion. Cette première étude permettait aussi, par une typologie des exploitations, d'identifier celles pour lesquelles une alternative serait plus acceptée (parc amélioré par exemple). Une deuxième phase de rechèrches avait pour cible le suivi des étables fumieres pour en déterminer l'efficacité technique ainsi que pour évaluer l'impact sur les performances animales. Ce suivi concerne les aspects suivants de la stabulation:

- la caractérisation des exploitations ayant adopté l'innovation;
- l'efficacité des modèles d'étables vulgarisés;
- la conduite de la stabulation par les agropasteurs (durée de sejour des animaux, quantité et fréquence de l'apport de litière, etc...);
- la croissance et la production laitière (le poids des produits des femelles en stabulation est aussi mesure);
- la quantité de fumier produite, ses destinations (cultures) et ses modes d'utilisation (période, modes d'épandage ou d'enfouissement). Les quantités de féces produites et de litière apportées sont mesurées;

les performances des animaux de trait sortis de la stabulation sur les chantiers de travail.

Cette opération de recherche est en cours au moment de la rédaction de cet article. Sa conception et sa mise en oeuvre a impliqué dans toutes ses phases les deux organismes de recherche et de développement concernés. Elle constitue ainsi l'ébauche d'une riche expérience de liaison recherche/développement dans un système agropastoral au Sénégal qui jettera les bases d'une collaboration au sein d'un cadre bien structuré de recherche/développement.

VII. CONCLUSIONS

La Haute Casamance recèle un haut potentiel agropastoral malgré l'effet de la sécheresse. Ce systeme de production est le théatre de mutations profondes induites par le développement de la culture du coton qui s'est accompagné d'une large diffusion de l'utilisation de la culture attelée sous l'action de la SODIFITEX. Cette dynamique à conduit à une réhabilitation de l'élévage, secteur auparavant négligé, après une meilleure appréciation de la place qu'occupent les productions animales dans la productivité globale du système de production.

L'insuffisance des programmes de recherche sur l'élévage longtemps catonne en station est en train d'être corrigé par une plus grande ouverture des investigations menées sur les besoins exprimés des clients de la recherche.

L'approche recherche/développement adoptée consiste a traduire en opérations de recherche les préoccupations des organismes chargés du developpement avec une identification commune des contraintes et des solutions alternatives. Cette approche supposant la conjugaison des efforts des deux parties engagées a le mérite de permettre une efficients allocation des ressources de recherche limitées sur des domaines de préoccupation des utilisateurs des résultats de la recherche qui sont ainsi immédiatement valoriés.

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IMPROVED AGROFORESTRY SYSTEMS AND CROP/LIVESTOCK INTEGRATION

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ABSTRACT

The role of trees and improved agroforestry systems in alleviating the numerous agricultural constraints and improving food production is being recognized by various governments and private farmers in Africa today.

This paper presents a brief description of existing and improved Agroforestry Systems for the arid and semi arid zones of West Africa. Interactions and integration of crops, livestock and trees and the role of improved systems in increasing and sustaining agricultural productivity are discussed. Research needs for efficient integration, management and utilization for sustained food and energy production are highlighted.

Donors, governments and private agencies have a major role to play in agroforestry technology development and implementation for improved food and wood production.

I. INTRODUCTION

One of the most serious problems facing the tropical world today is the imbalance between food production and demand. Coupled with the rapidly increasing populations, it is becoming increasingly difficult to meet minimum food and energy (fuel wood) requirements. This situation has put considerable pressure on arable lands leading to increased soil degradation due to continuous cropping, depletion of grazing lands, severe deforestation and environmental degradation reducing the potential for increased agricultural output. (Thrupp, 1981; FAO, 1979).

A careful study of the problems and limitations of the present traditional systems shows that there is need for an improved integrated system that would effectively utilize all available resources for improved food production. (FAO, 1983; Lungren and Raintreem, 1983).

Agroforestry is a sustainable land management system which has the potential for increasing the overall yield of the land; combines the production of trees (ligneous species) with crop and animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local population. (King and Chandler, 1987). The principal objective of agroforestry is the sustainable production of food and wood to meet present and future requirements while conserving the basic resources. The approach is the rational utilization of the improved resources leading to improved ecosystems (Nair and Fernandes, 1985). Efficient application of the agroforestry concept to traditional farming systems would greatly improve food and energy production in tropical Africa.

This paper examines both existing and improved agroforestry systems and discusses possible ways of integrating livestock into these systems for sustained agricultural productivity.

II. EXISTING FARMING SYSTEMS

The majority of farming systems, especially in West Africa, range from the extensive (shifting cultivation and nomadic herding) to more permanent and specialized types of farming (compound farms and terrace farming). Areas with very low population densities still practice shifting cultivation. However, with increased demographic pressures, and high cultivation densities, a large section of farmers practice semi permanent fallow systems. The length of the fallows, depending on availability of land and degree of degradation, range from 3 - 10 years (FAO, 1983; Mohamed-Saleem and Otsyina, 1986). Food crops are grown in specialized associations while cash crops are most often grown in pure stands.

1. Agronomic Practices

The slash, burn and hoe ploughing remain the most common method of land preparation. Although ox - ploughing is rapidly gaining grounds, its use is limited by a number of factors such as limited availability and high cost of suitable implements. Weeding and harvesting are often done by hand or animal traction. Little or no herbicides and fertilizer are used.

2. Farm Sizes and Division of Labour

An important feature of traditional farms is farm size. This is limited by the supply of labour during peak periods and inefficient tools. Farm sizes range from 0,2 - 5 ha per average family. Labour is available in the form of family labour, hired labour and organized labour groups within the community.

3. Livestock Component

Traditional farming systems especially, in West Africa, are centered around a home garden where livestock forms an important component of the system. Animal populations increase with increasing human population densities (Lageman, 1977). This trend seems to be on the increase with increasing populations and higher demand for animal proteins. Small holder farmers often own and manage small ruminants, poultry and small numbers of cattle for draught, milk, manure, transport and most importantly, meat. The animal component of the traditional farms plays a crucial role in the maintenance of soil fertility, without which the permanent farming systems (home gardens and adjacent areas) would be impossible.

Livestock also constitutes a savings account for the family, utilize household waste and fulfil social and cultural obligations (FAO, 1983; Otsyina, 1987). It makes a very significant contribution to farm income. Although livestock plays a significant role in the systems, no specialized feeding management and fodder production systems are developed. Small ruminants and poultry are often left to fend for themselves around the compounds while cattle are usually herded. Small amounts of supplementary feeding is done in the form of crop residues, browse, fresh herbs and household wastes during the dry seasons, when feed quality and quantity become major constraints to livestock production.

Crop/Livestock integration is highly specialized on home gardens where manure is used intensively. Other forms of integration include the grazing of crop residues after harvest, animal traction for land preparation and transportation (Figure 1). Efficiency of integration is very low at present. More efficient systems are required for self sustenance of both intensive and extensive traditional systems.

4. Agroforestry Systems

Traditional land use systems in West Africa are characterized by the presence of economic and medicinal trees, which are deliberately left on crop fields, home gardens and fallow lands through selective bush clearing and land preparation practices.

Fruit trees such as *Butyrospermum parkii, Parkia biglobosa* and *Adasonia petandra* are most frequently found on crop fields in the Guinea savannah zones (SAFGRAD, 1986). Fruits from such trees constitute an important economic resource for peasant families. *Acacia albida,* the magic tree, is most commonly encountered in the Sudano - Sahelian zones. It constitutes an important source of fodder for livestock during the long dry periods (Miehe, 1986; Felker, 1978). Due to its unusual phenological cycle, there is apparently little or no competition for light with the associated crops during the rainy season. These economic trees are usually associated with major crops such as maize, sorghum, millet, yams, cassava and various vegetables.

Tree densities vary among the various ecological zones and depend on the associated crop. Densities range from 50 - 100 trees/ha in the Guinea savanna zone to less than 20 trees/ha in the Sudano-sahelian zone.

4.1 Tree management and interactions

Management practices such as pruning and lopping have been adopted to reduce tree cover and shade on associated food crops. Very little or no other management of the trees is practiced. Sustained food production from associated crops is attained through systematic rotation of crops and fallows, usually 2 - 5 years, to ensure soil regeneration and pest control.

The major interaction between the tree and crop component is through litter and nutrient recycling. Farmers, however, realize and have taken note of favorable and unfavorable tree crop associations. For example, *Butyrosepermum parkii* and cereal crop associations are believed to improve cereal production while association with *Parkia biglobosa* tend to decrease cereal yields (Otsyina, 1987). *Acacia albida* is a tree favourably associated with cereal crops in the arid and semi arid zones due to its favorable phenology, soil improving qualities and fodder for livestock during the dry seasons (Felker, 1978; Miehe, 1986).

Tree crop interactions in the various associations and their effects on either component are not very well investigated and understood. Much more research is needed to clearly understand and improve on the traditional agroforestry knowledge.

4.2 Other Agroforestry Systems

Other than the traditional agroforestry systems, there are introduced fruit, shade, firewood, ornamental and other economic trees planted and managed in and around home compounds and nearby fields. Foods crops are often associated with these plantation trees during early stages of establishment

4.3 System Constraints

Major constraints in the traditional production system include:

a) Low and declining soil fertility resulting in low crop yields.

b) Labour bottle-neck during peak cultivation periods.

c) Competition for land between food and plantation crops.

d) Protection of young trees against animal damage (fencing)

e) Lack of knowledge and understanding of positive interactions of trees on crop and livestock.

f) Low availability and poor quality of fodder during the long dry seasons.

g) Low level of tree/crop/livestock integration

h) Low supply and high cost of fertilizers.

Improvements in efficiency of food production can only be achieved through efficient utilization of resources in the present traditional agroforestry systems and introduction of improved and more efficient systems and practices that are compatible with traditional agronomic practices.

III. IMPROVED AGROFORESTRY SYSTEMS

Due to the rapid declines in food production as a result of continuous cultivation, more efficient low-input agroforestry systems based on biological recycling of energy and nutrients for soil fertility regeneration and sustained food production have been developed.

Alley Cropping

One of such systems is "alley cropping", and agroforestry system developed as an alternative to shifting cultivation (Wilson and Kang, 1981; Kang *et. al.,* 1981a&b). It involves the cultivation in rows, usually 4 - 5m apart, of fast growing leguminous trees, such as *Leucaena leucocephala, Gliricidia sepium* and *Cajanus cajan,* etc. within crop fields. Food and forage crops are grown within the alleys and the trees are pruned periodically to provide mulch and green manure to maintain soil fertility and to minimize shading of the arable crops. This reduces the need for long fallow periods, while making continuous cultivation possible, and enhancing the efficiency of land use. The alley cropping system is widely gaining popularity in many parts of West Africa as a promising agroforestry system. Trials on alley cropping at IITA and ILCA (Ibadan) have shown considerable and consistent increases in grain and residue yields of cereals alley-cropped with *Leucaena* and *Gliciridia* (Figure 2) (Kang *et. al.,* 1980; Atta-Krah *et. al.,* 1986). Similar pilot trials in the semi-arid zones in Northern Benin (Figure 3) showed yield increases of maize and sorghum intercropped with *Leucaena and Cajanus cajan* (Pigeon peas) (OAU/SAFGRAD/BENIN, 1988). The system has shown much promise and has a great potential for adoption by small farmers.

Livestock Integration

The viability and adoptability of alley cropping in traditional systems depend greatly on the degree and efficiency of livestock integration. The possibilities and methods of livestock integration into agroforestry systems has been a major research concern to several institutions including the ILCA Nigeria programmes. The package which integrates livestock into alley cropping is termed "Alley farming" (Sanburg, 1985; Atta-Krah *et. al.,* 1986). The tree species used for alley farming should not only be good for soil fertility, but also be of good fodder value. Although the alley cropping concept remains the same, there is a need for modifications in the management and utilization of the trees to benefit the crops and livestock. A portion of the trees can either be cut and fed to animals as basal diets or as supplements, or grazed (browsed) after crop harvest.

Recent investigations were done into five main cropping systems in Nigeria:

(a) Continuous cropping without trees (conventional farm practice);

(b) Continuous cropping in *Leucaena* alleys;

(c) Grazed fallow/cropping rotation in *Leucaena;*

(d) Cropping/grazed fallow rotation in *Leucaena;*

(e) Continuous alley grazing in *Leucaena* alleys.

Results showed a consistent reduction in soil nitrogen and carbon contents with continuous cropping without trees compared to the treatments with trees. Soils under alley cropping and alley grazing had 35 and 42 percent more N than was obtained from conventional cropping systems after 4 years (Atta-Krah, 1988). Maize grain yields in alley cropping were consistently higher (40%) than yields under conventional cropping (Figure 4). With progressive grazing, maize yields became consistently higher in the grazed fallow/alley cropping rotation system (figure 5). The improvement in soil fertility status and maize yields was attributed to the additional organic matter and nutrients from pruning and manure from grazing animals.

Alley farming thus has a great potential for direct integration of livestock. Management of the trees, including time and frequency of cutting, proportion of prunings to be retained as manure and fodder, grazing pressure during growing periods and stocking rates to prevent tree damage need to be investigated in detail.

2. Fodder Bank/Feed gardens

Fodder bank is a concentrated unit of planted leguminous (herbaceous and shrub) species primarily managed and reserved for dry season feed supplementation of livestock (Saleem, 1986). Otsyina *et. al.*, 1987). The practice, developed by ILCA, is rapidly gaining popularity among traditional farmers in the humid and subhumid zones of West Africa. Reports (Otchere, *et. al.*, 1985) showed significant livestock gains in supplemented animals on stylo fodder banks. A further development of the fodder bank concept is the utilization of the soil nitrogen build up by the legumes for cereals through legume based cropping. This involves a systematic rotation of cereal crops on fodder banks with minimum fertilization. This allows continuous crop and fodder production on the same piece of land while minimizing grass invasion of the fodder banks.

Crop yields have been shown to increase by 40% following two to three years of *Stylosanthes* fodder banks (Saleem *et. al.*, 1986). The increase was attributed to the increase in organic matter and nitrogen build up from the legumes and manure from the grazing animals. This practice also offers direct integration of livestock and crops.

3. Mixed Cropping

In this system, trees are planted in regular or irregular patterns in association with food crops for the value of their fruits, soil conservation properties, fodder, fuel wood and cash. A good example is the *Acacia albida*/ cereal associations in the Sudano-Sahalian zones of Africa. *A. Albida,* by virtue of its phenology, provides nutritious fodder for livestock during the hot dry seasons. Animal manure and urine rejects are recycled into the soil during the grazing process. Research is underway to improve the existing *A. albida*/cereal systems and to continue to introduce it to more humid zones of West Africa.

Trials in Benin involving *A. albida* and *Leucaena leucocephala* in association with sorghum and cowpeas have shown significant increases in cereal yields in the associations compared with pure stands (Figure 5). Thus, in arid and semi-arid areas, where tree growth is slow and unsuitable for frequent tree pruning, such systems would prove very efficient for crop livestock integration.

4. Other Improved Agroforestry Systems

Other agroforestry practices of major interest in Africa include: woodlots, boundary planting and wind breaks. Among the numerous advantages, the supply of fuelwood and fodder seems to be the most important to the small farmer. Woodlots can be established on individual farms or on communal lands. During early stages of establishment, palatable grasses and legumes could be undersown to provide valuable fodder as well as to improve soil fertility.

IV. IMPLICATIONS AND RESEARCH NEEDS

Introduction of improved agroforestry systems and practices such as alley farming, mixed intercropping, and fodder banks that effectively integrate livestock would greatly improve efficiency of land use as well as utilization of available resources to the household. They will also bring about self sufficiency in food, meat and energy (fuel wood). However, due to the slow adoption of new technologies by traditional farmers, a great deal of work and effort is required to develop simple, compatible, and adoptable establishment, management and utilization strategies that would minimize labour input. Socio-ecological as well as technological factors need to be seriously considered in developing such packages.

Experiences with on-farm alley farming trials (Francis and Atta-Krah, 1989) pointed out factors such as poor utilization, incompatibility of established cropping patterns and rotation practices with the planting of trees on farms and tree tenure rules, as affecting the adoption of the package.

African farmers are very much aware of the economic and soil regenerating roles of trees; what is lacking is the technology of efficiently integrating this knowledge into the present farming systems.

Current on-station and on-farm research in the major international and some governmental institutions is directed to:

a) Selection and improvement of trees for specific environmental conditions;

b) Manipulative management of trees for specific systems;

c) Competitive and complementary interactions in tree/crop/ livestock associations;

d) Short and long term soil effects and plant nutrient requirements and water relations.

Serious extension and on-farm experimentation through a systems research approach is required to effectively introduce the new agroforestry technologies into the traditional systems.

V. CONCLUSION

Agroforestry appears to be an ideal system with great potential for food and wood production as well as environmental protection in both humid and arid zones of Africa. It is a direct solution to the constraints of shifting cultivation and ensures sustainable production of food and wood. Trees should as far as possible be involved at all levels of farming systems development.

Agroforestry systems, such as alley farming, mixing intercropping and fodder banks that include browse species hold much promise in the tropics.

As already pointed out, research through on-farm trials and effective extension are very much required to develop and improve agroforestry systems and integrate them into existing farming systems. Donor agencies, governments as well as co-operative and private agencies have an important role to play in ensuring the development and extension of such technologies through adequate financing, policy formulation and extension.

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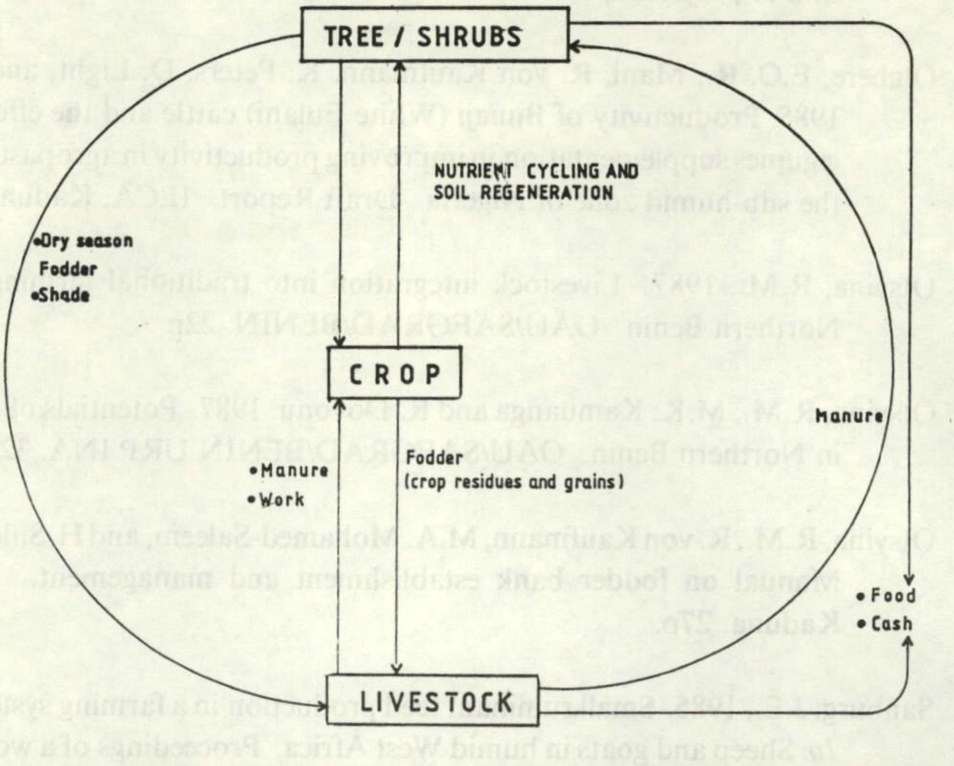

FIGURE 1: Interrelationships among trees, crops and livestock in a typical integrated system.

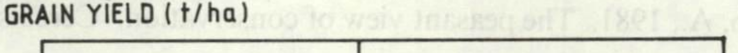

Figure 2: Grain yield of maize variety TZPB as affected by nitrogen application and 6 years of alley cropping with *Leucaena leucocephala* (Kang and Duguma, 1985).

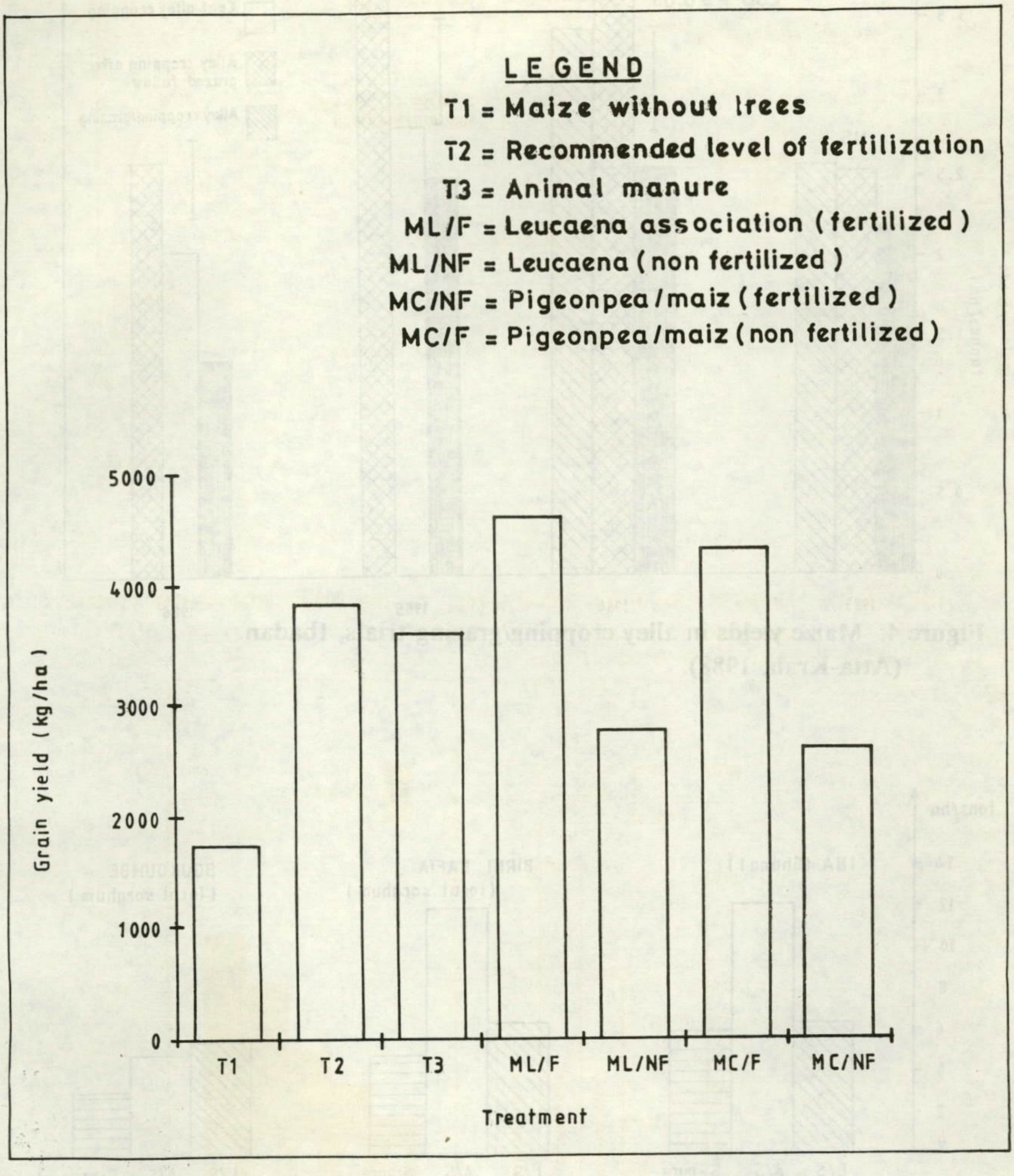

Figure 3: Grain yields of maize (TZB) alley cropped with leucaena and pigeonpea compared to various controls at Alafiarou.

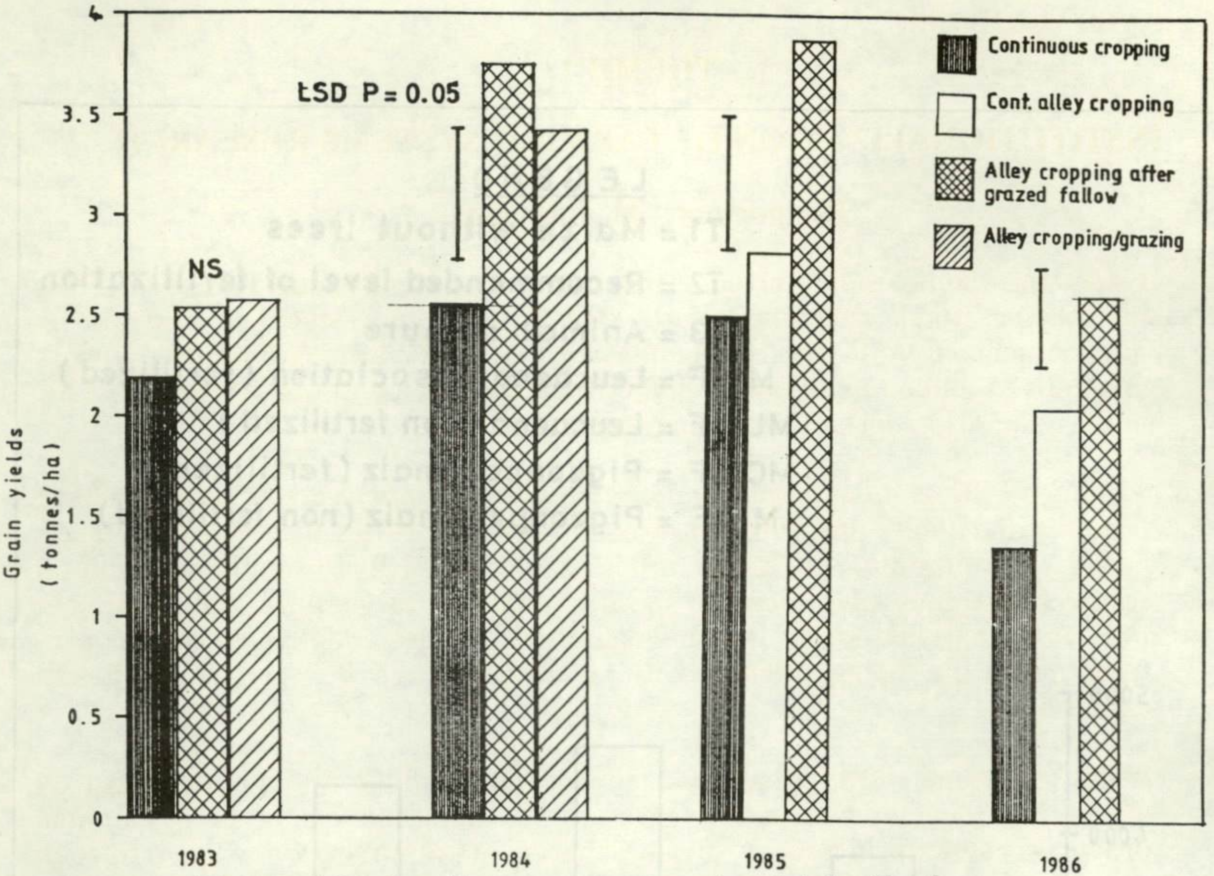

Figure 4: Maize yields in alley cropping/grazing trials, Ibadan. (Atta-Krah, 1988).

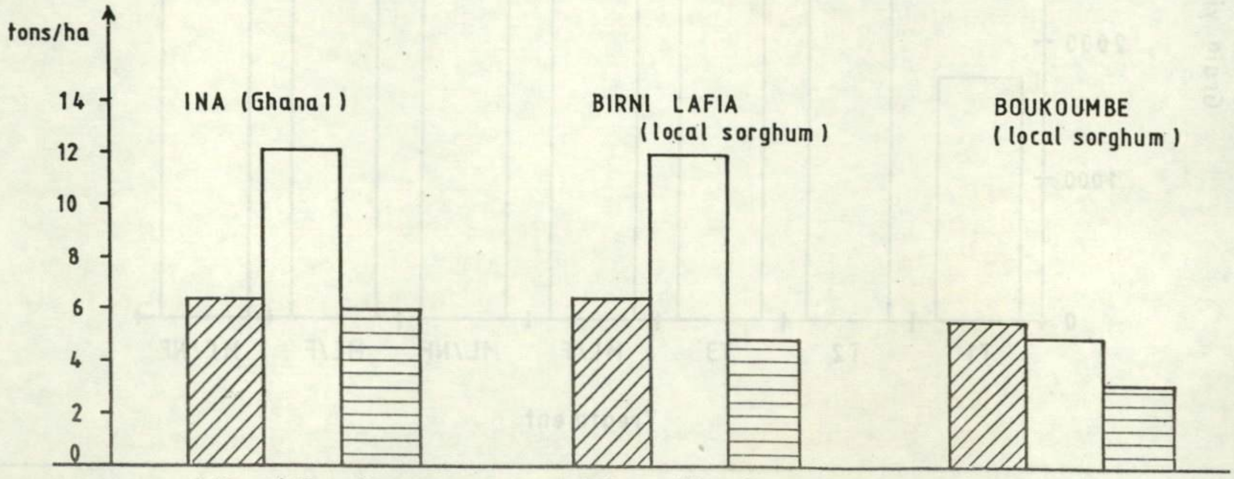

Figure 5. Yield of sorghum (Ghana 1) in association with *leucaena* (L) and albid (A) at three sites in Benin (1987).

THEME 1

INSTITUTIONALIZATION OF FARMING SYSTEMS RESEARCH

Rapporteur: M. Kamuanga

1.1 Under this theme, topics included the role of Farming Systems Research (FSR) in shaping food and agricultural policy, the experience of Nigeria in institutionalizing FSR, the role of the West African Farming Systems Network (WAFSRN) and an overview of SAFGRAD approach and management of FSR in the semi-arid zones of three member countries.

1.2 Although FSR as an approach and a philosophy to agriculture is known to have begun in the 1950's and 1960's, it was not until the 1970's that specific projects began to proliferate. In Nigeria, Senegal and Mali for example, agricultural research institutes have received specific mandates to organize and implement FSR at the national level. In many countries, on-farm adaptive researches (on-farm trials) are being promoted as an effective link between research and extension.

1.3 In his lead paper, Prof. Abalu pointed out that for FSR to have an impact on agricultural development and contribute to the achievement of sustainable production systems in Semi-Arid sub-Saharan Africa, practitioners need to seek ways of reforming existing infrastructural and institutional support services, while promoting the generation and adoption of relevant and improved technologies. In the short run, given the fixity of resource endowments, institutional economic environment, FSR should, in addition to the promotion of improved technologies, identify, and analyse institutional constraints and communicate, quickly and effectively, the findings to appropriate agricultural administrations. In the medium and long runs, FSR would need to help shape technical, economic, social and environmental policy options in order to effectively support new technologies.

1.3.1 It may be difficult, however, for FSR practitioners to tackle the micro-macro linkages and bridge the gap as technicians and policy analysis at the same time. In response to this concern, it was pointed out that the perception of FSR as simply micro research is seriously limiting the effectiveness of its output. Economic analysis in particular needs to embrace aspects of policy that are likely to affect the sustainability of improved production systems.

1.3.2 Improved technologies that are profitable to the farmers today may cease to be so tomorrow. It is therefore the duty of FSR economists to advise biological scientists on the effect of price changes with regard to technical choices. Social scientists need to keep the momentum, which resulted in their acceptance as equal partners in agricultural research as a result of their contribution to technology design, and the identification of socio-economic constraints to adoption.

1.3.3 Another question discussed referred to the appropriate time a country should engage in FSR activities. In response, it was pointed out that this depends on historical development, availability of research results from commodity and thematic programmes, availability of qualified manpower, etc. Nevertheless, FSR as a biotic approach to agricultural research should at anytime permeate all research programmes. Scientists must have a team perspective as, they are coming from different disciplines.

1.4 SAFGRAD's support to FSR country programmes dealt mainly with (1) the transfer of research methodology from the Purdue University FSU project in Burkina Faso (1979 - 1986), (2) the integration of an agro-ecological conceptual framework of resource based disciplines (agronomy, soil science, socio-economics, agroforestry) to agricultural production systems and (3) bringing together on-station scientists and development practitioners, to improve testing of technological innovations.

1.4.1 SAFGRAD's experience over the 1980 - 1989 period should be documented for the benefit of future country programmes. IFAD's phasing out of its financial support of SAFGRAD/FSR programmes, should not be interpreted as a signal that other donor agencies will follow suit. The evaluation team has recommended the continuation of support to FSR programmes, although preference will be given to the support of network to enhance host country FSR capacities. A major setback of the SAFGRAD/FSR programme has been the failure by host countries to provide counterparts to the technical assistants. This in itself has adversely affected an important aspect of FSR institutionalization. A particular lesson learned is that, some donor agencies are not capable or willing to support FSR beyond 3 - 4 years, despite the fact that research is generally a long-term undertaking.

1.5 Despite the fact that FSR has been successfully institutionalized in countries such as Nigeria, farmers are still using traditional methods of production, even where improved technologies are available and government policies, favourable. In view of this situation, what avenues can FSR practitioners offer to commodity researchers in the pursuit of their programmes? In response, it was pointed out that technical options cannot be expected to be adopted by all farmers at the same time, because there are differences in farmers' own technical capabilities and resource endowment. Commodity and thematic researchers should provide alternative technical options. i.e., development of varieties and agronomic practices for low, moderate and high level of inputs, in order to present different farmers with alternative choices.

THEME II

FSR COUNTRY EXPERIENCES

Chairman: J. Faye
Rapporteur: Robert Otsyina

The session started with a comprehensive account of the FSR experience of the SAFGRAD team in Cameroon. It noted three distinct objectives:

a. Development of agricultural technologies adapted to local conditions.

b. Technology transfer through on-farm trials.

c. Strengthening of national Farming Systems research capability.

Soil fertility and moisture deficit were identified as major constraints to crop production. These constraints were tackled through experiments (on-farm and station trials) with animal manure utilization and tied-ridging, improved variety screening and agroforestry practices.

Major achievements include among other things, improvement in inter-departmental collaboration in the national institutions.

Discussions following this presentation, indicated a very favorable support for the achievements as a good example to other country programmes. The use of manure and crop residues as alternative sources of fertilizer was discussed in detail. It became very clear that amounts of manure produced by the few animals managed by average farm families are too small to fertilize large (3 - 5) hectares. The competition between the use of crop residues for fodder and manure was highlighted.

The second speaker, *Dr. Fobasso* presented results of on-farm variety trials with peanuts, cowpeas, millet and sorghum in Northern Cameroon. Screening and preference trails led to the selection of CS 35 (improved variety) over the local.

Soil tillage practices such as tied-ridging gave good results. There were good indications that farmers are already adopting agronomic practices such as associations with long cycle varieties even before recommendations by researchers. However, farmers were reluctant to apply fertilizers to sorghum which was supplied by SODECOTON for cash crops. The average farmer could not afford fertilizers for food crops. In conclusion, he pointed out that improved varieties improve total food production.

The third speaker, *Dr. N'Gam (CNRADA)* presented FSR activities in Mauritania. After a brief description of the study areas, and its potential for crops and livestock production, he went on to describe FSR activities initiated by the University of Arizona in 1985. Detailed FSR activities were preceded by reconnaissance surveys along the river valley, which is the agricultural area to identify suitable agronomic practices and methodologies which could be introduced to other parts.

The FSR process has began with surveys and sums through pre-extension trials of promising technologies. This approach seems to hold good promise and would allow better understanding and collaboration, among the various institutions concerned.

The final speaker, *Dr. Mahaman Issa* briefly described in detail FSR activities in Niger. The major objectives of the FSR activities include:

a. Identification of constraints and technologies.

b. Social acceptability of improved technologies and their influence on improving living conditions of peasants.

Major constraints limiting their activities were severe lack of financial and human resources.

Despite these constraints it was concluded that: (a) there was good reception of new technologies introduced (b) Facilities and implements were severely lacking (c) The need for the development of improved technologies was a necessity.

Conclusions

In general the session presented important problems in farming systems research through on-farm trials in the Semi-Arid tropics.

The major constraints of soil fertility degradation, moisture stress and lack of appropriate technologies were highlighted by all speakers.

Farming systems research in the various countries thus seems to be at preliminary stages. More efforts are required in developing improved technologies for sustained food production.

Recommendation

Intensification of farming systems research activities in more countries and institutions.

Continued evaluation and dissemination of research results and problems should be encouraged through regular workshops and seminars.

3. Technologies developed and tested in one country should be replicated or introduced into other countries with similar agro-ecological conditions through FSR.

4. Financial and technical support for the various institutions to encourage more on-farm trials and extension is inevitable.

5. In order to be able to extrapolate results across countries, a well defined concept and methodology of FSR will have to be established by SAFGRAD in collaboration with researchers from various country institutions.

COUNTRY FSR - RECOMMENDATIONS

1. There is a need for uniformity in conceptualization and methodology of farming systems research, first at the national level and then among countries.

2. Need to accelerate training of FS research personnel to strengthen farming systems research in the various countries.

3. Considering the frequent adverse climatic changes such as drought stress, there is a need to characterise agro-climatic conditions. The PAN EARTH project proposal is very welcomed. It should help in building regional capabilities in characterising the climate in relation to agricultural production, modelling and interpretation of micro climatic changes in relation to food production.

4. In order to combat identified constraints and achieve sustainable agricultural production, there is a need to encourage efficient integration of all agricultural sub-systems, i.e. crops, trees and livestock components.

5. Since farming systems research is a long-term involvement, national governments and donors should also have long-term commitment to develop sustainable agriculture through farming systems research.

6. Due to over reliance on donor agencies, there is a need for core funding for SAFGRAD/FSR activities from well to do and benevolent African nations and well-wishing individuals for continued development of farming systems research in Africa.

RAPPORT DE LA SESSION III

Développement d'une agriculture viable

Les résumés présentés ci-dessous sont basés sur les notes prises pendant la présèntation de chaque rapport. Ces différents resumés tentent de soulever seulement d'une vue générale de la session les points saillants. Tous les rapports présentés par les intervenants ressortissants de Burkina Faso, de la Côte D'Ivoire de l'IITA/SAFGRAD et du Nord Benin, étaient sous une forme plus ou moins semblables et leur dénominateur commun était le dévéloppement d'une agriculture viable dans les zones semi-aride tropicale d'Afrique.

1. Burkina Faso: *M.P. Sedogo*

La communication présentée par cet intervenant relative á ce pays, porte sur l'amélioration de la production du sol au Burkina Faso. Les travaux ont été réalisés à Fara Koba et à Saria. Face aux contraintes pluviométriques et à la pression démographique, il fallait chercher de voies et moyens pour pallier à la dégradation de sol. L'accent a été mis sur plusieurs points principaux, visant la garantie de la fertilité du sol et al stabilité de rendement. Parallelement à la dégradation de la matière organique, on assistait à une augmentation de l'acidification de sol, dont plusieurs méhodes de lutte ont été envisagées à savoir entre autre l'utilisation de phosphate. Cette méthode n'a pas abouti à un résultat concluant. D'autres études ont été conduits sur les principaux éléments fertilisants. Les filières de la matière organique ont été étudiées et les critères d'appréciation ont été évalués. Plusieurs techniques sur l'économie de l'eau ont été mises au point et les orientations d'une manière générale ont été préconisées.

2. Cote d'Ivôire: *S. Doumbia*

La rapport de la Côte d'Ivoire a présenté une étude de systèmes de production améliorée dans le nord du pays axée sur la culture en couloirs. Ce type d'agriculture est caractérisé par un équilibre souvent satisfaisant entre population rurale, fertilité naturelle des sols et production vivrière. L'accent a été mis sur les techniques d'amélioration de la productivité du sol grâce à plusieurs méthode à savoir: la protection contre les feux de brousse, le choix des espèces pour la culture en couloirs en Cote d'Ivôire. Il faut noter que, l'introduction de la culture en couloirs entraîne deux types de modifications à savoir: l'amélioration de la productivité et celle du potentiel fourrager. Certaines contraintes sortout relatives à la main-d'oeuvre ont été identifiées. Les difficultés d'ordre soiologique et psychologique ont été aussi identifiées et plusieurs carences en éléments nutritifs ont été étudiées.

3. IITA/SAFGRAD: *J. M. Fajemisin*

Ce rapport ouvre une autre perspective sur le développement d'une agriculture viable: mise au point de variétés précoces de maïs et, potentiel pour l'augmentation de la production dans les zones de savane semi-arides. La zone a été divisé en trois, en fonction de la pluviométrie et de la longueur de celle-ci. On distingue la savane nord Guinéene, caractérisé par une pluviométrie variant de 900 à 1200 mm et une saison de culture allant de 4 à 5 mois, la savane soudanienne caractérisés par, une pluviométrie allant de 600 à 900 mm et une durée de culture de 3 à 4 mois et enfin, la savane sahelienne avec une pluviométrie allant de 300 à 600 mm dont, la durée de la saison varie de 2 à 3 mois. Un certain nombre de variétés a été développé et identifié pour les différentes zones écologiques ci-dessus citées. Le développement de variétés précoces est aussi un moyen écologique efficace afin de contourner les courtes saisons de pluies dans la culture de maïs dans la savane semi-aride. Les Institutions Internationales de recherche comme le SAFGRADE, l'IITE, et CIMMYT ont développé avec succès de variétés précoces, à haut rendement. De plus des efforts sont en cours pour l'amélioration de variétés précoces à haut rendement dans les conditions de sécheresse et aussi de résistance aux différentes maladie foliaries. Les techniques de conservations d'humidité et de fertilité du sol doivent accompagner l'amélioration de variétés précoces qui représente une seule composante vitale du paquet technologique dans le systéme de production. Donc l'adoption de variétés précoces, résistantes à enstruire du maïs avec les pratique de conservation d'eau du sol et de la fertilité par les paysans de la zone simi-aride ouvre un potentiel excédentaire de 1,24 million d'hectares réprésentant 41% d'augmentation pour la production de 1,83 million de tonnes.

4. ICRISAT: *S.V.R. Shetty*

Ce participant de l'ICRISAT a été absent et a donné le rapport relatif au rôle de systèmes de culture basés sur le sorgho pour le développement d'une production vivrière dans la zone soudanienne. Il ressort de ce rapport que les sources de variation dans la production du sorgho dans les zones semi-arides tropicales de l'Afrique de l'Quest restent la pluviométrie et les sols. Afin de comprendre le gap qui existe entre les rendements obtenus en stations et ceux des champs de cultivateurs, les premières recommendations doivent être identifiées et rédéfinies en fonction de différences agroclimatique et socio-économiques. L'expérimentation en milieu réel doit fournir un feed back avant la recommendation d'une technologie pour une adoption à grande échelle. Cependant, la généralisation de technologies à travers les zones semi-arides tropicales en Afrique de l'Quest est impossible, à cause de la diversité agro-climatique et de conditions démographique. Le faible transfert de technologies de la station vers les paysans montre l'importance de la fortification des programmes nationaux de recherche.

5. RSP/Benin: *M. Kamuanga*

Ce rapport présenté par Kamuanga a une particularité en soulignant le développement technologique dans la production de culture et l'évaluation de ressources limitées dans le cas du nord Benin. Il a fait la compariaison de quatre types de cultivateurs qui sont: les paysans non producteurs de coton et ne possedant pas de traction animale (27%), le 2e type les paysans qui font la culture manuelle (40%), le 3e type représentant les paysans possédant plus de 5ha de terre dont la moitié est reservée à la culture cotonniére (84%) et enfin le 4e type les paysans utilisant la traction animale, maïs ne reservant que 0.6 ha à la culture cotonnière. La comparaison de ces 4 type suggère que les efforts doivent être orientés vers les paysans dy type I, II et IV. La traction animale et al culture de coton sont hautement correlées avec revenue élévés. Les cultures majeures sont le sorgho, le manioc, le petit mil et le haricot. Il a été trouvé que la variété de maïs avec sorgho local. Le billonnage et l'application d'engrais augmentent le rendement grain de sorgho associé au niébé de plus de 30%. Le crotalaire planté comme angrais vert augmente le rendement de maïs de 45% lorsqu'il a été incorporé dans le sol au deuxième sarclage. Sor les sols pauvres ou dégradés, l'application de faible dose d'engrais chimique (30 kg/ha d'azote) avec un complément de 5 t/ha de fumure est aussi valable que l'application de 60 kg/ha d'azote. Aucune difference significative n'a été observée en matière de travail lorsqu'on plante sur billons. En utilisant la traction animale dans la confection de billons, résulterait à la réduction du travail exigé et d'accoroître la productivité. Vu la conjoncture actuelle dans la culture cotonniére, des efforts importants seraient orientés vers l'amélioration des infrastructures du marché pour les cultures céréalières et légumeuses.

RESUME DE DISCUSSIONS

Question: Rodriguez a demandé si la recherche nationale au Burkina Faso a recommamdé l'utilisation de billons cloisonnés à la Vulgarisation.

Reponse: Sedogo a répondu en disant que les travaux menes dans le domaine de billons cloisonnés au Burkina Faso pendant 5 à 6 ans ont donné des résultats très concluants et actuellement il recherche un matériel végétal adapté aux billons cloisonnés, un appareil propice à la confection de billons, lesquels font partie de thémes d'intensification dans les méthodes de production au Burkina Faso.

Une deuxième question concernant le phosphate. Beauxoup de travaux ont été faits dans le phosphate et qu'en est'ele de leur utilisation. Le problème le plus important concernant le phosphate a été de savoir comment l'utiliser totalement ou partiellement, la détermination des zones appropriées. Mais il s'est posé le probléme d'acidité. Il ya de prévision pour l'installation d'une unine de traitement de ce phosphat et aussi de possiblité d'eétude de la réaction de ce phosphate avec la matière organique au laboratoire à Zaria.

Question: Sidi a demandé à Doumbia comment ont-ils fait pour résoudre le probléme entre les éleveurs et les agriculteurs, et d'autres intervenants ont posé de questions sur le probléme de la gestion de paturage, de la nature des animaux et de problémes du fourrage.

Reponse: Il a repondu en disant que, la Côte d'Ivôire n'avait pas de tradition d'élevage et les paysans n'avaient aucun droit sur le pasturage, d'où une gestion individuelle est impossible, alors que l'exploition est communautaire.

Question: Comment est-il possible que le maïs remplace le sorgho et le mil alors qu'il est difficile pour le maïs d'avoir de bons rendements à cause de sa sensibilité à l'humidité due aux conditions pluvio-métrique erratique dans les zones semi-aride?

Reponse: La décision d'adoption du maïs précoce est faite par le paysan, la variété adoptée est de TZB (SR).

Question: Rodriguez a demandé à Kamuanga qui a suggéré l'utilisation de billons cloisonné au nord Benin, y avaient-ils des essais avant cette recommendation?

Reponse: Les billons cloisonnés au nord Benin en 1987 n'ont pas eu des résultats interprétatbles à cause de beaucoup d'érosion, d'inondation, d'où la non recommendation aux payans.

Le culture associée du niébé dans le nord Benin: sont-elles de pratiques de paysans ou de test de nouvelles technologies?

Response: Le niébé dans les pratiques paysannales est semé comme culture secondaire, associé avec le sorgho.

Question: Quel est le probléme de main-d'oeuvre soulévé dans la présentation.

Response: La main d'oeuvre constitue un goulot d'étranglement dans la mesure où l'utilisation de la traction animale pourrait donner de possibilité de faire plus. Donc, il ne faut pas confondre d'une façon générale, que la culture d'igname a le problème de main d'oeuvfre qui ne se pose qu'au moment de la confection de buttes et qu'il existe beaucoup d'activités parallèles.

Question: Qu'en est-elle de la supériorité des variétés de l'ICRISAT par rapport aux variétés locales?

Reponse: Les rendements se trouvent dans le rapport avec les noms de variétés concernées.

Dr. Taye a terminé la session en disant que l'interaction de l'activité de systéme de production montre qu'il est difficile de les résumer.

EXPOSE DE NTARE

Le diagnostic de la situation agricole des principaux pays producteurs de mil (NIGERIA, NIGER, MALI, NORD CAMEROUN) revèle une augmentation des superficies en mil, mais une stagnation voire une baisse de rendements.

La faible fertilité des sols, la sécheresse et les problèmes de calendriers culturals semblent etre les principles raisons à la base de ces performances médiocres.

Au nombre des recherches en vue d'améliorer ces performances on peut citer:

i). la gestion de la fertilité des sols.
ii). l'amélioration - de la structure des sols par le labour.
iii). l'approche systèmique des problemes au niveau de l'exploration.

Pour chacun de ces types de recherche, les premiers résultats peuvent être resumés de la manière suivante:

a) on observe une meilleure reponse des cultivars améliorés de mil à l'engrais notamment au cours des années à bonne pluviométrie.
b) une meilleure efficience de l'eau à des niveaux de fertilité élévés
c) l'intérêt des labours de fin de cycle.
d) l'intérêt du choix de bons cultevars, de techniques culturales améliorés s'est avère payant.
f) Enfin, il est important de tenir compte de la compatibilité entre espèce dans le cas des association culturales.

Question

Cet exposé a suscité deux types de questions -

Le premier concerne les problèmes liés à la gestion des associations culturales dans laquelle rentre le mil de second types à trait essentiellement aux objectifs commandant la production de niebé.

En ce qui concerne la gestion des associations culturales, il apparait que .

1) les niebés associés au mils sont traités aux moins deux fois, pour maitriser les insectes à la floraison et après la floraison

2) Dans de telles associations, très peu de paysans pratiquent le labour ils cultivent à la daba et sont assez souvent confrontés aux problèmes de mauvaises herbes - La culture attelée peut être une alternative intéressante dans la lutte contre les mauvaises herbes.

EXPOSE DES PARTICIPANTS DE GHANA

Dans son exposé, le représentant de GHANA, après avoir caractérisé sa zone d'intervention et procédé à quelques définitions de termes agronomiques dans un souci de clarification, a insisté sur l'augmentation de la productivité du sol comme principal remède à la pauvreté des sols.

Les pripales cultures pratiquées dans la region sont le sorgho, le maïs, l'igname, l'arachide, le mil et le niébé - L'intervenant a par ailleurs insisté sur l'importance des cultures associées qui de toute façon ont la preférence des paysans.

Au nombre des principaux résultats acquis à ce jour, on peut retenir:

-le fait que l'igname soit très sensible à l'effet précédent cultural.
-le fait que l'effet des léguimineuses se limite uniquement dans la rotation à fourniture de l'azote.
-la nécessité d'apporter du phosphate à culture de légumineuse.
-l'effet bénéfique de l'association arachide/sorgho sur l'améloration de la productivité du sol et enfin, l'identification d'un modèle de rotation satisfaisant dans le contexte local - les cultures successives de cette rotation sont:
-arachide
-maïs
-igname
-sorgho

Etant donné le caractère trés détaillé de cet exposé nous ne retiendrons qu'un seul type question à titre d'example.

En effet, le DR. RODRIQUEZ a posé la question de savoir comment l'intervenant pourvait expliquer l'échec relatif de la culture des maïs associe à l'arachide.

La réponse est qu'il a été observé que la succession arachide/maïs est bénéfique, mais pas l'association.

Etant donné le caractère délicat de la conduite des associations, la grande majoritées des questions enregistrées sont toutes relatives à des aspects de gestion.

Il a été notamment question de préciser la nature des traitements insecticides, leur nombre, l'époque d'applicaion et leur éventuelle spécificité.

Il ressort ainsi de l'expérence du Nord Togo, qui:

-le niébé dans l'association est traité avec un produit adapté, non toxique car les feuilles du niébé, sont consommés par les humains
-le niébé reçoit ainsi trois traitements

Les produits spécifiques au coton ne sont appliqueés sur cette culture que apres la récolte du niébé.

Malgré l'efficacité des produits de traitement du niébé, ces produits sont differents des produits insecticides utilisés Pour le coton, et il a été confirmé par l'orateur que les insectes parasite du niébé sont différents de ceux du coton.

On peut constater avec quelque regret que, malgré l'importance économique de niébé, cette culture continue d'être considéré par le paysan comme une culture secondaire.

Les problèmes rencontrés dans le stockage du niébé ne suffisent pas de l'avis de l'auteur à expliquer cette situation.

Cotton-cowpea rotation north Togo is very good (financially too) for the small farmers, but the crop association needs further refinement to satisfy the concerns of the cotton producing industry SOTOCO.

EXPOSE DE M. KABORE

Cet exposé, étant donné l'arivée à terme du project RPA peut être considéré comme faisant le point de plusieurs années de recherche - Ce caractère synthétique nous est clairement apparu dans l'exposé de M. KABORE, et pour respecter cet esprit, je ne rentrerai donc pas dans des details.

Il est également clairement apparu que l'eau et sa gestion ont representé l'un des principaux problèmes au cours de ce projet - A cela on peut ajouter l'introduction de variétés améliorées.

On peut retenir au niveau de la gestion de l'eau:

-que les billons cloisonnés permettent une meilleure infiltration de l'eau au frunant le ruisselement.
-que la technique des billons s'est avérée supérieure à celle du sémis à plat.
-que le grattage du sol, s'il permet une meilleure infiltration de l'eau, ne réduit pas la suscéptebilité de l'eau à l'érosion.
-que le facteur travail apparaît être le principal facteur limitant du billonage.

En ce qui concerne l'introduction de variétés amelioreés, les principaux résultats peuvent être resumés de la façon suivante:

-les trois variétés de sorgho introduites en milieu paysan se sont montrées aussi productives que les variétés locales dans les conditions du paysan.
-les résultants ont été moins probants pour le mil et le maïs dont deux variétés ont eu des performances inférieures à celle des variétés locales.

AU NIVEAU DE L'EXPOSÉ DU DR RODRIQUEZ

Le Dr. Rodriquez a réduit son intervention au seul cas des maïs et a insisté sur la diversités des terminologies permettant de définir les différentes zones climatiques.

Il a ensuite cités les différents facteurs impliqués dans la sécheresse qui sont:
Faible pluviometrie

Sol peu profonds

avant d'inventorier les moyens de reduction de la sécheresse - Ces moyens sont:

-la pratique du labour qui permet une meilleure infiltration de l'eau.
-l'augumentation de la capacité de stockage de l'eau des sols.
-le calage des cycles.
-Les questions se sont rapportées presque toutes à des aspects de détail concernant les techniques permettant de réduire les effets de la sécheresse.
-La question a été posée de savoir si l'orateur était d'accord avec le fait que ces résidues étaient des réperés de parasites, et comment ils étaient enfovis en milieu paysan?

Le fait de brûler les residus céréaliers étaient à l'origine de la dégradation des sols a repondu Dr. Rodriquez qui reconnu que ces residus devaient être utilisés comme du paillis étant donné la difficulté d'enfouisement.

-A propos des billons cloisonnés l'orateur a estimé que cette technique favorise les rendements sur le coton, petit mil et l'arachide, il a reconue l'existence possible d'effects négatif des billons cloisonnés sur le maïs.

RECOMMENDATION

Considérant l'importance de l'amélioration de la production du sol dans le développement d'une agriculture viable, l'atelier recommande qu'un accent particulier soit mis sur l'utilisation de matière organique et du phosphate natural afin de maintenir le niveau de la fertilité dans un systèmé d'exploitation intensive et encouragé par ailleurs l'utilisation de cultures en couloirs comme une alternative.

Considérant les résultats des travaux effectués en milieu paysan dans les dernières années et vue les difficultés rencontrées dans certains domains dans le développement d'une agriculture viable, l'atelier recommande qu'un accent soit mis sur les varietés locales on sur les techniques culturales existantes.

De ce point de vue les techniques relatives aux cultures associeés mériteraient plus d'attention, en égard à leur caractère bien adapté aux conditions de la petite exploitation.

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1992-03

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OAU/STRC - SAFGRAD

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