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FOOD GRAIN PRODUCTION IN SEMI-ARID AFRICA

COUNTRY REPORTS AND RESEARCH PROGRAMMES

PRESENTED AT THE INTERNATIONAL DROUGHT SYMPOSIUM

Editors

Joseph M. MENYONGA

Taye BEZUNEH

and

Anthony YOUDEOWEI

SAFGRAD
SEMI-ARID FOOD GRAIN RESEARCH AND DEVELOPMENT

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FOOD GRAIN PRODUCTION

IN

SEMI-ARID AFRICA

COUNTRY REPORTS AND RESEARCH PROGRAMMES.

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PREFACE

The food grains, namely Sorghum, Millet, Maize, Cowpea and Groundnuts are the staple food items of the people who live in the semi-arid regions of sub-Saharan Africa. Production of these food grains in sufficient quantities to meet the increasing demands of the rapidly expanding rural and urban human populations there continues to face many constraints, including the hostile and harsh climate, serious and continuous degradation of the fragile agricultural resource base and recurring droughts. These problems are further compounded by poor infrastructures, marketing systems, weak national research policies and programmes and extension services which receive relatively little support from national governments.

While local farming technologies are often sophisticated and contain valuable components for farming under high risk environments, these technologies also require important modifications to cope with the problem of sustained food grain production under an increasingly permanent farming system. The increased international awareness of Africa's food problems has given rise to more intensive research and development activities funded by a multitude of foreign donors and implementing agencies operating through national and bilateral agreements. Unfortunately, there is very little coordination of research activities within the region thus leading to considerable duplication of efforts. Within the semi-arid zone of Africa, one crucial role of SAFGRAD is to coordinate agricultural research and development efforts for the major food grains on a regional basis in order to substantially increase the quantity and quality of these food grains, and to minimise duplication of research in the semi-arid zone of sub-Saharan Africa.

During the International Drought Symposium organised by SAFGRAD in Nairobi, Kenya, in May 1986, one important activity was the presentation of country papers which attempted to review national agricultural research policies and priorities and document the state of agricultural research regarding dryland food grain production. The session provided the opportunity for national scientists to become aware of the current status of agricultural research in other semi-arid African countries and to exchange technical knowledge and experiences about food grain production in drought prone areas.

This publication is a collection of the 12 country reports which were presented together with records of the discussion of some of the reports, and the full list of participants at the Nairobi International Drought Symposium.

A second publication of the proceedings of the drought symposium will appear as a book, "Food Grain Production in Semi-Arid Africa", containing the scientific papers presented at the symposium.

Welcome Address By the Executive Secretary, OAU/STRC, Lagos, Nigeria.

Hon Minister for Agriculture and Livestock Development,
The Ambassador of the USA to Kenya,
Distinguished Delegates,
Representatives of International and Regional Organizations,
Ladies and Gentlemen,

It is with great pleasure that I welcome you to this symposium of the Semi-Arid Food Grain Research and Development (SAFGRAD), a project of the Organization of African Unity's Scientific, Technical and Research Commission (OAU/STRC), started since 1977 with generous financial assistance from the US Agency for International Development (USAID), the French Aid and Cooperation Fund (FAC) and more recently, the International Fund for Agricultural Development (IFAD). The contribution of these three main donors is gratefully acknowledged.

The African food crisis has already been well documented. I will therefore not attempt to treat it here now since I know that it will be presented and discussed more fully later during this symposium. All I can say here is that the area most affected by the food crisis is the semi-arid region, 300-900 km wide, stretching from the Atlantic across the sahel to the east coast of Africa and extending towards the coast from the eastern lowlands of Ethiopia to Southern Africa. With annual rainfall ranging between 300 - 1,100 mm, this area is characterized by high soil surface temperatures, low water infiltration, soil compaction and crusting and soil erosion in areas which are either over-grazed or over-cultivated. Other constraints include harmful pests, diseases and weeds.

SAFGRAD was created in an attempt to capitalize on and disseminate information and new technologies that were being generated by African national research systems and the international agricultural research centres to farmers towards the attainment of self-sufficiency in maize, cowpeas, sorghum and millet production in its 18 member countries which have since increased to 26. The first phase of its major component (financed by USAID) will end on 30 June 1986; a second phase is expected to follow almost immediately.

Managed from its Coordination Office in Ouagadougou, Burkina Faso, SAFGRAD has worked on the improvement of food grains in close cooperation with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for sorghum and millet, the International Institute of Tropical Agriculture (IITA) for maize and cowpeas and with Purdue University for farming systems research. An attempt to bridge the wide gap between research and the farmer was initiated with on-farm testing in five member countries through its Accelerated Crop Production Officers' (ACPO) programme.

Without overlooking some of its failures, I am happy to mention the following major achievements attained by SAFGRAD during its first phase:

- Its research collaboration with ICRISAT,IITA and Purdue University as well as with the agricultural research systems of its member countries provided SAFGRAD with a unique mechanism for generating appropriate crop production technologies within the semi-arid regions of Africa.

- While giving due respect to the sovereignty of its member states, SAFGRAD has effectively utilized its OAU umbrella to facilitate the movement of scientists (for monitoring tours workshops and conferences), information, improved crop varieties and technologies to many member countries. Through its regional network on food grain research, more than 750 leading African and other international crop scientists have attended SAFGRAD workshops. They now have a better opportunity to exchange valuable ideas and information on problems of common interest.

- Crop varieties possessing such qualities as high levels of resistance to drought, pests and diseases, extra-early maturity have been developed with ICRISAT and IITA. Many of them are now being tested by several national programmes of member countries.

- The ACPO programme has been a major contribution in linking research to the farmers. Pre-extension testing has provided a sound basis for developing valid extension themes while obtaining feedback to researchers on farmer acceptance and/or constraints to adoption.

- SAFGRAD has succeeded in training (in collaboration with other institutions) more than 30 African scientists at higher degree levels in various fields and aspects of food grain research and production and more than 100 Africans in short-term training lasting for not more than six months. The short-term training involves laboratory methodologies and various aspects of field training.

- The farming systems research programme has been involved in three member countries (Benin, Burkina Faso and Cameroon) where SAFGRAD scientists are providing vital support to national FSR programmes of the three countries. The focus has been on evaluating technologies which maximize the use of non-purchased inputs while continuing to practise minimal applications of purchased inputs.

- The latest important SAFGRAD achievement has been the development of a simple ridge-tyer which can be used when preparing ridges by animal traction. Tied ridges help to reduce rainfall run-off, soil erosion and moisture stress, thereby increasing crop yields. This device which has been tested for two years, may constitute a major breakthrough in peasant agriculture in the 600-900 mm rainfall zone of many African countries. You will be provided with more details on this implement in the course of the symposium.

Your Excellencies, Distinguished Delegates, Ladies and Gentlemen, I have just given you a quick review of some of the research progress which SAFGRAD has achieved during its first phase. In Phase II of the USAID-funded component, SAFGRAD will be better focussed and streamlined, shifting major emphasis from resident research to collaborative research networking services, thereby strengthening national research programmes to benefit from one another in the development and transfer of production technologies. Of course, SAFGRAD's IFAD-funded farming systems research programme and any new programmes from other donors will be continued while assuring overall SAFGRAD efficiency.

The desire to organize this symposium arose during SAFGRAD's Consultative Committee meeting of 9-10 April, 1984, when it was recommended that the Coordination Office, in collaboration with ICRISAT, IITA and other agencies, should plan and organize a symposium, before the beginning of SAFGRAD II, on drought as it affects food grain production in the semi-arid regions of Africa. The symposium should :

- be simple, specific and educational and based on well defined themes which are directly related to the relevant problems of stabilizing food production in the semi-arid regions of Africa;

- ensure that most of the discussions are limited to African drought problems; and

- lead to the identification of research priorities relating to drought stress, which can be used later by researchers from affected member countries.

The OAU/STRC therefore expects that, from your deliberations and exchange of research findings during this symposium, an action document will be prepared for later use by those OAU member countries affected by drought. It is also expected that scientists returning to their various countries after the symposium will be confronted with a new challenge to streamline their existing programmes to be more relevant to the needs of their respective countries.

I wish to express my gratitude to the Organization of African Unity for the continued support given to SAFGRAD. This, indeed, is a positive indication that OAU's involvement is not limited just to political issues but more especially to genuinely seeking long-term solutions to the problems which African countries face in achieving food self-sufficiency for their rapidly increasing populations. My gratutide goes to the Government of the Republic of Kenya not only for accepting to host the symposium in this beautiful conference centre but for providing SAFGRAD with facilities for its regional activities in Eastern Africa.

I cannot forget the Division for Technical Cooperation among Developing Countries of UNDP, the International Development Research Centre of Canada, USAID, IFAD and other funding agencies that have made it possible for many delegates to attend this symposium. Lastly, I wish to thank the international research centres, especially ICRISAT and IITA with whom SAFGRAD has maintained close cooperation for many years and, of course, the national programmes of member countries for their cooperation and technical support for the common target of achieving food self-sufficiency for Africa.

I wish you success in your deliberations.

Opening Address by Hon. William O. Omamo, E.G.H., M.P., Minister for Agriculture and Livestock Development, at the Official Opening of the International Drought Symposium at Kenyatta International Conference Centre on Monday, 19 May, 1986.

Mr. Chairman,
Ladies and Gentlemen,

On behalf of His Excellency President Daniel Arap Moi, the President of the Republic of Kenya, the Government and the people of this country, it is my pleasure to welcome you to Nairobi, the capital city of Kenya, the green city in the sun. Nairobi is a friendly city and is accustomed to welcoming visitors from all over the world. I encourage and welcome you to explore and enjoy its hospitality and popular attractions during your spare time. I understand that most of you are scientists or leaders of research organizations related to the core subject of the symposium, DROUGHT

Ladies and Gentlemen, this international drought symposium is particularly timely and significant because it is being held at a time when the devastating effects of the recent drought and famine on the lives of millions of fellow Africans is painfully fresh in our memories. It is also significant because it is being held in sub-Saharan Africa where the drought and famine were most severe.

About two-thirds of the land area of Kenya is arid or semi-arid and as such, drought and the management of the semi-arid environment are of very special interest to Kenya. Our national Dryland Farming Research Station at Katumani has the national responsibility of carrying out research relevant to our dryland farming situations. Several of our scientists from Katumani and elsewhere in Kenya will present papers on the Kenyan experience and will participate in the discussions. The SAFGRAD project of the OAU has been working closely and actively with our Katumani programme and has been promoting the networking concept on sorghum and millet improvement for the Eastern Africa region. Kenya is pleased to serve as the SAFGRAD regional co-ordination centre on the semi-arid zones of our region. The overall regional effort of SAFGRAD is expected to continue to contribute to improving and stabilizing food production in semi-arid sub-Saharan Africa.

Ladies and Gentlemen, last year much of the International Press was preoccupied with the drought and famine disaster of sub-Saharan Africa. It is well-known to all of us that there was overwhelming response from the International Community to contain the disaster. Notwithstanding all of the commendable efforts of relief and assistance, the drought problem of Africa is far from over. The temporary lull of the drought problem and last week's floods and torrential rains we have

witnessed in Nairobi and its environs should not slacken our long-term efforts to search for lasting solutions to the drought problem. In semi-arid parts of our continent, drought is the main physical environmental stress limiting food production. The fact that much of sub-Saharan Africa is unable to produce the food it needs and that food production in the region has been on the declining trend is well documented. The long-term solution to the confounded problem of drought and declining food production of Africa is to create the overall conducive situations and technologies that foster and improve food production. It is important to improve crop yields under drought stress through improved cultivars, better agronomic and cultural practices, improved soil and water management and conservation techniques, and related approaches.

Although we are aware of the commendable efforts of the OAU/STRC/SAFGRAD in Eastern and Southern Africa, we need a much more expanded programme for the semi-arid parts of the sub-region, i.e. expanded effort in improved food production strategies, environment protection and rehabilitation commensurate with the magnitude of the problem and the vastness of the sub-region.

The Lagos Plan of Action of the OAU underscores the importance of food self-sufficiency for the OAU member states. Food production in the vast semi-arid environments of the continent has to play a significant role in contributing to food self-sufficiency of Africa. Food production under such rainfed situations of the drought-prone areas is indeed difficult and precarious.

With the accelerated degradation of the semi-arid environment and the ever rising population pressure on this fragile semi-arid environment, we can predict with very high degree of certainty that future drought are going to entail painfully much heavier toll of lives and further deterioration of the crop environment. Drought stricken Africa waits, with anticipations, the outcome of your deliberations on how to manage judiciously and survive with the semi-arid and drought-prone environment.

Using the papers scheduled to be presented in this symposium as basis, I trust that you will openly discuss the many facets of the complex drought problem and deliberate on future strategies and courses of action to mitigate the drought problem in sub-Saharan Africa.

Ladies and Gentlemen, I understand that you have a fully loaded programme for the five days of the symposium and therefore I should not take any more of your time but merely wish you fruitful deliberations. It is now my pleasant duty to declare this international drought symposium officially open.

Thank you.

1. BURKINA FASO

RESEARCH STATUS, PRIORITIES AND NEEDS FOR DRYLAND FARMING DEVELOPMENT IN BURKINA FASO.

Leopold Some, Sansan Da and Sibiri Sawadogo
INERA,
B.P. 7192
Ouagadougou, Burkina Faso.

SUMMARY

A land-locked country in the heart of West Africa, Burkina Faso, like the other sahelian countries, suffers from endemic drought which has been growing worse since 1967, and constraining the success of an essentially rainfed agricultural system practised by 92% of the population.

Faced with such a situation, research efforts which are undertaken to find effective solutions have yielded a number of appreciable findings especially on :

- The selection and improvement of drought adapted crop varieties.
- Agricultural techniques for better utilisation of water.
- Aspects of water balance in crop plants.

The research activities do not cover all the soil-climatic and hydro-agronomical problems that constrain Burkinabe agriculture.

It is for this reason that from 1985, INERA has, in association with policy-makers, adopted eight programmes for priority execution, and coordination at the national level. The programmes are :

i. Programme on water-soils-fertilisation-irrigation-agricultural engineering.

ii. Research on production systems.

iii. Sorghum - millet - maize.

iv. Annual oilseeds and leguminous plants.

v. Market gardening, fruits,roots and tubers.

vi. Rice.

vii. Cotton.

viii. Animal production.

The costs of execution of these programmes have been evaluated at 40 million US dollars during the next five years.

INTRODUCTION

Burkina Faso, which covers an area of about 274,000 km^2 is, like the other sahelian countries, affected by desertification, resulting in the diminution and destruction of soil productivity potential.

Apart from the numerous problems encountered in its development due to its geographical situation, as a land-locked country, Burkina Faso has been suffering for the last ten years from endemic drought, whilst demographic growth during the same period has been the highest ever recorded: 41% increase in the resident population from 5.6 million in 1975 to 7.9 million in 1985, according to the last two population counts. 92% of this population live mainly on agriculture and livestock rearing on 2.6 million hectares or 30% of the arable land of the country.

The spatial distribution of the population is very uneven with highly populated regions with more than 100 inhabitants/km^2 in the central plateau and the north western region surrounded by the least inhabited zones of the east, the south west and the far north.

The extreme north is a sub-desert region and mainly pastoral, the other two better-watered regions have lands suitable for agriculture, but on which very haphazard land cultivation is being done by migrants coming in from over-populated zones. As agriculture is mainly rainfed, it is no longer a profitable occupation in most ecological zones of the country where the threshold of land occupation has been exceeded. In these regions, pressure by man and animal as well as severe climatic conditions speed-up the desertification process. Indeed, deforestation, for the production of wood for domestic fuel and the traditional system of agricultural and animal production (land clearing, over-grazing, bush fires) contribute in diminishing vegetation cover thus exposing the soil to the effects of wind and water erosion. This results in the decrease of soil water reserve and a fall in the water table.

It is in such a situation of degradation of soil-climatic conditions that the country has to produce more to attain food self-sufficiency. To do this, agricultural and livestock research at the national level should be able to generate technologies to solve the production problems of farmers and stock-breeders, and thus help them to increase their production. Research efforts have already been undertaken with the support of scientific cooperation at the bilateral and international levels. This has resulted in a number of appreciable achievements in several fields and especially in the field of drought control.

RESEARCH EXPERIENCE ON DROUGHT RESISTANCE

A Summary of the Rainfall Problems of the Country

Because of its geographical situation, Burkina Faso has the same rainfall conditions as the other countries in the sudano-sahelian zone, and as such, research experience on drought elsewhere in the sub-region is generally applicable.

Thus, an analysis of the annual rainfall data of seven stations representing the different ecological conditions of the country shows, for the period from 1920 to 1983, variations around the average between the number of dry years following a number of more humid years. There are no set patterns of the periodicity of these variations. Years of drought can be found mostly during the last decade as shown in Table 1.

Table 1. Frequency of dry periods during the years 1971-1983 In Burkina Faso.

Station	Mean Average(mm) 1920-1983	Rainfall over a 10-year period of drought(mm)	Number of variations observed	Number of variations between 1971-1983
Dori	523	367	4	3
Ouahigouya	674	499	6	5
Dedougou	926	706	7	7
Fada N'Gourma	868	685	4	1
BoboDlsso	1122	881	8	3
Banfora	1160	864	4	3
Gaoua	1133	877	7	4

In the course of the same rainy season, a pronounced change, both in time and space, of rainfall recorded in the country, was generally observed. Because of this, the mean annual rainfall values extending over the years under consideration were practically not important in the determination of climatic hazards. Thus, it is better to know the frequency of rainfall in a given month or year. Table 2 gives such an example for the Ouahigouya Station.

Table 2. Variability in the rainfall pattern of Ouahigouya: period 1948-1979.

Probability (rainfall>x)	Threshold X In mm							
	month year	April	May	June	July	Aug.	Sept.	Oct.
0.8	511	0.4	10	60.8	114.5	146.4	89.3	2.3
0.5	673	11.6	25	86.5	167.7	207.4	121	16
0.2	784.0	18.5	47.6	123.2	228	278.9	158.8	43.6

Given the frequency analyses of the rainfall pattern and taking into consideration the evolution of the climatic situation, the National Meteorology Department undertook a study of the best dates for sowing crops in each agro-climatic zone.

CROP IMPROVEMENT AND SELECTION

The number of crop species studied and improved for drought resistance is very much reduced because of the multitude of plants which abound in the semi-arid zones and which should be taken into consideration in a global strategy for a steady and productive agricultural system.

Indeed, the important part of the activities of selection and improvement are carried out on cereals (sorghum, millet and maize), legumes (soybeans and groundnuts) and cotton according to the mandates of the different Research Institutes which have initiated agricultural research in the country before the creation of the national structure. The aim of the selection process was mainly to obtain short-cycle, high-yielding crop varieties. For sorghum, several short-cycle varieties (90) with high yields of 3 to 3.5 t/ha have been identified: IRAT 204, SPV 35, IRAT 202, etc.

For millet, new creations such as IRAT 172 and 173, IKM 8101 etc., produce up to 1.5 to 2 t/ha. For maize, research results are numerous and the selection process goes even further to the extension of inter-varietal (IRAT 98, 100 and 102) or complex (IRAT 81) hybrids with potential yields of 5-6 t/ha. Unfortunately, the numerous problems of technology transfer between research stations and farmers, and the lack of adoption of appropriate agricultural techniques by the farmers, make it impossible to implement this experience within the national agricultural production system.

STUDIES ON WATER-SOIL-PLANT RELATIONS

Major research in water-soil-plant relations focus on the maintenance and restoration of soil fertility and on the control of rainwash, erosion and water harvesting through agricultural techniques.

Studies on:

a) The maintenance and restoration of soil fertility are carried out on a long-term basis. An example of the device set up at the agricultural research station of Saria since 1960 illustrates the objectives of this work. The tests are as follows:

Manuring

i. Absolute reference check - no manure added since 1960.
ii. Fmr: mineral manuring low-level recycling of sorghum straws.
iii. Fmo: low grade mineral manuring 5 t/ha of manure, every 2 years.
iv. Fm: low-grade mineral manuring.
v. Fmo: high grade mineral manuring - 40 t/ha of manure (every two years)
vi. 6 F.M. - high-grade mineral manuring.

Cropping Series

sorghum continued
sorghum-cotton rotation
sorghum-legume rotation.

The quantities of NPK elements resulting from mineral fertilisation are as follows:

fm: 37-23-14
FM: 60-23-44.

The experimental design is a split plot of six replicates. After a 25-year period of tests, results have shown that mono-cultivation of sorghum results in soil sterilisation in spite of mineral fertilisation; rotation of cereals/legumes maintains long-term productivity whilst the addition of 5 t/ha of manure every two years maintains the organic status of the soil.

b) A study of water harvesting techniques was carried out from 1982. Presently, it covers twelve locations (Fig.1) representing all the soil-climatic situations of the country except the far north zone.

In each station, several techniques are compared to an absolute reference-check as shown in Table 3.

The observations made in certain sites on water dynamics, the evolution of the rooting system and the phenological modifications of cropping make it possible not only to measure and compare the yields obtained but also to explain these yields by simulation of the water balance on the plot according to the model presented by IRAT/CIRAD. To date, this study has been concerned with the principal cereals of the country: sorghum, millet, maize, as well as groundnuts and cotton. Table 4 presents average cereal yields obtained in five situations.

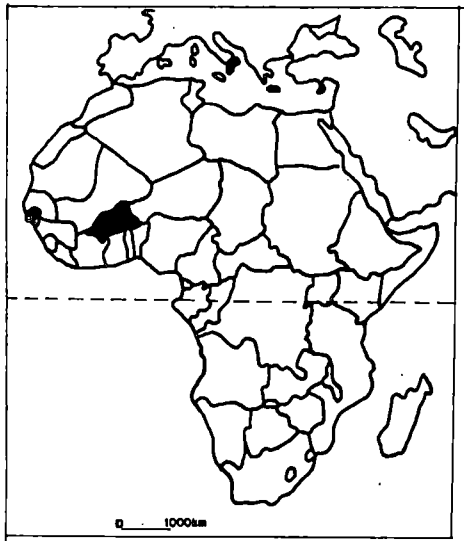

Figure I. Map of Burkina Faso Showing Study Sites

Table 3.. Site Tests Undertaken in 1985

		SABOU NA	ZIGA	TO	KAS-SOU	KOLBI LA	GAM-PELA	S A R I A		KIE	FARA	TOES SI	BOGAN DE	FARA KOBA	NIAN GOLO KO
								HAUT	BAS						
1.	Unexploited reference check	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.	Surface ploughing) Animal begining of rainy) Traction season)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4.	Ridge ploughing													x	x
7.	Surface ploughing ridging a month later						x	x	x						
8.	Surface ploughing ridging 1 month. Partitioning a month later			x	x	x	x	x	x	x			x	x	x
9.	Humid scarification, Mechanical hoeing after every satisfactory down pour	x	x									x	x		
10.	Direct sowing ridging after tillage and partitioning a month later	x	x	x				x		x			x		
11.	Surface ploughing-ridging and partitioning a month after sowing	x	x	x	x	x	x	x	x	x	x	x	x	x	x
12.	Tied-ridge-sowing at every meter	x	x	x	x	x	x		x	x	x				

Table 4. Average Yields (kg/ha) With Water Management Techniques.

	Ref check	Surface ploughing	Ridged ploughing	Ploughing Ridging Partitioning	Crop
Sabouna 82/83	592	994	918	1,020	Mil
Saria 82/84	1,112	1,622	1,417	1,693	Sorgho
Saria 82/84	1,151	1,598	1,657	2,115	Sorgho
Gampela 82/84	990	1,937	1,824	2,238	Sorgho
Farako-Ba 82/84	2,024	3,270	2,624	3,060	Mais

c) Studies on the status of water balance actually concern the definition of the water needs by an evaluation of crop factors (kc) and through measures of rainwash and erosion. The evaluation of crop factors is carried out with the help of two lysimetric tanks set up in 1983 at the SARIA and FARAKO-BA stations. Satisfactory results have been obtained in sorghum and maize under rainfed agriculture for tomato and melon as off-season crops. Studies on rainwash and erosion have been carried out since 1971 on the SARIA site. From 1982, the apparatus has been used to measure the impact of certain conserving techniques and water harvesting in order to control water balance.

Results have shown that on the tropical ferruginous soils of SARIA with an incline of 0.7%, average rainwash reaches 30% to 35% without soil preparation; with good surface ploughing, rainwash can be decreased to 20%-25%, whilst tied ridges greatly reduce or stop it completely. The quantities of eroded soils are enormous and can be up to 20 t/ha.

RESEARCH AND DEVELOPMENT OPERATIONS

Research and development efforts are carried out in Burkina Faso by State bodies and non-governmental organisations (NGOs). Rainwash erosion control and in general, defence and soil restoration actions (DRS) are the main concern of all.

To date, some 230,000 ha of arable land have been given anti-erosive treatment mainly by the construction of small earth or stone dams. The other research and development operations are mainly carried out through a number of multi-locational and pre-extension trials undertaken in different locations by researchers and the extension service workers of the rural populations. As far as studies on animal breeding are concerned, these have been done by ORSTOM in the Sahel province on the improvement and productivity of natural pasture-land and on agro-pastoral production systems aimed at identifying constraints and proposing solutions.

RESEARCH PRIORITIES AND NEEDS

Research priorities for the promotion of Burkinabe agriculture are defined by eight (8) national programmes which were adopted by the National Seminar on Agriculture and Livestock Research

in February 1985. The control of the effects of drought for better yield and better animal production is the main guideline of each of these programmes. However, it is to be noted that the principal actions of these programmes are already executed by INERA with the assistance of the various research institutions within the country. These are the CIRAD institute for bilateral cooperation, international and regional institutions such as ICRISAT and SAFGRAD and the national research projects such as CERCI.

BASELINE PROGRAMMES

The programme on Water/Soil/Fertilisation/Irrigation/ agricultural engineering aims at improving production conditions through water management, the use of fertilisers especially local ones and agricultural equipment. It seeks immediate solutions to the priority development problems of Burkinabe agriculture. A number of research themes have been identified as priority to ensure a judicious use of the available resources. They are :

- Studies on water balance
- Studies on the different techniques of soil and water conservation
- Studies on the improvement and maintenance of soil fertility.

The Research programme on the Production Systems (RPS) aims mainly at improving the productivity of farmers and livestock breeders under the stable agricultural systems in each agro-ecological zone of the country. To do this, the RPS should obtain deeper knowledge of the different production systems and their constraints in order to assist basic research. In its role as the "driving force" between research and development, the RPS should make it possible to promote the transfer of well-known technologies throughout the country.

BASIC CROP RESEARCH PROGRAMMES

Research on Sorghum, Millet and Maize.

The aim of this programme is to improve the food productivity and quality of the cultivars of the principal cereals of the country. This means the creation and adaptation, for each agro-ecological zone, of suitable varieties (depending on the cropping cycle) with a high yield potential capable of sustaining stable production.

Research on the Annual Oil Producing Plants and Legumes.

The main objective of this programme is to improve the productivity and quality of high protein cereals especially groundnuts and cowpeas.

It should be possible in the short-term to perfect high-yielding cultivars of good nutritional value (oil and/or protein content).

As far as soybean is concerned, work is being done on the adaptation of local varieties giving regular yields and free from germination problems.

Research on Market Garden Crops and Fruit Trees

Within the framework of a global strategy for drought and desertification control, as well as the attainment of food self-sufficiency, the market-gardening and fruit tree cultivation components are emphasized. It is for this reason that the different activities of research in this field are focussed on improving the productivity and quality of legumes and fruit crop species.

Research on Rice

To increase national rice production, research objectives aim at improving the productivity and quality of rice cultivars adapted to the agricultural conditions with partial or total water control. For this , research effort will be mainly directed towards the introduction of highland rice cultivars from neighbouring countries (especially Cote d'Ivoire) as well as the selection and creation of high quality productive cultivars (both at the milling and consumption levels) adapted to rainfed (low-lands) or irrigated conditions.

Research on Cotton

As the main export crop of Burkina Faso, cotton occupies very large areas in the western zones where soil-climatic conditions still allow its cultivatioon. National agricultural research has, as a short-term objective, the improvement of cotton cultivation by rapidly providing farmers with improved cultivars (high-yielding cotton grains: high oil content and good quality fibres) and appropriate cultivation techniques. To this end, many research activities have been defined from the scientific experience already gained in the past years by IRCT/CIRAD in the subregion.

Research on Animal Production

Livestock Research has been neglected for a long time in national research. The severe drought of 1973/74 vividly exposed the fragility of the poorly developed agro-pastoral system of sahelian stock-raising. Consequently, research objectives will aim at improving the predominating local breeds and improving fodder species which provide the basis of animal nutrition. Making livestock production sedentary is top priority in the control of desertification. To this end, studies will be carried out on appropriate types of stock-rearing (ranching, feed-lot, etc.) and different animal-breeding techniques which have not yet been well adopted.

STRATEGY AND MEANS OF IMPLEMENTATION

The redefinition and reinforcement of agricultural research is the main focus of the Five-Year Development Plan of Burkina Faso, 1986-1990. The Ministry of Higher Education and Scientific Research and that of Agriculture and Animal Husbandry are in charge of the execution of this research component in close collaboration with the Institute of Agricultural Studies and Research (INERA).

These activities would involve cooperation with international and bilateral scientific organizations which will be invited to participate in the implementation of the different national research programmes.

The resources needed for the execution of the five-year agricultural research programme are sub-divided into :

1. Personnel, where an important effort will be made to deal with the problem of insufficient, or the absence of technical and research personnel.

2. Financial, where a total of 13 billion francs CFA or about 40 million US dollars should be made available in the next five years, 13.7 million dollars being needed to launch the programmes in 1986.

CONCLUSION

Since the causes of desertification which hamper the promotion of Burkinabe agriculture are numerous and diversified, it would be unrealistic to seek a simple and common solution to this problem. This is one reason why apart from agricultural research activities, research on ecology and forestry should also be included as well as conservation measures of the fauna and flora. The National Revolutionary Council (the political organ in power in the country) has underscored this problem and so launched three country-wide control schemes which are :

- Bush-fire control
- Restrictions on the abusive felling of trees
- The control of stray animals.

Many political and technical measures have been taken to control drought and the promotion of dry-land agriculture in Burkina Faso. Nevertheless, the country is aware of the importance of cooperative action at the international level to help eliminate the problem of drought which is a real challenge to humanity at the end of this our 20th century.

DISCUSSION

Arias

What evidence and criteria are used to determine research needs and given priorities within each research programme?

Some

In a country like Burkina Faso, everything is practically a priority for agricultural development. But in order to make judicious utilization of the scarce means placed at our disposal, we had to grade the priorities on the basis of the immediate problems faced by farmers in increasing their production on the one hand, and on the basis of the major crops used as food for our populations (sorghum, millet and maize) or providing the country with foreign currency (cotton for example) on the other hand. I think that other members of the Burkinabe delegation may better clarify my idea.

Diallo

Which research projects are you implementing in order to cope with the irrigated projects planned by your government?

Some

We have reported, without details, the irrigation problems within the Water-Soil-Fertilization-Irrigation-Agricultural Engineering programme. Several research activities have been defined for this purpose but we have not included them in the synthesis of our research priorities which we have just presented.

Gonda

Since soil fertilization has become a major concern during these drought years, has a study been carried out on soil fertilization - drought relationship?

Some

Since 1985 we have been conducting at SARIA Agricultural Research Station an experiment on the effect of water economy techniques on the efficiency of fertilizers, particularly rock phosphate, the solubilization of which is known to depend on soil moisture. Mr. Nicou with whom we are working in the framework of bilateral scientific cooperation may give additional information in this respect.

Kanyenji

Noting that sorghum is one of the major cereal crops in Burkina Faso, and assuming that the labour required for bird scaring on sorghum fields is provided by the family, mainly children; how do you deal with the bird problem, especially in situations where the children are not available during school terms?

Some

The problem of crop pests and generally the problem of crop protection exists in Burkina Faso. To cope with such a problem, we have the support of a CILSS regional project (CILSS = Permanent Inter-state Committee for Drought Control in the Sahel). But I don't think that we have solutions to the specific problem of birds you are mentioning. Farmers have also depended on children to scare away birds, but this has its own limitations.

Nicou

What is the relationship between soil fertilization and water stress?

Some

Few studies have been conducted in Burkina Faso on the relationship between water stress and soil fertilization. This is why we have initiated new experiments in this field, but results are now available from other sahel countries like Senegal where it has been shown that during drought, the effect of fertilizers is reduced. In this case water economy techniques such as ploughing may result in a better absorption of fertilizers to save the crop.

2. BOTSWANA

CURRENT STATE OF DRYLAND AGRICULTURE AND RESEARCH ON FOOD GRAINS IN BOTSWANA.

L.M. Mazhani
Senior Agricultural Research Officer
Department of Agricultural Research
Private Mail Bag 0033,
Gaborone, Botswana.

INTRODUCTION

The estimated climatically suitable land for arable agriculture in Botswana ranges from 3% to 5% of the total land area of about 582,000 square kilometres.

The country has no true mountains and is therefore relatively flat, ranging from 900 to 1200 m above sea level. The western two-thirds of the country is comprised of the Khalari, most of which is savanna.

The soils of Botswana are mostly medium to coarse grained sandy loam. This phenomenon characterizes the major cultivated soils although there are isolated pockets of clays and sandy clay loams. Most soils are low in nitrogen and phosphorous and topsoil pH values range from 4.3 to 7.4. During the cropping season, the soils have high surface temperatures and evaporation rates are also high.

Water is the primary limiting factor to crop production in Botswana. Rainfall in the main arable area varies from 570 to 350 mm per annum, most of the rainfall falling from October through April, but frequencies and distributioins are erratic.

Mean maximum temperatures rise to 33 degrees centigrade at the peak of the crop season in January and mean minimum temperatures fall to 4 degrees centigrade towards the end of the season.

The major field crops in Botswana are *Sorghum bicolor* (L.) Moench (sorghum), *Zea mays* L. (maize), *Pennisitum americanum* (L.) (pearl millet), *Vigna unguiculata* (cowpea), *Arachis hypogea* (groundnut) and *Helianthus annuus* (sunflower). Crop yields are low and under more normal circumstances, average yields seldom exceed 400 kg per hectare for sorghum.

EFFECTS OF DROUGHT

Drought has occurred frequently during the past five years in Botswana, and it has become more frequent and more severe, adversely affecting food grain production in the country. Production dropped from 54,200 tonnes to 7,300 tonnes (Table 1) over the period 1981 to 1985, although annual demand for basic food grains rises to about 200,000 tonnes.

Table 1. Estimated production of main crops 1978-1983

	1979	1980	1981	1982	1983	1984
Sorghum						
Average yield Traditional (kg/ha)	91	215	224	103	131	114
Average yield Commercial (kg/ha)	423	460	450	131	988	153
Production (000 tonnes)	4,2	29,1	28,3	3,8	5,2	5,7
Maize						
Average yield Traditional (kg/ha)	84	167	306	282	257	67
Average yield Commercial (kg/ha)	310	907	893	774	1123	217
Production (000 tonnes)	2,3	11,6	21,4	12,4	8,8	0,5
Millet						
Average yield Traditional (kg/ha)	112	159	148	132	69	86
Average yield Commercial (kg/ha)						
Production (000 tonnes)	0,9	2,9	1,8	0,5	0,4	0,7
Beans/Pulses						
Average yield Traditional (kg/ha)	70	144	176	118	64	135
Average yield Commercial (kg/ha)	200	250	700	500	350	50
Production (000 tonnes)	1,0	1,8	2,7	0,5	0,3	0,4
Total Production (000 tonnes)	8,5	44,8	54,2	17,2	14,4	7,3

Source: NDP 1985-91.

The worst effects of the drought which include the dwindling seed stocks are still very much with us. It is essential that a more radical approach to national food production be adopted in order to overcome the present difficulties. The present situation calls for change in the current production technology and requires appropriate water harvesting and conservation techniques.

RESEARCH PROGRAMMES ON DRYLAND AGRICULTURE

Agricultural research is conducted primarily by the Department of Agricultural Research which is under the Ministry of Agriculture. The headquarters is located at Sebele (10 km north of the capital town - Gaborone) and there are three regional substations located at Goodhope, Mahalapye and Maun. The national agricultural station at Sebele was established in 1968. Prior to the establishment of the research centre, research was limited mainly to screening of introduced materials and few landraces.

The department of Agricultural Research is responsible for research on dryland crops, with major emphasis on development of improved production technology for sorghum, pearl millet, cowpea, groundnuts. Research disciplines include plant pathology, entomology, soil fertility, crop rotation and farming systems.

Sorghum Genetic Improvement Programme

Sorghum is considered to be the most important cereal in terms of total area under cultivation and it is the major staple food crop for the rural population. The national yield averages are low 300 kg/ha (Table 1) although in experimental plots yields up to 3000 kg/ha have been reported with improved cultivars and exotic hybrids.

Recently, a sorghum breeding programme was initiated aimed at producing cultivars that yield better than those currently being grown in the country. Improvement will be achieved by introducing drought tolerance and better yield-stability in local and adapted germplasm.

The screening of introduced cultivars and landraces has resulted in the release of three improved selections (Segaolane, Marupantse and Twon) and two introductions (8D and 65D). Some feed-type hybrids from the United States of America had good performance in grain yield but they were very poor in grain quality and had floury endosperm which are not acceptable to local consumers. The selection programme to improve the existing varieties will be continued for the maintenance of varietal purity.

In 1983, more than 5,000 sorghum lines were obtained from various sources through the SADCC-ICRISAT Sorghum Millet Improvement Programme. The materials were evaluated for genereal performance and about 73 promising materials were selected on the basis of agronomic desirability and tolerance to drought. Eight of the selected lines were included in the inter-varietal crossing block to develop elite inbreds. During the same year 130 sorghum landraces and sixty pearl millet collections were planted, but yield data could not be obtained due to severe drought. Also 33 A and B-lines of sorghum were obtained from Nebraska and were evaluated for adaptation. Four female lines (CK60A,N48A, Tx623 and K56A) were the most drought tolerant.

The best local cultivars were crossed to these steriles to determine their restorer or maintenance reaction. Three cultivars (Segaolane, Twon and 65D) gave pollen-sterility to the progeny of crosses with cytoplasmic-pollen-sterile. One of these lines (Segaolane) is being converted into cytoplasmic male sterile female parent by backcrossing.

Two random-mating populations of sorghum have been established. They are based on a male sterile gene system, ms3 and are maintained separately in isolated blocks. Promising germplasm with known fertility reaction will be added accordingly by crossing them with male sterile segregates from existing populations.

Pearl Millet Research

Work on pearl millet has so far concentrated on the selection of landraces, and great improvements over the yield of landraces have been achieved through selection of a composite (Serere 6A). Serere 6A (an introduction from Uganda) has proven to be well adapted for cultivation throughout the country.

Groundnut and Cowpea Research

Exotic and local varieties of groundnut and cowpea are being tested to determine their tolerance to drought, earliness to maturity, plant type, flowering habit and yield potential. Emphasis is placed on identification of varieties that produce reasonably well under low rainfall conditions.

Plant Pathology

Disease surveys and identification of crop pathogens dominate the activities of this sub-division. Control methods for problem crop pathogens will be studied.

Entomology

At present most of the work is devoted to problems related to the sorghum aphid (*Melanaphis sacchari*). Methods of controlling crop pests by cultural and chemical measures will also be studied.

Soil Fertility

The activities of this sub-division comprise investigation of soil phosphorous requirements for sorghum production. Soils are being studied for their phosphorous absorption and release characteristics in an attempt to determine the optimum rates of phosphorous to be applied.

Crop Rotation

The application of artificial fertilizer, particularly nitrogen is not an economic proposition for most farmers. Therefore research was initiated to examine the efficiency ' of legume/cereal rotations. The study has generated encouraging results which suggest that rotations are beneficial to the cereals even under dry conditions.

Farming Systems Research

There have been four projects with a farming systems orientation in Botswana. Funding for the projects have been obtained through bilateral aid. However, a proposal for institutionalization of Farming Systems work in Botswana has recently been submitted to the Ministry of Agriculture for approval. The latest farming systems project, the Agricultural Technology Improvement Project (ATIP) began in 1982. The main purpose of the poroject is to improve the capacity of the Ministry of Agriculture's research and extension programmes to make farming systems recommendations relevant to the needs of resource-poor farmers. Multi-disciplinary teams have been established at Francistown and Mahalapye with the headquarters at Sebele.

CURRENT STATUS OF WORK DONE ON DRYLAND AGRICULTURE AND RESEARCH

Work on varietal screening has led to the release of improved cultivars of sorghum, pearl millet, groundnut and cowpea which have yielded comparatively better relative to landraces. The improved variety of sorghum (Segaolane) and cowpea (Blackeye) are widely used and have had significant impact on both the resource-poor farmers as well as the commercial growers. However, there is a need to continue with a screening and breeding programme in order to broaden the genetic base of improved cultivars.

Improved cultural practices are yet to be developed as current packages are deficient in many ways. Tillage in particular requires special attention as it has direct influence on water infiltration and retention.

COOPERATION WITH REGIONAL AND INTERNATIONAL RESEARCH CENTRES

Botswana's agricultural research department has established link with the following institutions (see Table 2) mainly to promote th exchange of germplasm, literature and participation in scientifi meetings:

Table 2. Collaborative Programmes between the Botswana Department of Agricultural Research and other Institutions.

Centre	Germ plasm	Consul-tancies	Training	Coopera-tive Pro-gramme	Docu-menta tion
SAFGRAD	+		+		+
ICRISAT	+		+		+
SADCC-ICRISAT	+		+	+	+
CIMMYT			+		+
SACCAR	+	+	+	+	+
Kansas State University		+	+	+	
Colorado State University		+	+	+	
Michigan State University		+	+	+	
University of Nebraska	+	+	+	+	+
INTSORMIL			+	+	+

CONSTRAINTS TO RESEARCH ON DRYLAND AGRICULTURE

Manpower

There is a shortage of fully qualified research scientists in fields like laboratory services, agricultural engineering, statistics, agricultural economics, plant genetic conservation, etc., as indicated in Table 3.

Table 3. Distribution of Agricultural Research Manpower in Botswana (1986).

Discipline	Local Personnel	Contract Personnel	Project Staff
Director of Agricultural Research	-	1	-
Coordinator, Animal Production Officer	-	1	-
Chief Arable Research Officer	-	1	-
Seed Technology	-	1	-
Farm Machinery	-	1	-
Groundnuts	-	1	-
Sorghum/Millet Breeding	1*	-	-
Sorghum Agronomy	-	-	1
Weed Research	-	1	-
Cowpea Research	-	-	2
Plant Nutrition	1*	-	-
Crop Rotation	-	1	-
Farming Systems (Animal Production)	1	-	1
Farming Systems (Agronomy)	2*	-	3
Farming Systems (Econ.)	-	-	4
Statistics/Computer	1	-	-
Laboratory Services	1	-	-
Agricultural Economics	-	1	-
Agricultural Engineering	1	-	-
Plant Pathology	1*	-	-
Entomology	-	-	-
Horticulture Research	1	1	-
Melapo Rersearch	-	-	2
Range Research	1	-	1
Animal Nutrition	1*	-	1
Small Stock	1	-	-
Dairy Research	2	-	-
Animal Breeding	1*	-	-
Total	16	10	15

* = M.Sc. and above.

Funding

Although Botswana's agricultural research system is entirely dependent on Government for its recurrent budget, some significant contribution comes from donors through bilateral aid as shown in Table 4

Botswana's contribution to donor-sponsored projects is usually in the form of vehicles, support staff, housing etc.

Table 4. Project Funding in Botswana

Project	Donor	Research Budget(p.a) (Pula)	
		Donor	GOB
National Programmes	Botswana Govrmt.	-	3,632,110
Dairy Development Research	IDRC	50,000	50,000
Foundation Seed Production and Control	UNDP/FAO	466,000	60,000
ATIP (Farming Systems Research)	USAID	250,000	50,000
ADNP (Farming Systems Research)	SAREC/SIDA	200,000	50,000
Central Research Station (Facilities)	GoB	-	220,000
CRSP/Cowpea	USAID	400,000	-
CRSP/Sorghum and Millet	USAID	240,000	-

HIGH PRIORITY AREAS FOR RESEARCH ON DRYLAND AGRICULTURE.

The primary objective of research must be to produce recommendations that will considerably increase yields and reduce the large fluctuations in production. In order to achieve the stated objectives more emphasis will have to be given to screening and breeding for crop varieties suitable for dryland farming in semi-arid environments. Sorghum and pearl millet should receive high priority. The search for varieties of cowpea and groundnut crops must also be intensified.

Research on agronomic practices will include plant density studies, date of planting, weeding and fertilizer use, particularly phosphorous.

- There is a need for new soil-water management techniques which will improve water infiltration and conservation.
- Farming systems (FS) studies will be strengthened by institutionalizing the FS teams in Botswana. Priority will therefore be given to expand the present programmes to study farming systems at more sites.
- Studies on suitable pest and disease control techniques will also be pursued vigorously.

National out-look and Policy Regarding Dryland Agriculture, Research and Development

Agricultural research is intended to generate appropriate information which may assist Government in implementation of its National Development Plan which seeks to, (1) attain self-sufficiency in staple crops, (2) raise rural incomes through production of agricultural surpluses, and (3) create rural employment opportunities to reduce migration to urban areas.

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DISCUSSION

Abebe

I wonder whether varietal development is of top priority as opposed to development of appropriate agronomic practices since average yields are 300 kg/ha in farmers' fields as opposed to 3,000 kg/ha in research fields. This implies that high yielding varieties are already available and the yield gap is basically due to lack of transferable agronomic technology.

Mazhani

It is true that we already have superior varieties which respond to improved agronomic technology. However, I have indicated that priority is given to both the development of superior varieties and the development of improved agronomic technologies. The development of improved cultural practices is the responsibility of INTSORMIL, a USAID- sponsored project.

Agboola

Looking through your programme there is no work on soil management, soil fertility evaluation and management, farm mechanisation and tool development. What is your government doing about this?

Mazhani

The department does not have well-trained personnel in these fields but efforts are underway to train scientists to fill these gaps.

Ohiagu

The sorghum national yield average is estimated at 300 kg/ha compared with 3000 kg/ha obtained from research stations. What is your extension service like in order to bridge this yawning gap between research and production figures from local farms?

Mazhani

I can only comment on my observations from 3 years in Tutume district. There has been a severe drought in the area for the last 3 years. The government has had to implement a major drought relief programme in the area and the only people available to administer these programmes at the village level are the agricultural extension agents. For that reason, extension agents have had to give priority to administration of drought relief projects and have not, therefore, had much time left for extension of improved practices.

Mamadou

(i) As far as sorghum development is concerned, bird attack is a problem. Has a solution been found in Botswana?
(ii) Has the problem of seed production of hybrid sorghum been solved in Botswana?

Mazhani

(i) We do not believe that there is a genetic solution to the bird attack problem. However bird scaring seems to be the best solution so far.
(ii) The current recommendation is ón open pollinated varieties. Presently no local hybrids are produced in the country.

DROUGHT IN ETHIOPIA: CAUSES, CONSEQUENCES AND MANAGEMENT.

Seme Debela
Institute of Agricultural Research
Addis Ababa
Ethiopia.

INTRODUCTION

Historical records of Drought in Ethiopia

The recent drought related famine is not an isolated incident in the long history of the Ethiopian nation. It is unique in one aspect however: it has been covered by national and international mass media in an unprecedented manner.

Although complete historical records are hard to come by, droughts have been known to occur in disturbing frequencies in both the highlands and semi-arid lowlands of Ethiopia. The first record of severe drought in the northern highlands is in the 9th century, when the religious order of the day ascribed it to the wrath of God who ".....prevented the heavens from sending forth rain ...".

Later writings mention severe droughts occuring in the 12th, 14th, 16th, 18th and 19th centuries. In the 20th century alone, at least three droughts have hit the country so far: the mid-1960s, the early 1970s and the current one. During the 19th century, the worst drought to hit the country was during the three year period of 1888-1890 which was followed by disease epidemics that decimated both humans and domectic animals, particularly cattle. The aftermath of the drought as well as of the disease epidemics was still taking its toll when Emperor Menelik II was forced into the Battle of Adewa in 1896.

It should be noted that these historical records cannot be considered complete, for obvious reasons. In most cases, the authors of these texts are the royal chroniclers, foreign adventurers travelling through the country at a particular period of time and/or foreign missionaries working in the country. These authors can only record what they have actually seen and, in some cases, what they have heard. As a result, they can write only severe occurrences taking place in their immediate vicinity. Records could also be lost due to the frequent battles between rival war lords, natural or man made disasters and/or even the death of the authors.

Human Consequences of Drought

The impact of recurring droughts on human population can range from almost negligible to totally catastrophic, depending upon the state of technological and economic development of a society. In the Ethiopian context, all the major and long lasting droughts have had serious consequencess on the population inhabiting the drought affected areas. However,

past historical records do not give reliable quantitative information of the actual numbers of people affected by such disasters. In most cases we have to be satisfied with subjective statements such as this lamentation written by one 12th century chronicler "....famine and plague broke out on the land, the rain would not fall on the fields and great tribulations came upon the people ...."

Even recent incidences cannot be recorded accurately. However, it is estimated that something like 200,000 people perished during the great drought of 1972-74. The actual number of people affected in one form or another is variously estimated at close to 3 million. As the drought related drama of 1984-85 is still unfolding, it is not possible to give an estimate of human losses at this time. But suffice it to say that it is one of the worst natural disasters ever. The total number of people affected is said to be close to 8 million. Out of this, at least 1.5 million people will have to be resettled in more favourable areas.

The social and economic consequences of droughts is not less horrifying. The destruction of the fabrics of social organizations and the breakage of family life have psychological impact that lasts a long time. The massive resettlement schemes, although they undoubntedly have long-term benefits, create short-term adjustment problems, particularly to the elderly.

DROUGHT PRONE AREAS IN ETHIOPIA

General Description of the Country

Ethiopia is a relatively large country with a total area of 1,240,000 km^2 (124 million hectares). Over 65% (ca. 80 mill. ha) of this is considered suitable for agriculture. Currently, however, no more than 13% (ca. 16 mill. ha) is cultivated annually, although a substantial amount of land is additionally used for grazing.

Altitude in the country ranges from 110 meters below sea level in the Danakil Depression to over 4,550 meters above sea level in the Siemen Mountain Ranges. Figure 1 shows that the Ethiopian land mass can be grouped under three relief features: the Central Highlands (above 1500 m. a.s.l.), the Adjoining Lowlands (500-1500 m. a.s.l.) and the Coastal Plains (below 500 m. a.s.l.). The Central Highlands are divided into the Western and the South-Eastern Highlands by the Great Rift Valley. About half of the country is below 1500 meters a.s.l.

The climatic regions of the country are depicted in Figure 2. It can be noted that there are roughly three climatic zones, namely -

1) The Tropical Highland climates;
2) The Tropical Lowlands climates; and
3) The Arid climates.

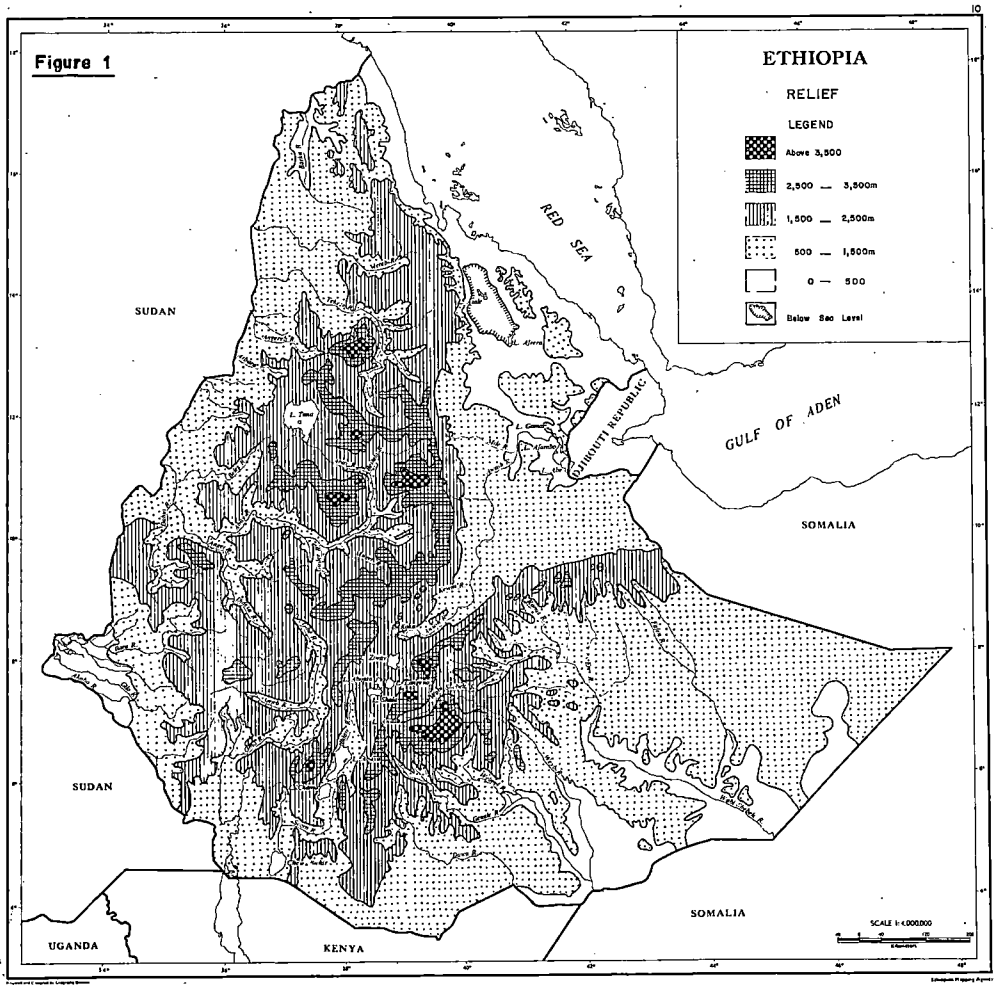
Figure 1
ETHIOPIA
RELIEF
LEGEND
Above 3,500
2,500 — 3,500m
1,500 — 2,500m
500 — 1,500m
0 — 500
Below Sea Level
RED SEA
GULF OF ADEN
SUDAN
SUDAN
SOMALIA
SOMALIA
UGANDA
KENYA
DJIBOUTI REPUBLIC
L. Tana

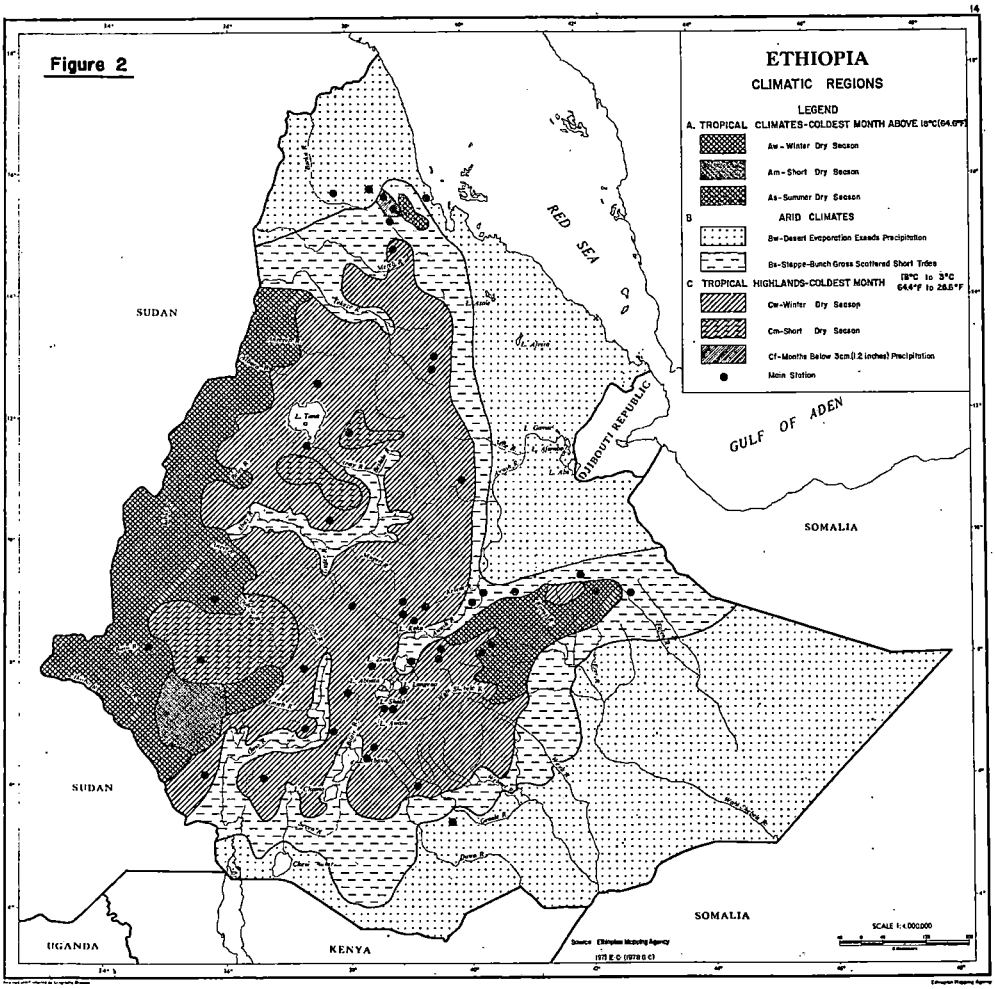
Figure 2
ETHIOPIA
CLIMATIC REGIONS
LEGEND
A. TROPICAL CLIMATES-COLDEST MONTH ABOVE 18°C(64.0°F)
Aw-Winter Dry Season
Am-Short Dry Season
As-Summer Dry Season
B ARID CLIMATES
Bw-Desert Evaporation Exceeds Precipitation
Bs-Steppe-Bunch Grass Scattered Short Trees
C TROPICAL HIGHLANDS-COLDEST MONTH 18°C to 3°C 64.4°F to 28.5°F
Cw-Winter Dry Season
Cm-Short Dry Season
Cf-Months Below 3cm(1.2 inches) Precipitation
Main Station
RED SEA
GULF OF ADEN
DJIBOUTI REPUBLIC
SUDAN
SUDAN
SOMALIA
SOMALIA
UGANDA
KENYA
L. Tana
SCALE 1:4,000,000

The Tropical Highlands essentially enjoy a kind of temperate climate with the average temperature of the coldest month ranging from 3 degrees centigrade to 18 degrees centigrade. The Tropical Lowlands are warm, wet and humid, with no month having less than 19 degrees centigrade in any day of the year. The Arid Lowlands are hot and dry in the interior and hot and humid in the coastal plains.

The mean annual rainfall status of the various parts of the country is shown in Figure 3. Rainfall received in various parts of the country varies from almost nil in the north-eastern coastal plains to over 2500 mm in the south-western Tropical Lowlands. In general, total amount of precipitation received consistently decreases as one travels from west to east. Areas with less than 600 mm. of annual rainfall are generally left for grazing purposes.

Finally, a few remarks on population. According to a 1984 general population census, the Ethiopian population is estimated at a little over 42 million, about 89% of which is rural. Population density and distribution are shown in Figure 4. Most of the population is concentrated in the Central Highlands, with a significantly smaller number inhabiting a restricted portion of the Adjoining Lowlands. The highest density of people (over 100 persons/km^2) is in the North-Western Sidamo, South-Western Shewa and North-Eastern Tigrai Administrative Regions. A large portion of the country has a population density of less than 50 persons/km^2.

Geographic Location of Drought Prone Areas.

The great droughts of the 1960s, 1970s and 1980s in Ethiopia are not isolated incidences in the African context. In fact, they are an extension of the great droughts that devastated the sahelian zone of sub-Saharan Africa.

Fig.5 shows the drought prone areas in Ethiopia. These areas encompass whole or some portions of no less than 11 of the 14 Administrative Regions of the country. It could be noted from this figure that at least six of the Administrative Regions have over 50% of their total land areas susceptible to droughts. In fact, it is these same Administrative Regions that have suffered droughts on and off for the last three decades.

Environmental Description of Drought Prone Areas

The drought prone areas have the following environmental characteristics:

> Altitude: The majority of the drought prone areas lie at altitudes below 1500 meters a.s.l., although there are some areas with altitudes between 1500-2000 meters that are devastated by recurring droughts.

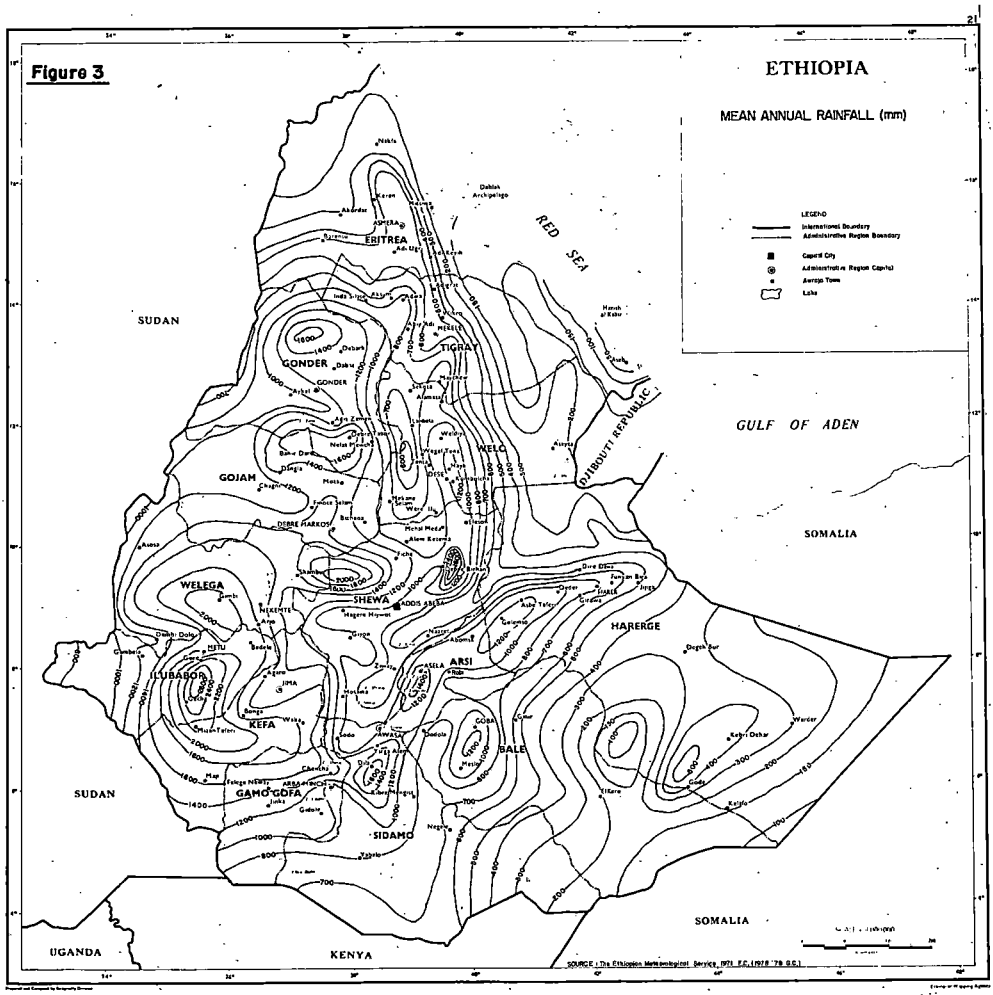
Figure 3
ETHIOPIA
MEAN ANNUAL RAINFALL (mm)
LEGEND
International Boundary
Administrative Region Boundary
Capital City
Administrative Region Capital
Average Town
Lake
RED SEA
GULF OF ADEN
SUDAN
ERITREA
TIGRAY
GONDER
WELO
GOJAM
WELEGA
SHEWA
ARSI
HARERGE
ILUBABOR
KEFA
BALE
GAMO GOFA
SIDAMO
DJIBOUTI REPUBLIC
SOMALIA
UGANDA
KENYA
SOURCE : The Ethiopian Meteorological Service, 1971 E.C. (1978 - '79 G.C.)

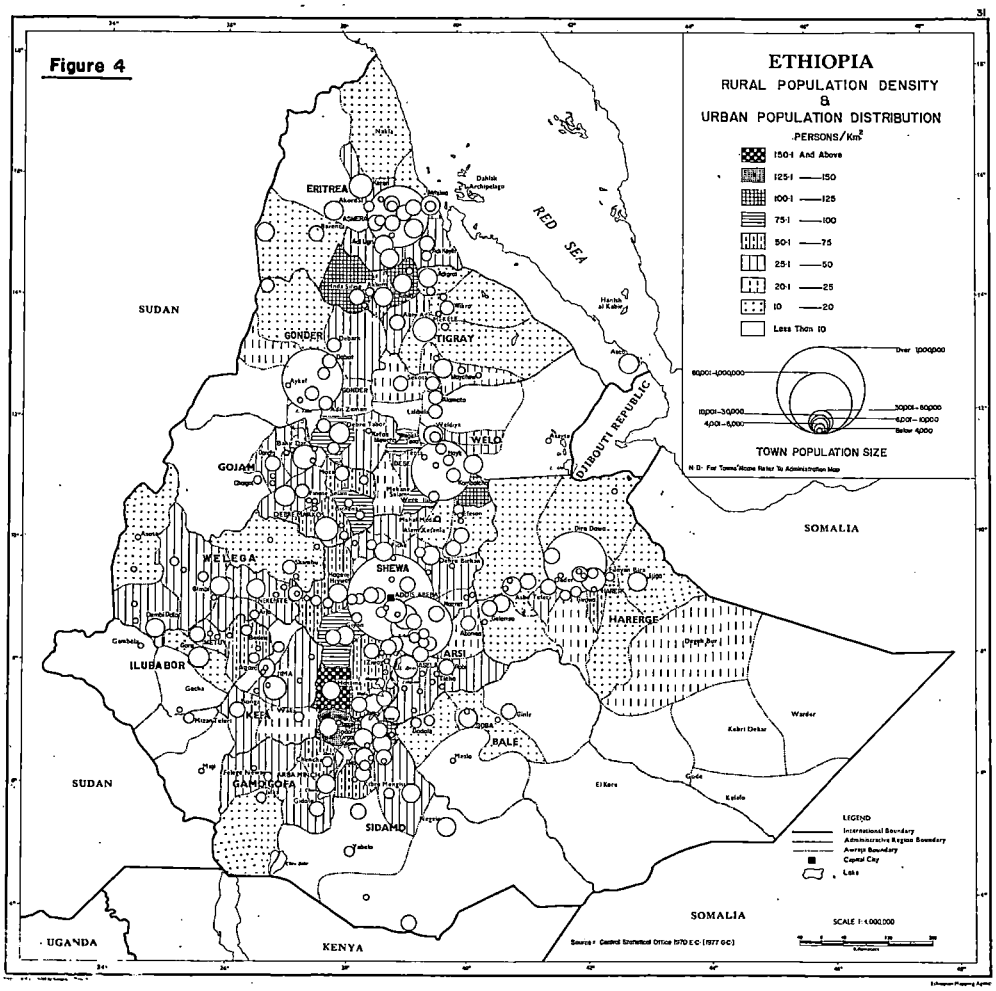
Figure 4
ETHIOPIA
RURAL POPULATION DENSITY
&
URBAN POPULATION DISTRIBUTION
PERSONS/Km²
150-1 And Above
125-1 — 150
100-1 — 125
75-1 — 100
50-1 — 75
25-1 — 50
20-1 — 25
10 — 20
Less Than 10
Over 1,000,000
60,001-1,000,000
30,001-60,000
10,001-30,000
6,001-10,000
4,001-6,000
Below 4,000
TOWN POPULATION SIZE
N.B: For Towns Name Refer To Administration Map
ERITREA
SUDAN
GONDER
TIGRAY
WELO
GOJAM
WELEGA
SHEWA
HARERGE
ILUBABOR
KEFA
BALE
SIDAMO
GAMBELA
ARSI
DJIBOUTI REPUBLIC
SOMALIA
RED SEA
UGANDA
KENYA
LEGEND
International Boundary
Administrative Region Boundary
Awraja Boundary
Capital City
Lake
SCALE 1:4,000,000
Source: Central Statistical Office 1970 E.C. (1977 G.C.)

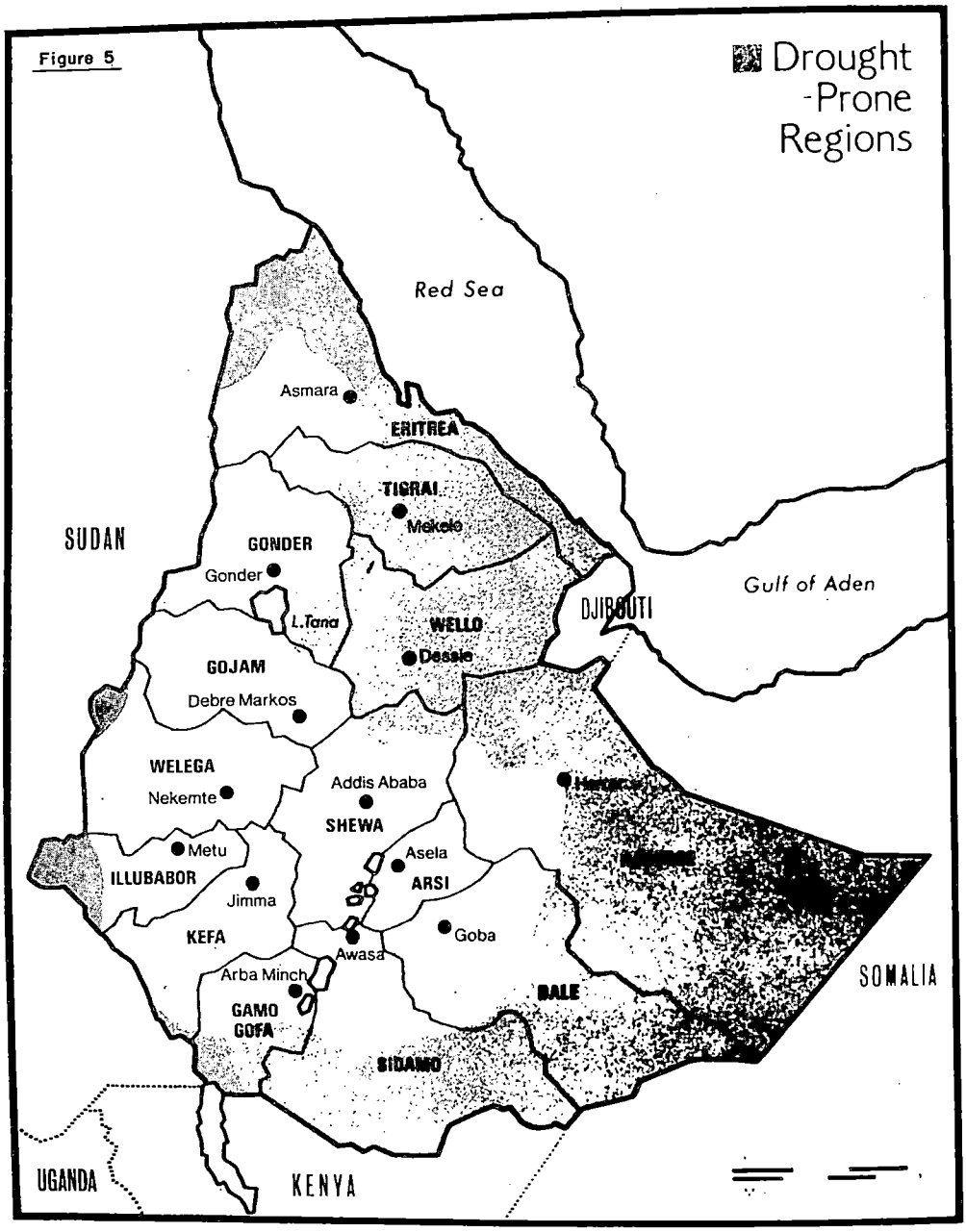
Figure 5
Drought -Prone Regions
Red Sea
Asmara
ERITREA
TIGRAI
Mekele
SUDAN
GONDER
Gonder
L.Tana
WELLO
Dessie
DJIBOUTI
Gulf of Aden
GOJAM
Debre Markos
WELEGA
Nekemte
Addis Ababa
SHEWA
Metu
ILLUBABOR
Jimma
Asela
ARSI
KEFA
Awasa
Goba
Arba Minch
GAMO GOFA
BALE
SIDAMO
SOMALIA
UGANDA
KENYA

- Topography: Most of the eastern lowlands affected by droughts generally have a flat to a gently undulating topography. However, a good portion of the drought prone highlands have a mountainous and very rugged terrain.

- Climate: The drought prone areas in Ethiopia are mostly located in the arid and semi-arid portions of the country, although there are important sections in the Tropical Highlands. A look at Fig.3 shows that the average annual rainfall received in the drought prone areas varies widely from location to location. For example, the average annual rainfall at Mekele (northern portion of the Central Highlands) is between 500 - 600 mm whereas it is over 900 mm at Hosana or Saddo (Southern portion of the Central Highlands). On the other hand, most of the drought prone areas in the semi-arid areas receive not only less than 400 mm per year, but also the arrival of the rains is unpredictable and the distribution erratic.

- Vegetation: Without exception, all the drought prone areas in the Central Highlands have lost their natural vegetation, mainly due to deforestation and over-grazing (Fig.6). As a result, these areas are exposed to severe erosion. The intense rainfall coming over a short period of time accelerates the erosion process.

  The lowland drought prone areas on the other hand, have grassland or thorn bush vegetation. Here, winds play a major role in intensifying erosion activities.

  Fig.7 clearly indicates that these drought prone areas are subjected to a desertification process whose intensity ranges from moderate to very high. The major causes for accelerating the desertification process are deforestation, overgrazing and recurring droughts.

MAJOR CAUSES OF DROUGHT

It is accepted that droughts are the necessary consequences of deficient rainfall. However, this definition, while basically valid, is fatalistic as it does not suggest feasible steps to overcome or minimize the negative consequences of recurring droughts. It is my opinion that there are other natural and socio-economic causes for drought. It is, therefore, better to define drought in the following manner:

> "drought is a condition whereby insufficient moisture is available to support normal biological activities".

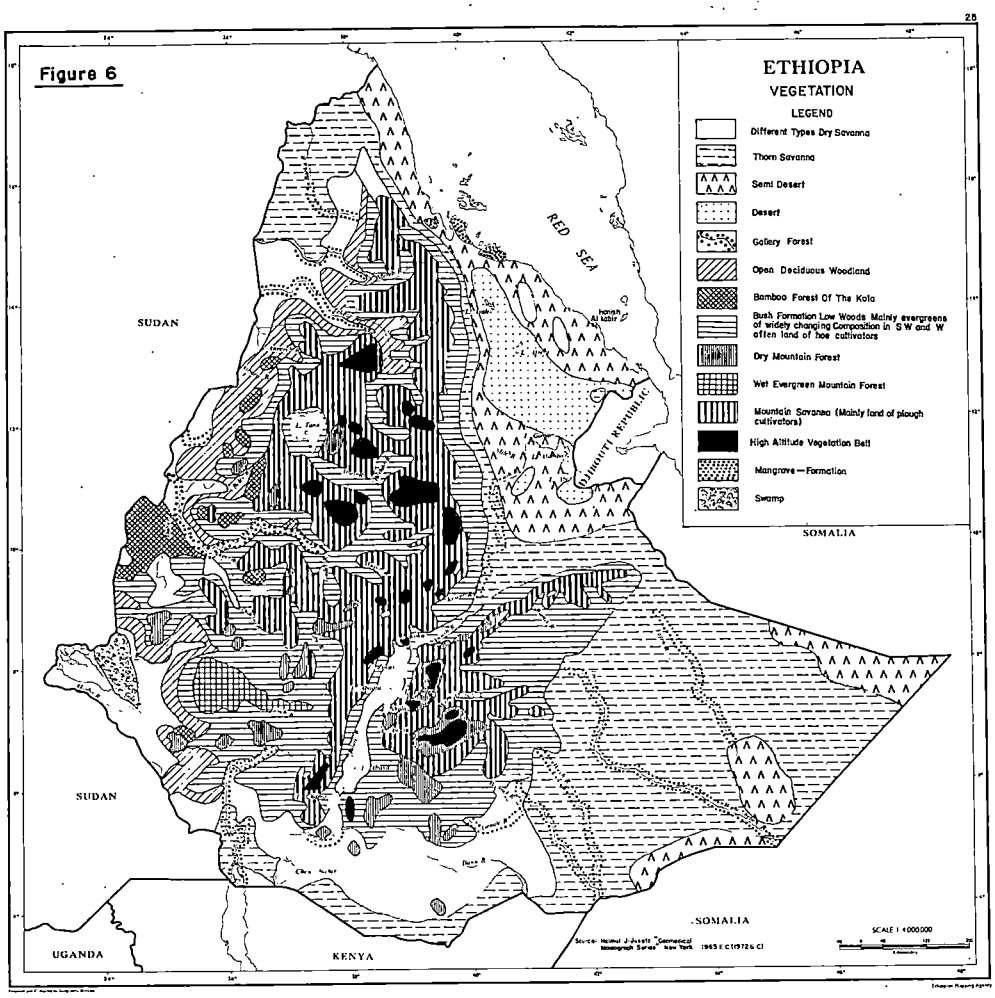
Figure 6
ETHIOPIA
VEGETATION
LEGEND
Different Types Dry Savanna
Thorn Savanna
Semi Desert
Desert
Gallery Forest
Open Deciduous Woodland
Bamboo Forest Of The Kola
Bush Formation Low Woods Mainly evergreens of widely changing Composition in S W and W often land of hoe cultivators
Dry Mountain Forest
Wet Evergreen Mountain Forest
Mountain Savanna (Mainly land of plough cultivators)
High Altitude Vegetation Belt
Mangrove—Formation
Swamp
RED SEA
SUDAN
SUDAN
SOMALIA
SOMALIA
UGANDA
KENYA
DJIBOUTI REPUBLIC
SCALE 1:4000000

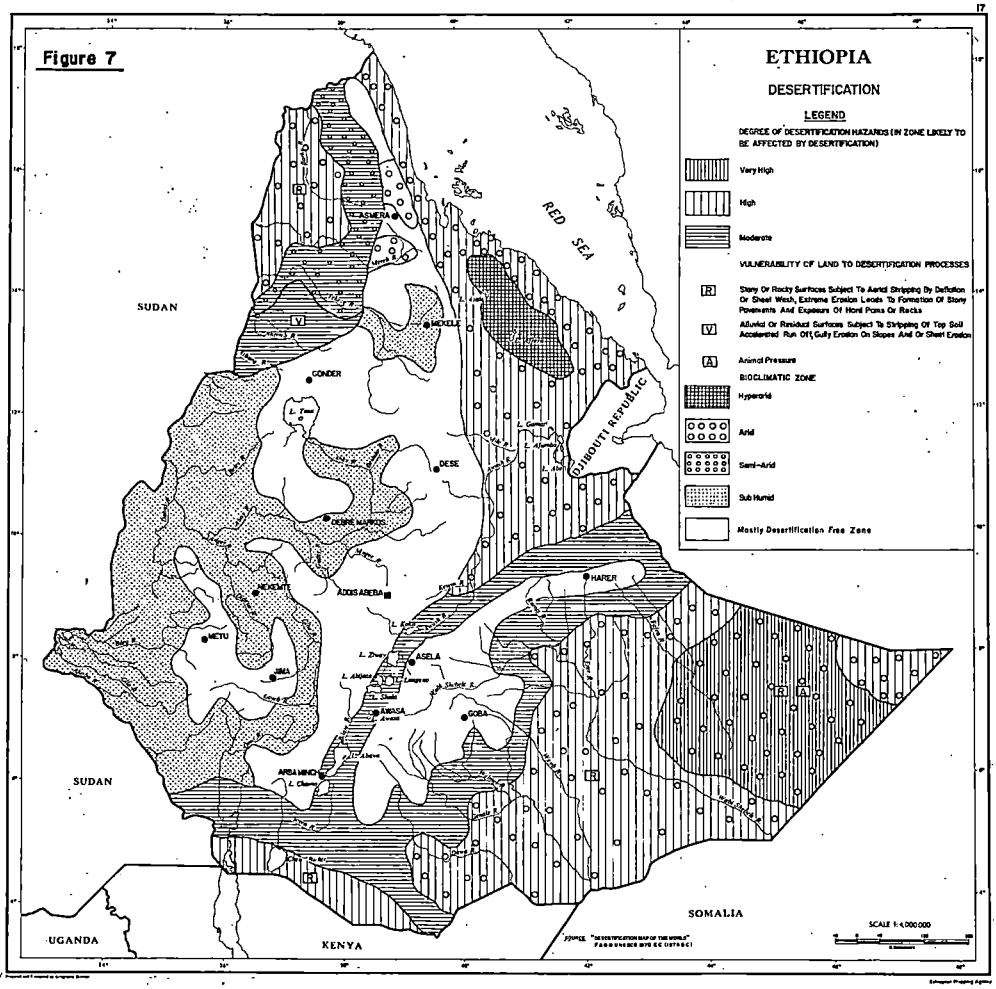
Figure 7
ETHIOPIA
DESERTIFICATION
LEGEND
DEGREE OF DESERTIFICATION HAZARDS (IN ZONE LIKELY TO BE AFFECTED BY DESERTIFICATION)
Very High
High
Moderate
VULNERABILITY OF LAND TO DESERTIFICATION PROCESSES
R
Stony Or Rocky Surfaces Subject To Aeriol Stripping By Deflation Or Sheet Wash, Extreme Erosion Leads To Formation Of Stony Pavements And Exposure Of Hard Pans Or Rocks
V
Alluvial Or Residual Surfaces Subject To Stripping Of Top Soil Accelerated Run Off, Gully Erosion On Slopes And Or Sheet Erosion
A
Animal Pressure
BIOCLIMATIC ZONE
Hyperarid
Arid
Semi-Arid
Sub Humid
Mostly Desertification Free Zone
RED SEA
SUDAN
ASMERA
MEKELE
GONDER
L. Tana
DESE
DEBRE MARKOS
ADDIS ABEBA
NEKEMTE
METU
JIMA
ASELA
AWASA
GOBA
ARBA MINCH
HARER
DJIBOUTI REPUBLIC
SOMALIA
UGANDA
KENYA
SCALE 1:4,000,000
SOURCE "DESERTIFICATION MAP OF THE WORLD" PUBLISHED BY EC (1976)

This definition, though not strictly rigorous, not only indicates the root causes of the problem but also gives a clue to what needs to be done to improve conditions for normal biological activities. We can now examine some of the major elements that lead to drought conditions.

Climatic Factors

Deficiency in total amount as well as in distribution of rainfall is the major climatic factor that gives rise to drought condition. Annual water deficit in soil is aggravated by high temperatures, low humidity, etc., that tend to encourage evapotranspiration. In the Ethiopian case, it can be noted from Fig.8 that the drought prone areas are characterised by high average annual water deficient.

Soil and Site Factors

The amount and duration of moisture stored in the soil is very much influenced by soil and site characteristics. In the Ethiopian highlands, the mountainous topography coupled with the denuded vegetation results in substantial amount of rainfall lost through runoff. In the lowlands, soil characteristics, despite the mild topography, are not conducive to soil moisture storage for any length of time. In both cases, reduced rainfall, especially if it is erratic in distribution for an extended period of time will surely lead to drought conditions.

Agricultural Practices

There is no question that, in the Ethiopian context, defective crop and animal management techniques have enormously contributed to the acceleration of desertification in many parts of the country. The wrong choice of animal and crop types, inappropriate tillage systems, improper stocking rates, etc., have very much contributed to the degradation of land, which eventually easily falls victim to even mild fluctuations in rainfall amount and/or distribution.

Socio-Cultural-Economic Factors

Not only natural phenomena can be accountable to land degradation that actually makes a community susceptible to drought hazards. Socio-cultural habits and traditions result in non-sensitivity of a community to environmental management requirements. In other cases, economic limitations lead to complacency in the face of impending disaster. In the Ethiopian context, it is fair to state that all the three factors have played a significant role in degrading the environment.

STEPS TO OVERCOME THE PROBLEM

In general, man will be free from the scourge of drought only when he attains the capability to influence weather systems or weather patterns. As this does not seem possible, at least in the short-term, the next target to aim for is to develop water resources - both surface and underground - to ensure adequate

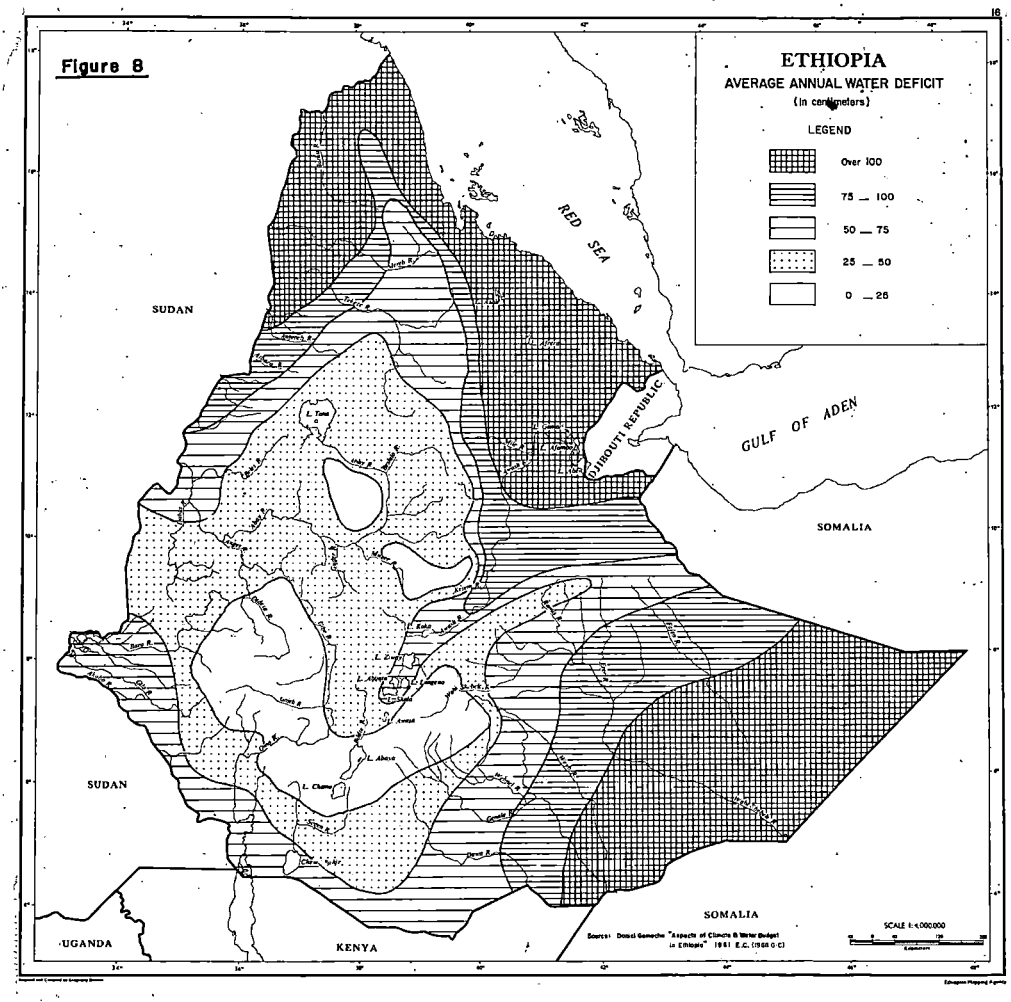
Figure 8
ETHIOPIA
AVERAGE ANNUAL WATER DEFICIT
(in centimeters)
LEGEND
Over 100
75 — 100
50 — 75
25 — 50
0 — 25
RED SEA
GULF OF ADEN
SUDAN
SOMALIA
DJIBOUTI REPUBLIC
UGANDA
KENYA
L. Tana
L. Zway
L. Abaya
L. Chamo
L. Abeya
L. Ashenge
L. Hayq
L. Kulbi
L. Afdera
L. Gamarri
Tekeze R.
Atbara R.
Setit R.
Baro R.
Gilo R.
Akobo R.
Sobat R.
Blue Nile
White Nile
Atbara
Mareb R.
Gash R.
Baro
Omo R.
Gibe R.
Ghelo R.
Dabus R.
Sagan R.
Ganale R.
Dawa R.
Wabi Shebele R.
Jubba R.
Genale R.
Ramis R.
Fafan R.
Shebele R.
Erer R.
Daketa R.
Weito R.
Gumara R.
Tekeze R.
Tigris R.
Euphrates R.
Nile
Source: Dessi Gemechu "Aspects of Climate & Water Budget in Ethiopia" 1961 E.C. (1968 G.C)
SCALE 1:4,000,000
Kilometers

supply for all needs. This seems a possible solution but at high cost, financially and technologically. The recent suggestion of conducting the Amazon River to Africa under the Atlantic Ocean is a case in point.

Both the above options must remain a long term desire for the resource poor countries like Ethiopia. So, we must look for other options that are closer to our means. These options can be presented as follows:

Proper Management of the Natural Environment

By this I mean the development and implementation of schemes that facilitate the use of the environment according to its inherent characteristics and capabilities. Thus, the conduct of land classification studies, the introduction of land use planning and the implementation of land use regulations are among the first steps that need to be taken to minimize the impact and duration of droughts.

Improvement of the Socio-Economic Environment

This is a very crucial factor that has not been given the attention is deserves. In Ethiopia, one of the trigering factors to the 1974 mass uprising is drought. The improvement of production relations and the introduction of economic and other incentives will go a long way to encourage proper management of the environment, and minimize the disastrous impacts of recurring droughts.

Improvement in Agricultural Practices

Incorrect agricultural practices are major contributors to environmental degradation. Therefore, a more environment-concious and more efficient agricultural production system must be devised and put to use in the shortest time possible. This will call for the establishment and/or strengthening of well functioning agricultural education, research and extension services.

I believe that strong and well-directed research and development holds the key to a successful future in the drought-prone areas, even more so than in the naturally well-endowed areas. Research areas that need emphasis are meteorological phenomena, socio-economic issues and agricultural technologies and practices.

In Ethiopia, research needs and priorities can be defined more or less accurately in the areas of agriculture. However, it is very important to note that no less than a positive change in social transformation is required to manage droughts. One can develop tillage systems that conserve soil moisture, select crop varieties and animal types suited to semi-arid environments, develop agro-forestry schemes to play a multi-purpose role in the life-style of the community, etc.

At the end of the day, however, these schemes will be useful only to the extent that the user community is aware of their existence and adopts them to solve problems. Awareness and adoption, as we all know, are influenced by a myraid of socio-cultural habits and inclinations and by economic factors. Under the Ethiopian conditions, these are infinitely harder to tackle than the generation of appropriate agricultural technologies and practices. Therefore, the government faces a difficult task in engineering social transformation.

REGIONAL AND MULTI-NATIONAL COOPERATION

This is a vital area that cannot be left untouched in such important gathering of scientists and policy-makers from Africa and other continents. I believe that multilateral cooperation is crucial in many aspects:

Research and development.

The collective scientific manpower and facilities can be more effectively used by creating cooperative and collaborative research and development activities at sub-regional, regional and at continent-wide levels.

Information exchange and experience sharing.

This is an area where a lot can be gained from cooperative efforts.

Joint development programmes.

Neighbouring states can work out joint investment plans and programmes in the development of, for example, their water resources particularly rivers that cross their political boundaries.

THE STATUS, PRIORITIES AND RESEARCH NEEDS TO PROMOTE DRYLAND AGRICULTURE IN NORTHERN GHANA.

K.O. Marfo
Agricultural Research Station
Nyankpala
Ghana.

ABSTRACT

The northern sector of Ghana, mainly consisting of Guinea and Sudan savanna vegetation, produces a sizeable percentage of Ghana's upland rice, millet, sorghum, maize and food legumes which include groundnuts, cowpea, pigeonpea, bambara groundnut and soybean.

This area, however, has erratic unimodal type of rainfall which makes it imperative to identify suitable genotypes of the above-mentioned crops which give stable yields.

This paper describes some of the efforts being made to evolve materials which give stable yields in the occurence of these abiotic conditions such as drought and heat and also accompanying agronomic technologies which will enable maximum production of these crops. The paper also briefly touches on the constraints presently existing in attempts to reach these goals.

INTRODUCTION

Agriculture accounts for 57% of the GDP IN Ghana, hence the backbone of the country's development. During 1984, the overall increase in agricultural output was 10% whilst that for 1985 was 4% (Annon. 1986).

The northern sector of Ghana produces the major bulk of the country's rice, sorghum, millet and food legumes. However, the area is characterised with unimodal erratic rainfall conditions. In 1975, the Government of West Germany agreed to support active agricultural research in this important food growing zone leading to the upgrading of the Nyankpala Agricultural Experiment Station originally established in 1948. Basically the station is to evolve suitable genotypes of sorghum, millet, rice, maize, cowpea, groundnuts, bambara nuts, pigeonpea and soybean for this dry ecological zone. The varieties to be developed should not only be high yielding but resistant to biotic stresses such as diseases and insect pests and also to abiotic stresses such as drought and heat. In addition, technological packages, with little external inputs, were to be developed to accompany these newly evolved materials to enable them produce maximum yields when incorporated into the various cropping systems existing in the area.

Attention is therefore being paid to mainly cereals and legumes, because the two complement each other satisfactorily in protein quality and content and also cereals provide a rather inexpensive source of carbohydrates for consumption.

An additional advantage of legumes is their ability to fix nitrogen essential for subsistence agriculture in addition to being able to give reasonable yields during moisture deficit seasons.

AGRICULTURAL PRODUCTION

In 1983, the government of Ghana launched a 3-year elaborate agricultural policy with the aim of emphasizing and promoting specific crops in ecological zones where they do very well. Table 1 shows the agricultural productivity of 2 of these crops during the period 1983 to 1985.

Table 1. The Agricultural Output of Maize and Rice during the period 1983-1985.

CROP	MAIZE			RICE		
YEARS	1983	1984	1985	1983	1984	1985
Area cultivated (ha)	400,000	486,000	388,000	40,000	57,000	67,000
Output (metric-tons)	172,000	574,000	411,000	40,000	66,000	90,000*

* As at August, 1985.

The table clearly indicates the havoc that erratic and inadequate rainfall can cause by reducing yield levels in 1983. For example, whilst the average yields of maize in 1984 and 1985 were overe 1 ton/ha, it was about 0.4 tons/ha in 1983. The average annual rainfall for 1983, 1984 and 1985 in northern Ghana were, 667,1100 and 956mm respectively. Thus efforts to develop or select for materials with stable yields become imperative.

STRATEGIES

The mandate of Nyankpala Agricultural experiment station in the northern savanna zone of Ghana lays emphasis on evolving crop varieties that are able to withstand unpredictable rainfall conditions and moisture stress. Sorghum and pearl millet were designated as the most important cereal crops in this zone. This is because of low stable yields produced by traditional farmers over the years. Prominence was also given to

developing materials of various maturity, groups of other cereals and legumes for areas with different rainfall regimes. Hence in the crop improvement unit, there are now resident plant breeders for sorghum and pearl millet, rice (with emphasis on upland rice), maize and legumes including groundnut, cowpeas, bambara groundnut, pigeonpea and soybean. Simultaneously, the Farming Systems Group includes soil chemist and fertility specialist, microbiologist, agronomists (both on-station and on-farm) and agricultural economists.

The general approach is that after new varieties have been developed, the farming system group uses these materials in their on-station experiments to develop suitable agronomic techniques. Based on successful performance of these materials, they are then evaluated with the various technologies at the farmers' fields. Basically, the on-farm experiments consist of the following:

(a) The nominated elite materials using the recommended technological packages accompanying them.

(b) The improved lines grown under the farmers traditional conditions; and

(c) The farmers own cultivar using his traditional methods of caring for the crop.

Below are brief comments on some of the efforts being made to sustain dryland agriculture in northern Ghana:

Pearl Millet and Sorghum

Presently, although the area under late millet is larger than that of early millet, more emphasis is being placed on the development of suitable varieties of this early crop. This is because the early planting of the early materials leads to early harvesting of the crop to fill the "hunger gap" that occurs during June and July of each year. As a result of this, pearl millet is considered the most important crop in the upper half of northern Ghana (the sudan savanna zone) where it covers an area of about 157,300 ha. Early millet is mainly found in the north eastern part where rainfalls are rather unpredictable with unfertile soils. Here, population improvement programme has been initiated in some of the local and some exotic materials obtained from Nigeria. Variability is quite considerable with some superior gene-types yielding up to 2.2 tons/ha.

Sorghum on the other hand is the second most important cereal crop after millet and maize in the sudan and guinea savanna zones, respectively. For example, in the northern part of the guinea savanna, it occupies an approximate area of 88,500 ha. However, mainly tall photosensitive local sorghum varieties which flower towards the end of the rainy season are planted.

An improved late photosensitive variety (115-120 days to flowering) with good grain quality, high yield potential and medium plant height is therefore needed for the northern region of Ghana (guinea savanna). However, for the upper region (the sudan savanna) because of the short rainy season, an early photosensitive high yielding variety with better grain quality and storability is required.

Emphasis is therefore being laid on screening of local germplasm for superior lines. Populations have been established and a hybridization programme has been initiated to develop such suitable materials under our conditions. This is due to the fact that most of the exotic materials either failed to yield grains or gave poor grain yields. Even where reasonable yields have been obtained from these exotic materials, grain acceptability is always a problem.

Rice

This crop is becoming increasingly important in the diets of Ghanaians. Presently, production is below demand, thus importation supplements the quantity produced locally. Most of the rice grown in the country is upland rice which is mainly concentrated in the guinea savanna zone and valley bottoms of the sudan savanna.

Since 1964, consistent rice research in attempts to develop high-yielding genotypes resistant to the major insect pests and diseases has been done at Nyankpala. From 1957, 16 varieties of rice have been recommended and of this, eleven came from the Crops Research Institute with Nyankpala station playing a major part (Olufowote, 1983). Simultaneously, with the varietal improvement, investigations on cultural practices were also conducted which helped to increase rice production from 30,000 tons in 1960 to 80,000 tons in 1976. However, since then, production has been declining due to technical and institutional difficulties (Mercer-Quarshie, 1984), until 1984 and 1985 seasons.

Research on rice has been reactivated since 1982 in efforts to identify suitable varieties of rainfed rice with emphasis on upland cultivation through observational nurseries of materials emanating mainly from the International Rice Research Institute (IRRI) in Philippines and the West Africa Rice Development Association (WARDA), based in Monrovia. Such promising lines pass through initial yield trials, multi-locational yield tests and on-farm tests for eventual release.

Unfortunately since 1982, the performance of some of these lines have not been very consistent, with varietal responses between and within most of the locations showing very low and insignificant correlations (Dekuku, 1985). It is therefore necessary that these materials are further tested for more years since no reasonable inference can be drawn from the present results. This unimpressive performance may be attributed to the significant variation in the rainfall patterns since 1982.

Besides these attempts at selection of suitable rice varieties, some rice genotypes of various maturity groups (89-120 days) are being monitored in planting date trials at both the guinea and sudan savanna zones to find their reaction to drought and blast incidence.

Maize

Although active maize research programme is taking place at Nyankpala, in cooperation with the Ghana Grains Development Project, funded by the Canadian International Development Agency (CIDA) with CIMMYT in Mexico as the executing agent, emphasis is on the guinea savanna zone rather than the sudan savanna. In this direction, population improvement procedures are being used to develop 5 varietal types namely, 120-day white dent, 105-day white dent, 110-day yellow dent, 90-day white dent and 90-day yellow flint. In addition to these, materials are also being screened for resistance to Striga and streak which are becoming very important in this ecological zone, particularly during dry years.

Groundnut

Groundnut is becoming a very important crop, both as a source of vegetable oil and protein. It is estimated that the area under groundnut cultivation in the guinea and sudan savanna zones of Ghana have increased from 82,000 ha in 1970 to 134,000 ha in 1982. This is partly due to the ability of the crop to give stable, although moderate yields, (about 1 ton/ha) even during moisture deficit seasons.

The groundnut improvement programme here is targeted at developing stable high yielding varieties which are resistant to the prevalent foliar diseases like early and late leaf spots, *Cercospora arachidicola* and *Phaeoisariopsis personata* (formerly known as *Cercosporidium personatum*), respectively. In addition, critical monitoring of rust, *Puccinia arachidis* and insect pests resistance are also performed.

Whilst emphasis is placed on identifying long duration maturity materials for the guinea savanna zones, materials with shorter duration (about 90 days) are preferred in the rather comparatively dryer sudan savanna areas. As a result of these consistent efforts, a material called F-mix has been identified with maturity period of about 115 days and oil content of about 46% and acceptable "table quality" which is being released. This material is also being used in hybridization programmes with some early maturing materials to improve on field dormancy levels when the latter materials are planted in the guinea savanna. Concurrently, efforts are being made to identify high performing early maturity varieties of groundnut for the sudan savanna which has a shorter rainfall duration with materials received from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. This group of early maturing materials will be tested in the second year on the farmers' fields in 1986.

Cowpea

Cowpea occupied 115,000 ha of farm-land in 1970 but the area has been reduced to 73,000 ha in 1982. The major cause in the decline of the area under cultivation is the average poor yields (estimated at 0.08 tons/ha) produced by the farmer (compared with 1.5 tons obtained on experimental fields).

These low yields may be attributed to the damage caused by insect pests and diseases with the former being of much more importance. Collaborative efforts are going on between this station on the one hand and the International Institute of Tropical Agricultue (IITA), Ibadan, and Semi-Arid Food Grains Development Project (SAFGRAD), based at Ouagadougou to identify materials of various maturity groups which perform well here. A short duration material (IT - 82E - 16) with acceptable grain quality and the medium maturing material TVX 4677 - 088E is in an advanced stage of being recommended to farmers; the only problem with the latter is unacceptability of seed coat colour. One cannot loose sight of the importance of early cowpea, especially as a preceeding crop in rice fields or planting it after harvesting of rice crop to take advantage of the residual moisture in the soil. For example, in 1985, about 400 kg/ha of cowpea grains were produced in our experimental plots when the crop was planted before seeding rice.

Efforts are also being made to screen for drought resistant materials. Unfortunately in 1984 and 1985, because of the relatively higher rainfall obtained in the sudan savanna area, results obtained from the testing of the materials could not be conclusive. Thus, it might be necessary to test such materials with the assistance of a soil physicist who can monitor soil moisture regime to enable moisture supply to be controlled during the offseason under irrigation.

Although Striga is not a problem in the guinea savanna area in Ghana, it is becoming increasingly important in the sudan savanna zone. Thus, attempts will be made to screen and test Striga resistant or tolerant materials in this ecological zone.

Pigeonpea

This is one of the hardiest crops in that it thrives well on marginal and inadequate moisture level soils. This is evident when one sees it as the only food crop still having green foliage months after the rains. The crop is mainly intercropped, grown as a hedge or single plants near houses. In some cases, it is used to demarcate farm lands.

A programme was initiated in 1980 by assembling diversified germplasm followed by screening to identify suitable lines that can be used as intercrop, fallow or an alley crop. Hitherto the land races grown by the farmers were mainly late photosensitive types which showed little variability in plant types.

Preliminary investigations indicate that early planting of some of the early maturing varieties give reasonable yields because they can avoid the build up of post flowering insects. (Annual Reports 1982, 1983). Generally, these early maturing and the medium maturing materials have a greater potential in the dryer areas of the sudan savanna. ICPL - 1 and ICPL 270 have the best potentials for the early and medium maturing.

Bambaranut

Bambaranut, Vigna subterranea (formerly known as Voandzea subterranea) is believed to be indigenous to these dry areas. In Ghana, however, this crop has not received much attention in the northern savanna zone although records show excellent work done in the coastal savanna of Ghana where the area put to the crop is not extensive.

The 1970 Agricultural Census gave the area under bambaranut cultivation in the sudan savanna zone as 28,700 ha, and the rest of the country cultivated 2,800 ha.

Experience has shown that the crop does better in areas where the rainfall intensity is not high. Consequently, plants in the sudan savanna zone outperform those at the guinea savanna where there are many disease problems, especially Sclerotium rolfsii and Cercospora leaf spots.

Initial screening of some local germplasm and materials received from national programmes in Burkina Faso and Mali has resulted in the selection of some lines which are being evaluated multi-locationally in the entire spectrum of the savanna region. It is hoped that within the next few years, suitable materials from the programme will reach the farmer.

AGRONOMIC CONSIDERATIONS

Alongside crop improvement, attempts are also being made to investigate various cultural and or agronomic practices which will enable the crops enumerated above give optimum yields. For example, studies on pigeonpea intercropping with maize have indicated that a ratio of 3 rows of maize to 1 row of pigeonpea has an advantage over either pure crop of maize or pigeonpea (Annual Report 1982, 1983). This arrangement allows better utilization of moisture and nutrients by both maize and pigeonpea as observed by Saxena and Yadav, 1975. Similarly, studies in nutrient utilization in maize/cowpea cropping systems have shown the efficiency of land use in addition to reduction of fertilizer requirement of maize and soil fertility maintenance. There are other intercropping studies involving the various food legumes and the Cereals include relay cropping, plant population, spatial arrangement and sequential cropping studies, bunding of rice fields, and tying of ridges studies.The aim of these studies is to find the most suitable innovations for the various ecological zones in order to minimise moisture competition and to improve on the yield levels of the various crops.

CONCLUSION

It is suggested in this paper that there is no direct breeding programme for drought resistance in the crop improvement research in northern Ghana. The absence of a crop physiologist and a soil physicist on our station makes it difficult to embark on such a project.

Nevertheless, the indirect methods of trying to identify or develop suitable crop varieties for dryland agriculture through systematic testing of our materials in as many locations as possible including the farmers' fields, eventually satisfies our quest for varieties that are suitable for our dry erratic rainfall conditions.

Thus within the foreseeable future, the programme will continue to depend on "drought" resistant materials emanating from some of the international agricultural research centres and other national programmes.

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DISCUSSION

Some

Since Nyankpala station has the same climatic conditions as the south-east and even some parts of central Burkina Faso, I would like to know what you are doing particularly in the field of water economy techniques.

Marfo

Time did not allow me to go through the detailed report but you might have heard me say bunding of rice fields, suitable crop legumes (i.e. maize or sorghum after yams), intercropping, etc., help in minimising drought risk. Nevertheless, much could have been done but resource limitations such as lack of soil physicists or soil and water management experts and physiologists are the problems.

Amable

TVX 4677-088E was mentioned as being desirable agronomically, but unsuitable in terms of seed coat characteristics. What are the preferred seed coat characteristics in Northern Ghana?

Marfo

The premium is on white rough testa varieties. In the absence of this, red rough varieties are preferred. Low preference is for tan or black seeds; thus attempts are being made to hybridize a white coat local variety with TVX 4677-088E.

Akundabweini

It has been mentioned by several people that Bambara groundnut is one of the legumes they have included in their work. This is indeed a drought tolerant crop, but it seems like there is very limited research being done on this crop particularly in semi-arid areas. What are your experiences with this crop in Ghana?

Marfo

It is true that Bambara groundnut is a drought resistant crop. However, improvement programme is very difficult since even the mode of hybridization has not been well worked out. Experience shows that slight deviation yields nothing. The need for collaborative work was initiated with funds from GTZ.

Agboola

Have you been meeting your fertilizer needs? Is there any move to start soil testing programme in relation to fertilizer use?

Marfo

Yes, we have been getting enough fertilizer since 1984 with the help of the World Bank and other donor agencies. This is because one cannot reap anything from our savanna soils since the soil is inherent in low nitrogen. Thus, with the rehabilitation of the agricultural sector, it becomes imperative to get enough fertilizers.
Soil testing in relation to fertilizer use is being done by the soil chemists and fertilizer specialists on our research station.

5. GUINEA

RESEARCH NEEDS AND PRIORITIES FOR THE PROMOTION OF DRYLAND AGRICULTURE IN THE REPUBLIC OF GUINEA.

Bernard Koundiano
Ministry of Rural Development
B.P. 576
Conakry, Republic of Guinea.

SUMMARY

The Republic of Guinea lies on the West African Coast between latitudes 8 degrees and 12 degrees 30 north of the Equator and covers an area of 246,000 km^2. It is bound in the north by Guinea-Bissau, Senegal and Mali, and in the east by Cote d'Ivoire, in the south by Liberia and Sierra Leone and in the west by the Atlantic Ocean, with a coast line of 300 km. The population is estimated at about 6.4 million inhabitants on an average density of 24 to the km^2. 85% of the population is made up of peasants. Annual population growth is about 2.8% and 18% of the population live in the towns. Rural exodus is on the increase. Arable land makes up 28.5% or about 8 million hectares of the territory. The area presently under cultivation is about 1.4 million hectares, 5.7% of the territory or 17.5% of the total cultivable land.

There are four ecological zones or natural regions with two seasons in the year (dry season and rainy season).

AGRICULTURAL ZONES OF GUINEA

Lower Guinea or Maritime Guinea

This region occupies 18% of the country and covers a narrow coastal zone with an annual rainfall varying from 2000 to 4300 mm. The main agricultural produce includes: rice, coconuts, kolanuts, bananas, pineapples, citrus fruits and salt.

Intermediate Guinea or Fouta Jallon

This region covers 20% of the country and is composed of a set of high plateaux with an altitude ranging from 600 to 1,500 m. Rainfall varies from 600 to 2000 mm per annum. The main crops grown are fonio, maize, legumes and citrus. The main asset of the region is the trypanotolerant Ndama cattle.

Upper Guinea

This area which is savanna region, covers 40% of the country with an altitude ranging from 200 to 400 m. The climate is sudano-guinean with a dry season lasting 7 months and rainfall ranging from 1000 to 1,700 mm per annum. The main crops grown are rice, tobacco, cassava, mangoes, citrus, millet, sorghum and groundnuts.

The Forest Area

This area covering 22% of the national territory, enjoys an equatorial type of climate with rainfall varying from 1700 to 3000 mm. It is a mountainous region with mountain relief reaching 1,600 to 1,700 m in altitude. Because of the region's potential, it is possible to grow a large number of crops: fruits, tobacco, rice, coffee, cocoa, cowpeas, cassava and oil palm.

It can be seen that these regions differ considerably as far as climate and topography are concerned. In spite of this remarkable agricultural potential, production is still insufficient and the government is obliged each year, to import very large amounts of food, especially rice. This is due mainly to the climatic changes observed since 1973 with consequences which are being felt more and more in the country.

DRYLAND AGRICULTURAL ZONE IN GUINEA

This concerns the northern part of the country comprising the natural regions of upper and intermediate Guinea - covering a little more than 50% of the territory. There are two types of climate here, the sudano-guinean and the foutano-guinean.

The rains generally start in May-June and end in October. Annual rainfall ranges from 500 to 1,500 mm and the rainfall index, according to the zones, goes from 4-2-6 to 4-3-5, although not quite long ago it was up to 6-2-4.

At Koundara, for example, with a foutano-guinean climate, the rains in 1985 started in mid-June and ended in October with a total rainfall of 981 mm in 55 days, then there was a break of 15 to 20 days in June, just after the planting of rice, fonio and millet. This resulted in bad harvests. In the savanna region of the sudano-guinean zone, the same phenomenon was observed, resulting in considerable shortages of water. There were also serious floods along the valleys of the large water-courses, causing serious damage to the rice, fonio and groundnuts.

These floods occur almost every year because of the heavy silting of the water-ways, thus impeding good water drainage. Here are to be found ferralitic soils sometimes associated with lithosols and soils of the cuirasse. The pH ranges from 4.5 to 5.5 for highly degraded soils. These are soils devoid of phosphorous and averagely rich in nitrates. The presence of organic material (manure and compost) and agricultural lime, can improve their fertility.

Alluvial soils. These are found in the alluvial plains (along the water courses) and the lowlands. These soils are generally rich in organic matter and as a result, are over-exploited by traditional peasant farmers. Some of these soils are of a sandy texture particularly favourable to the leaching of mineral elements. They are usually flooded.

CROPPING SYSTEMS

i. Shifting cultivation occurs on the hill or mountain slopes. This is done on recently cleared and burned-off land with long periods of rotation allowing the land to remain fallow. The duration of fallow periods have become shorter and shorter because of demographic pressure and the volume of farming carried out. For the average peasant, all farming operations, from land clearing to harvesting, are done manually. Weeding is not a common practice and no fertilizer is used in this type of cultivation. Yields vary according to the natural fertility of the soil as well as on regular rainfall.

Tapade cultivation is done around dwelling houses, in enclosures well protected from stray animals. Yields are generally high because of permanent fertilisation with household waste. The areas are not large but some peasants rely on it for the main part of their incomes.

ii. Cultivation in the lowlands and valleys. Rice occupies almost all available land. This is usually flooded lowland rice as well as irrigated rice. The main constraint here is the lack of water or the low level of water in the plain. This makes cultivation hazardous in times of drought, especially for floating rice. Irrigated cultivation is done by a very small group of families because most peasants do not yet know how to manage water.

PRESENT STATE OF RESEARCH

Up to 1962, Guinea had an important research station in Bordo (Kankan) for savanna crops. A faculty of agriculture was set up in the same spot and the objectives of the station were henceforth re-oriented. Since then research has decreased so much that activities have ben rather limited.

In these zones, research aims at adapting the imported germplasm to local conditions. No scientific infrastructure exists; there are only plot trials.

As from 1980 trials on rice (WARDA), maize and cowpeas (SAFGRAD), cassava and sweet potatoes (IITA) were launched in the two natural regions. Since then interesting results have been obtained in spite of material and financial constraints encountered by the agricultural services in charge of these trials. Some varieties have done well and will be used in extension programmes among the peasants. They are :

Maize (IRAT 178, SAFITA 102) yielding about 3.30 t/ha.
Cowpeas (white wonder, TN88-63) average yield 0.85 t/ha.

Programmes on millet, sorghum and groundnuts should be planned for the future.

CONSTRAINTS

- Irregularity in the rainfall pattern despite an apparently average annual rainfall.

- Lack of training for peasant farmers and the inefficiency of extension services.

- The poor state of infrastructures especially access roads to farms.

- The lack of adequate storage facilities.

- Insufficient marketing systems, well expressed by the insufficient means of transportation.

- Insufficient means of production (agricultural equipment, seeds, fertilizers, phytosanitary products, etc.) as well as the lack of modern means of production for the peasants.

The training of personnel for research and production often has no relation with the real needs. The trained staff generally lack practical experience and the level of specialisation is not satisfactory:

- Agronomic constraints include phosphorous deficiency, soil toxicity, etc.

- The cultivation systems: There are damages caused by grainivorous birds, rodents, insects, etc., as well as weeds.

- Non-adapted agricultural mechanisation and the rare use of animal traction.

RESEARCH PRIORITIES

The Fouta Jallon and Upper Guinea regions considered as dryland zones in Guinea have great agro-sylvo-pastoral potentials which remain untapped because of the lack of basic infrastructure and well defined research programmes.

Considering the impact that the development of these zones could have on the rest of the country, it is urgent that research work which should ensure the equilibrium between man and his natural environment be carried out. This work can, in our opinion, be done without too many difficulties, utilising the data that already exists in the neighbouring countries of Senegal, Mali and Cote d'Ivoire, dealing in general with the same subjects.

It is therefore necessary to study certain problems which could be the following.

i. Socio-economic surveys

ii. Cultivation systems (agricultural time-table, cultivation techniques, rotation of crops, etc.).

iii. Species and varieties adaptable to the zone.

iv. Soil and water management.

v. Fertilizers.

vi. Relations between agriculture and animal husbandry.

vii. Pastoral water supply.

viii. Weeds, pests and diseases.

ix. Production conservation (cowpeas for example).

x. Food and nutritional policies: In addition, recourse to the ever-increasing importation of foodstuffs creates upheavals in the trade balance of the country. The importation of food products results in a change in the food habits of the urban populations bringing about devaluation of local products. It is because of all these problems that we are trying to set up food security policies and nutritional programmes based on the improvement of production, storage, processing and marketing of food products.

xi. Mechanisation of the production system. This has been a problem both for the farmers and the government because of the choice of poorly adapted agricultural implements. Mechanisation can be quite simple (manual tools) animal traction or motorisation.

xii. Soil preservation and the eco-systems. In order to ensure continuity of rural life in drought-prone areas, it is important to provide a green-belt by planting trees which can create a micro-climate suitable for the reproduction of a domestic eco-system. For example, small dams for the planting of fruit trees and fodder plants.

xiii. The improvement of extension methods. The traditional production system (cultivation with long periods of fallowing and extensive ranges) demands a lot of space, its extension will soon have to be limited. Recourse to more intensive, but economical techniques, both in energy and space are indispensable. However, the adoption of these methods must go through an extension phase. The experiments carried out in other countries could serve as a base-line for comparing data, taking into consideration the historical and technical criteria of the planned extension systems.

NEEDS

i. Training of national researchers in the following fields:

- Agronomy: of cowpeas, maize, millet, sorghum, and groundnuts (4).
- Soil Science (2).
- Phytopathology (2).
- Irrigation/drainage (2).
- Agricultural engineering (2).

ii. Assisting with expatriate staff: Specialists in cowpeas, maize, millet and sorghum.

iii. Construction and equipment of a laboratory in Kankan (Upper Guinea) and at Labe (Intermediate Guinea).

iv. An Accelerated Crop Production Office (ACPO) for Upper Guinea where research results are already promising.

v. Selected seeds with experimental trials (cowpeas, maize, millet, sorghum).

vi. Phytosanitary products and fertilisers for the trials.

vii. Extension worker (1).

viii. Continuation of the training of students in the research centres of the dry zones.

ix. The search for funds (donors).

x. Strengthening of cooperation with other research stations at the sub-regional, regional and international levels.

CONCLUSION

The problem of agriculture in the dry zones is not only due to water (insufficient water), but also to the economic and social system. The methods of agriculture should therefore be adapted to the economy of the region. Research should consequently be based on an integration of all aspects of agriculture, namely, animal husbandry, maintenance of soil fertility, control of dryland agriculture, better management of water resources, improved marketing circuits and finance.

To do this, financial means, laboratory equipment and highly trained specialists working in multi-disciplinary teams are needed. It is also necessary to set up research networks in the zones concerned.

Finally, a coordination of results thus obtained for a large dissemination through extension services (research/extension) is necessary.

RESEARCH NEEDS IN THE SEMI-ARID AREAS OF KENYA.

W.W. Wapakala
Director of Research
Ministry of Agriculture & Livestock Development
Nairobi
Kenya.

INTRODUCTION

Kenya is predominantly an agricultural country with over 90% of its population deriving their livelihood from agriculture directly or indirectly through farming and other related Agro-based Industries. Besides, agriculture accounts for between 35-40% GDP and generates over 65% of the country's export earnings. The majority of the farming community are smallholders or pastoralists with a small portion of large-scale farming both engaged in the growing of food crops for subsistence and for the export market.

The Arid and Semi-Arid areas of Kenya constitute a significant proportion of the potential agricultural lands and has been variously estimated to cover 74-82% of Kenya's total land area. The current and the last two development plans 1974-78 and 1979-83 have emphasized the development of these areas as a government priority. This paper will focus attention on semi-arid areas receiving rainfall of between 500-800 mm with bi-modal or uni-modal distribution.

CHARACTERISTICS OF THE SEMI-ARID AREAS OF KENYA.

The Semi-Arid areas of Kenya have been defined as the areas receiving a rainfall of between 500-800 mm per annum approximately totalling 5.5 million hectares or 10% of Kenya (See Tables I and II). These areas were previously considered suitable only for extensive livestock production but due to increasing population pressure, the production systems are increasingly introducing cropping and crop technologies that were previously not meant for these areas.

Table I. Land Capability Classification in Kenya.

Potentiality	Annual Rainfall	No. of Ha. in '000	% of Land Mass
High	857 mm and above	6,785	11.92
Medium	612 - 857 mm	3,157	5.55
Low	612 mm and below	42,105	73.98
All Others		4,867	8.55
Total		56,914	100

Source: Omuse J.K. and Adala J.J. - Food Policy Research Inventory 1960-1983.

Table 2. Ecological Classification of land in Kenya.

Ecological Zone	Area of Land in '000 ha	%	Ecological and Agricultural Major Features
I	80	1	High Altitude, barren land use - water catchment and tourism
II	5,300	9	High potential, forest vegetation, Coffee, Tea, Pyrethrum grown. Dairying practised.
III	5,300	9	Medium Agricultural land, most large-scale farming of maize, wheat and barley done here. Other crops grown and livestock kept.
IV	5,300	9	Land of marginal arable potential. Subsistence farming and pastoralism carried out. Game Parks also found here. Development of dryland farming techniques for this zone.
V	30,000	52	Area of moderate Rangeland development Potential.Wildlife is found here, but livestock development holds good potential.
VI	11,200	20	Most of the North Eastern Province and Northern Kenya lies in this zone. Rainfall is sparse and erratic. Vegetation is made of annual species. The normal way of living is nomadic pastoralism.
Total	57,180	100	

Source: Pratt, Greenway and Gwyme (1966).

Rainfall is the single most important factor limiting agricultural production in these marginal and semi-arid areas. The rainfall characteristics which are important in this respect include, the total amount received in a growing season, its duration and distribution within and between seasons. The second aspect of the semi-arid areas is the topography of the land, mostly made up of rolling uplands or plateau with varying degrees of slope depending on location. The soils have weak surface structure mainly due to low organic matter and high sand content, which distingerate under rain drop impact resulting in surface sealing (Muchena 1975) leading to high run off. High intensive storms tend to reduce the infiltration rates considerably. The soil depth is also very variable from very deep to very shallow in places due to the presence of murrams (petroplinthite) layers (Muchena 1975). The water holding capacity is medium, hence only a limited amount of water can be stored irrespective of the quantities of rainfall received. In Eastern parts of Kenya a bi-modal rainfall pattern prevails whereas in the West of the Rift Valley, the semi-arid areas are characterised by a uni-modal pattern (see Figure 1).

GOVERNMENT OBJECTIVES AND POLICY IN THE SEMI-ARID AREAS

The Government of Kenya fully recognizes the serious situation of the semi-arid areas and is committed to the implementation of wide ranging programmes of economic and social development with the objective of :

(i) Evolvinng more developed and less risky farming systems that would make the semi arid areas self reliant for its food requirements and attain higher and sustained agricultural productivity while simultaneously conserving and upgrading the status of natural resources.

(ii) Integrating the semi-arid lands more closely into the main stream of national economic activity.

(iii) Developing the necessary infra-structural support needed including research, extension cooperatives input supplies, marketing, storage, credit services, roads, water supplies and other essential amenities. Some of the constraints to be addressed are summarised in Tables 3 & 4.

Figure 1

KENYA: *AGROECOLOGICAL ZONES 4 AND 5*

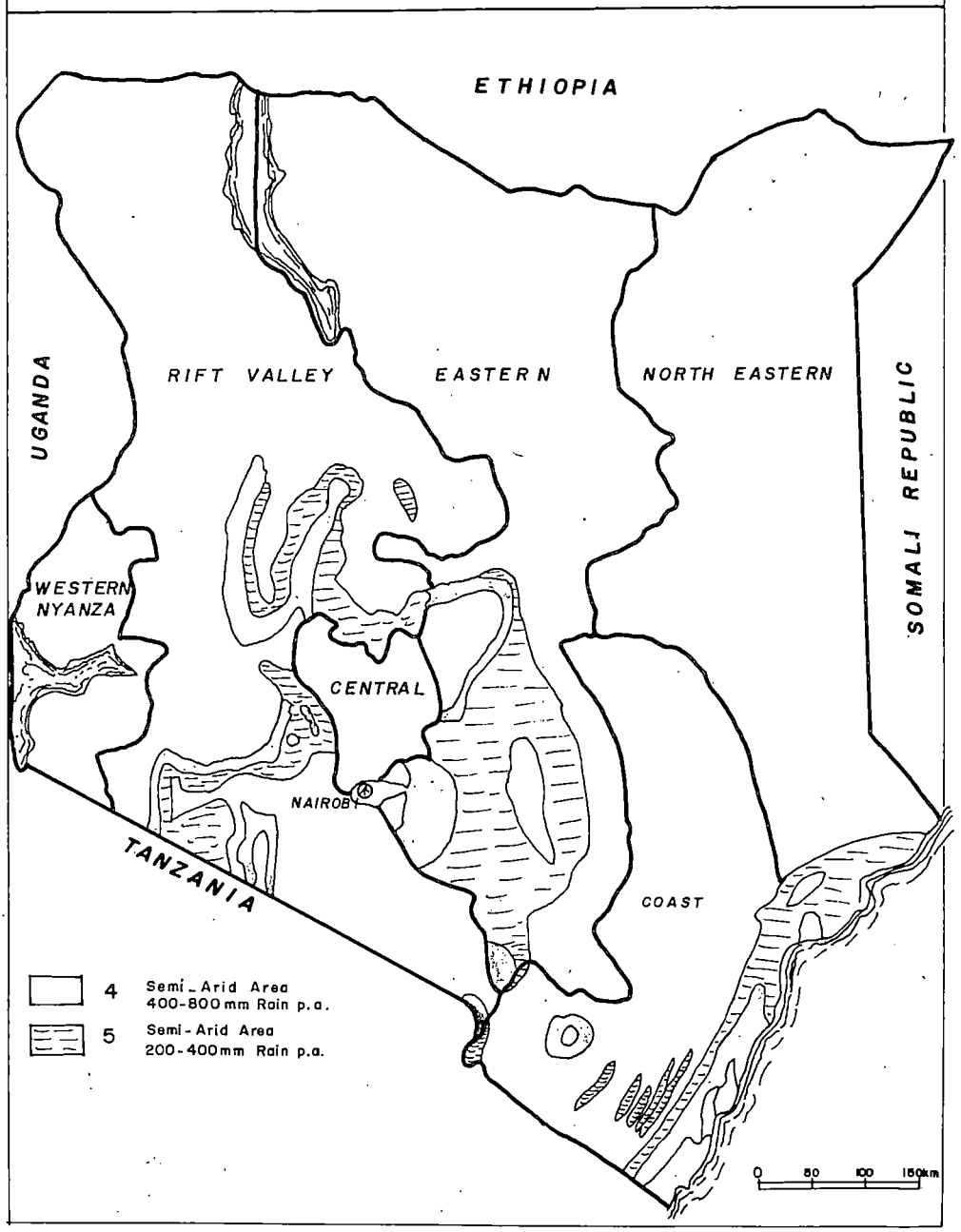

Table 3: Some Factors Limiting Yields of Various Major Crops in the Semi-Arid Areas of Kenya.

CROP/COMMODITY/RESOURCE		LIMITING FACTORS
CEREALS		
(a)	Maize:	Poor seed, low cultural practices late planting, sub-optimal spacing, soil fertility problems, poor weed pest and disease control, post-harvest losses, identification of high yielding drought escaping or tolerant varieties.
	Sorghum & Millets:	Lack of seed of recommended varieties, bird damage, insect pests and diseases. Poor marketing and pricing, mode of utilization as maize substitute in livestock and poultry feeds.
	Root and Tuber Crops: Sweet Potatoes:	Lack of Improved varieties, lack of 'Clean' propagation materials, little or no Agronomic package developed, pest (weevil) and diseases especially mosaic virus.
	Cassava:	Lack of Improved varieties and clean planting material free from African Mosaic virus disease Agronomic packages, cooking and utilization aspects.
	Grain Legumes: Beans, Cowpeas and Pigeon peas:	Poor seed (diseased, cracked, etc) Lack of improved varieties, Poor agronomic practices: Poor Seedbed, late planting, poor or late weeding. Diseases and poor marketing and pricing. High post-harvest losses.
	Soil and water Management:	Tillage methods, soil conservation measure, tillage equipments, soil fertility factors, water-harvesting techniques, efficient water management techniques. Crop rotations.

Table 4. Types of Livestock and Production Constraints.

TYPE OF LIVESTOCK	CONSTRAINTS TO PRODUCTION
Beef Cattle:	Pests and Diseases, lack of clean water and poor nutrition, overstocking, lack of improved stock.
Dairy Cattle:	Pests and diseases, lack of feeds and fodder, shortage of improved stock, poor management.
Sheep and Goats:	Lack of Improved stock. Poor management, Pests and diseases.
Poultry:	Diseases, unstable prices for poultry products, costly feeds, poor management.
Bees:	Lack of Improved bee-hives, harvesting techniques and processing.

CROPPING SYSTEMS IN THE SEMI-ARID AREAS.

Crops in the semi-arid areas of Kenya can be grown in sole stands, in mixtures, in relays or in sequences or rotations. Each one of these constitutes a cropping system. However, the different systems have been developed under different climatic conditions and scale of production and thus tend to be productive under a given set of conditions. Most small-scale peasant farmers in both the humid and the semi-arid areas tend to practice mixed cropping, intercropping or relay cropping for various reasons taking into account the risks or advantages involved. In areas where production is limited by moisture availability even with maximum water conservation, the cropping systems adopted should attempt to maximize water use efficiency. With adapted crops a farmer may choose whether to grow his crops as a sole stand or in mixtures provided the combined water requirements of the constituent crops is adequately met by the available soil moisture. This can be achieved through cultural practices such as plant population adjustments etc. By careful selection of crop combinations and sequences, farmers in the fragile environments can utilise residual moisture for subsequent crops and or hedge against complete crop failure in extremely bad years. Three major cropping systems have been identified in areas with different micro-climatic conditions in the region (Bakhtri et al, 1982, Rukandema 1984).

FARMING SYSTEMS

The ultimate aim in the development of the dryland farming technology is to enable the evolution of stable farming systems which are less vulnerable to the fluctuations of the physical environment experienced in the semi-arid areas. In Kenya, priority areas requiring attention include soil and water conservation so as to maintain or increase the yields of crops or forages, the development of adapted crop varieties and the development of appropriate cropping and cultural methods which aim at achieving high water nutrient use efficiency without further degradation of the basic resources. This can be achieved through several ways such as the addition of inorganic fertilizers, use of N_2 fixation by Rhizobia or recycling of crop residue and animal waste.

SOIL AND WATER CONSERVATION

The soil and water management and conservation efforts should be seen as the first priority towards the stabilization of agricultural production in the semi-arid areas. The main thrust of research efforts should cover such practices such as terracing, tillage systems, effects of cropping patterns, establishment of wind belts and dams, in addition to current efforts in terracing of slopy land. Other methodologies such as contour tillage, tied ridges, planting grass, minimum tillage, stubble mulch tillage can be very effective. (Arnon 1972). The use of water conservation to mean dam construction has similarly led to the exclusion of many farm practices that restrict rainwater where it falls so as to enter the soil and later become available to the crop growth. In order to achieve effective conservation it is necessary to draw whole farm plans including all other facets ranging from terracing to cultural practices on an integrated basis. Currently, terracing is by

and large accepted at farm level as a cultural practice therefore greater attention should be directed towards development of tillage and cultural methods which are effective in rainfall conservation, including field ridging, contour ridging and zero-tillage as these have been shown to be effective in increasing yields under condition of low rainfall (Lawes 1965, LeMere 1953, Peet and Brown 1960). There is need to conduct studies on how to maximize use of available rainfall through efficient management of run-off, water harvesting techniques, micro-catchments and supplementary irrigation based on crop water requirements at critical stages of development. The efficient management of available water resources can be expected to substantially increase production in these areas.

USE OF ADAPTED CROPS

It has already been mentioned that the rainfall duration in the semi-arid areas of Kenya average about two months while the available crops reach maturity in three or more months. The most important objective in the development of suitable crops for these areas is to tailor maturity dates of the adapted varieties to the rainfall duration and amount respectively. In order to achieve this, the crop improvement programmes have two goals. The first goal is the development of quick maturing varieties with drought escaping characteristics. The second goal is the development of drought tolerant/resistant crops within a suitable maturity length. The synchronization of the crop maturity length with available moisture regime is of critical importance. Several on-going active major programmes are briefly described below:

Maize Improvement Programme

Maize is one of the most important food crops of the area and a breeding programme established in 1956 has produced several improved early-maturing maize varieties. These include eight synthetic varieties and three composites. Katumani composite B is the most widely grown. However, a recent composite Makueni is early-maturing, with wider adaptation and stable yields over the lower range of the environments. In addition, resistance to pests and disease is incorporated in this crop improvement programme.

Sorghum and Millets Programme

Sorghum and Millets are the other important cereals for the arid and semi-arid areas of Kenya. Major efforts are concentrated on the development of drought-resistant, good quality, short-term to medium-statured early maturing genotypes, with insect and disease resistance, with particular emphasis on Sorghum charcoal-rot. Several good grain quality sorghums have been developed such as 76T-23, 954063 and NES 7360 for the medium and low altitudes respectively, where efficient bird scaring is not possible. Due to their persistent testa, they are unattractive to birds. Besides the identification of drought and disease resistant varieties there is need to improve the quality and types that can effectively substitute white maize flour for taste and or with acceptable baking qualities.

Grain Legume Improvement Programme

The major grain legumes of significance in these regions include the dry beans, pigeon peas and cowpeas. These constitute an important source of protein for the majority of people who cannot afford to include animal protein regularly in their diets. The yield of food legume are generally poor as these crops are severely affected by a wide range of fungi, virus diseases, and insect pests. The bean project developed several cultivars viz GLP - 24, GLP - 2 (Roko) and GLP - 1004 for high, medium and marginal rainfall areas of bean growing respectively. These varieties have been well accepted by farmers in the higher rainfall areas.

The Mwezi-moja variety selected for the semi-arid areas however is not sufficiently drought tolerant to stabliize yields in these areas. There is therefore need to identify drought and heat resistant bean cultivars capable of stabilizing yields over a range of the semi-arid environments.

The other grain legume of major importance in semi-arid areas of Kenya is Pigeon pea, which is usually grown as a mixed crop and rarely as pure crop. Tall, late varieties are grown, intercropped with either cereals or other legumes or both. Early-maturing lines which fit into bi-modal rainfall patterns have been identified from selection of the local germplasm. Yields of over 2000 kg have been attained from early maturing lines of KCS 74-1, KCS 22-4, KCS 13-11 and KCS 21-12. The ratoon crop generally yielded higher than the first harvest. Several lines of medium and long-maturity groups with large grains have been identified. Other aspects of pigeon pea improvement include development of insect pests and disease-resistant materials.

The third aspect of grain legume improvement programmes is the development of indeterminate, semi-spreading, dual purpose, widely adapted, disease and insect-resistant lines of cowpeas suitable for the dryland areas. Cowpea is widely used both as grain and as a vegetable providing a highly nutritious source of proteins and vitamins. The indeterminate types are said to perform better under drought conditions than determinate types (Chaturverdi et al 1980). Katumani 80, a selection from local germplasm is an indeterminate cultivar adapted to low altitudes (below 1300 m), Machakos 66 is an indeterminate dual-purpose type with prospects of good performance in higher altitudes (above 1300 m). Cowpea yields are low due to lack of high-yielding varieties with resistance to insect pests and diseases. Insects continue to pose major problems in cowpea production systems. There is need to focus research efforts on the development of insect-resistant/tolerant varieties and also appropriate technologies for integrated pest management to reduce yield losses.

Root and Tuber Crop Improvement Programme

The major research thrust in these crops relate to Cassava and Sweet Potato. In both cases, the constraints to increased production is lack of suitable varieties with resistance to diseases and pests. In cassava, there is need to develop high yielding, cassava mosaic disease-resistant cultivars, with good tuber characteristics, taste and cooking ability. The major research efforts on sweet potato should address the problem of susceptibility to weevils and viruses.

AGRO-FORESTRY SYSTEMS

Woodfuel accounts for about 75% of the total national energy consumption, while other sources including crude oil accounts for only 25%. In Kenya, 70% of the tree resources are in the semi-arid lands. In 1980, of the estimated total national demand of 20.82 million metric tons, 61% was for fuelwood, 35% for charcoal production and the remainder (6%) for building, fencing and for industrial uses. The need to develop agro-forestry in these areas is crucial in meeting our energy needs both for the rural and urban populations. Existing afforestation techniques should also be improved using local and exotic tree species adapted to these regions. Innovative ways in which multi-purpose trees and crops can be grown in combination or sequence, should be determined.

LIVESTOCK PRODUCTION SYSTEMS

The rearing of livestock (cattle, sheep and goats) plays an important role in the production systems of small-scale farmers in the semi-arid areas of Kenya. The seasonal scarcity of fodder both in terms of quality and quantity is the main production constraint and besides causing low productivity in animal meat and milk and other products, crop production is also affected by the limitation imposed on availability of drought power. The primary source of feed for livestock on most small-scale farms in these areas is natural pasture and the improvement in the management and utilization of this important resource should be an essential point of departure leading towards a positive and more productive livestock feeding/production system. To effect this improvement there is need to establish the major factors that limit the productivity of pasture in order to quantify its contribution in the production system. The second aspect is the need to identify highly productive and drought resistant fodder trees and shrubs, legumes and grasses capable of carrying the livestock through the dry season. Thirdly, the grazing management of both pasture and livestock to ensure the optimum carrying capacities for maximum resource utilization. Fourthly, the selection of suitable breeds and class of livestock combination to exploit the available feeds. In addition to the above, there is need to integrate livestock systems into wider farming systems by the use of farm crop bi-products for maximum utilization of available feeds and the subsequent recycling of animal manure for crops and farm energy.

RESEARCH PERSONNEL

The need to develop research institutions with adequate infrastructural facilities and well-trained manpower is crucial if the entire scope and magnitude of the dryland technology are to be seen in the right perspective. Despite the recent efforts in the training of personnel in the last few years, a wide gap of well-trained scientists with the capacity and capabilities in the various fields of dryland farming technology still exists. Besides Breeders and Agronomists, there is an acute shortage of specialists such as Hydrologists, Soil-Water engineers, Storage engineers, Soil scientists, Agro-meteorologists, Livestock scientists, Food scientists and Social scientists. The acute shortage of well-trained scientists poses major research constraints. (ISNAR 1982, 1985).

SUMMARY

An attempt has been made in this paper to enumerate some of the main problems and features associated with research and development of the semi-arid areas of Kenya. The major problems encountered in dryland farming may be grouped into the following researchable areas:

(a) i. The development of appropriate soil water management methodologies which would ensure continued land use and productivity on a sustained long-term basis without degradation.

ii. The development of appropriate tools and tillage equipments for timely working of the land.

(b) i. The development of adapted crop varieties that are tailored to fit within the limited rainfall with drought escaping mechanism and or tolerance/resistance. The adapted varieties should incorporate pest and disease resistance.

ii. The development and availability of high quality certified seed and maintenance of these varieties and lines.

(c) The identification of suitable grasses, forages,legumes and fodder shrubs and the required management systems to ensure increased production on a year-long production basis.

(d) The development of Agro-forestry techniques suitable for the same and areas using local and exotic tree species adapted to these areas.

(e) The selection and introduction of suitable livestock breeds with the genetic potential to exploit fully the available feed resources and high conversion efficiency.

(f) The development and formulation of suitable farmers' production packages which are within the farmers' reach and better able to cushion him against the vagaries of the unpredictable environment characteristic of the semi-arid areas.

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DISCUSSION

Some

Could you elaborate more on the systems of soil moisture conservation in Kenya?

M'Arimi

(i) The problem of moisture conservation through tied ridges and other tillage methods in Kenya was being tackled systematically. Following conclusion that tied ridges were most effective, the Agricultural engineering department in the University of Nairobi started working on efficient ox-drawn equipment for the purpose. By 1982 a useful piece of equipment was already developed and undergoing testing.

(ii) It was considered that ox-drawn ploughs were already in use in the area, hence the introduction of the equipment would play exactly the same role as existing ploughs. Ridges would be made along the contour and later use manual labour for cross tying. The extra labour was considered more than compensated by increased yield in maize. However, field figures on labour use and costs particularly with recent increases in wages may require updating in light of the other farming enterprises.

Levi

In West Affica, cowpea is used for fodder with grain, we see the East African dual purpose cowpeas as being used for leaf-cum-grain. Assuming that high stable yields can be achieved through crop improvement, where do you see the greatest impact coming from? High leaf, high grain or high fodder yield?

M'Arimi

In Kenya, cowpeas are grown for grain use in Eastern Kenya as well as vegetable form. In Western part of Kenya, they are used as vegetable preparation. The two systems of utilization are basically related to the customs of the people in these areas.

STRATEGIES FOR DROUGHT CONTROL IN NIGER

J. Gonda, N. Jika, A. Moussa,
A. Moukaila and C.R. Reddy,
Ministry of Higher Education and Research
Niamey, Niger.

INTRODUCTION

One of the major problems facing current agricultural research consists in increasing food crop yields so as to counterbalance population growth throughout the world. In the Sahel in particular, and in the developing countries in general, the lack of appropriate technologies to solve this problem, results in disastrous conditions of poverty and famine. In the Sahel, the drought which has been constantly raging since the 1970s is worsening this situation. In Niger, which is a sahelian country, millet and sorghum are the most important staple cereals covering nearly 90% of the cultivable areas, (of which 2 million ha is occupied by millet); followed by cowpeas and groundnuts. It is worth noting that all these food crops are grown in the southern fringe of the country (less than 25% of the total area of the country) where annual rainfall ranges from 200 to 800 mm. The rainfall is often very unevenly distributed both in space and time and this same fringe has been severely hit by years of drought, the most recent and the most catastrophic being the drought years of 1972-1973-1974 and those of 1982-1983-1984.

At the research station of Tarna, it has been observed that from 1979 to 1980, water deficit has gone up to 38.6% (in comparison with 1979) and the rainfall recorded in 1985 (341.7 mm) is still far from the mean average of 500 mm for the region, although an increase of 43.75% (in comparison with 1984) has been recorded (see table 1):

Table 1 The rainfall pattern of Tarn from 1976 to 1985

Year	- 1976,	77	78	79	80	81	82	83	84	85
Rain-fall (mm)	- 446.8	548.1	452.5	556.5	511.5	413.8	285	213.7	237.4	341

Due to the pressure of this persistent drought and its harmful effects on food production, research in Niger has adopted a mid-term control strategy, based on a programme which aims at perfecting early lines of the most popular local varieties such as millet, sorghum, cowpeas and groundnuts. In this paper we present how this strategy is being carried out.

DROUGHT CONTROL STRATEGIES IN NIGER

DEFINITIONS

What is drought?

In many documents, the harmful effects of drought are described in detail but the definition of drought is not given. In this presentation, we shall define drought **as being a period of insufficient water supply during which the development and production capacities of the plant are reduced.**

What does drought resistance mean?

Like the definition of drought, the definition of resistance to drought has not been precise. It is for this reason that we will try to give a definition of resistance to drought as follows:

In the same soil and within the same climatic conditions, resistance to drought is the aptitude of a plant (production) undergoing water stress to produce an acceptable yield, near or equal to the yield it would produce under favourable water conditions.

After having given definitions for drought and drought-resistance, we can safely say that food crops in general and cereals in particular, undergo certain processes in order to resist drought; the important processes are:

drought avoidance, a process during which precocity plays an important part;

drought tolerance where the cycle and osmotic adjustment play an important role by enabling the plant to maintain good cellular turgidity under moisture-stress conditions.

Adaptation or resistance to drought are important where appropriate agronomic materials are available.

Two adapted strategies from Niger.

A short and mid-term drought-avoidance strategy by the adoption of a method of purification during which the early lines of our local varieties are improved.

A long-term strategy based on a joint INRAN-ICRISAT programme to develop pools of early genes between local and introduced varieties, especially of African origin.

During periods of drought, it was observed that the early genotypes were the most suitable, maturing early, thereby avoiding the drought and using the little moisture available. Promising results have been obtained during trials in drought-prone conditions where the early material developed had been tested. We now describe below the purification method used in the improvement of millet, sorghum, groundnuts and cowpeas.

Method of Purification

This is a method for the rapid improvement of local population yields specific to the different ecological and rainfall zones in Niger, considering at the same time, the origins of these populations (see Figure 1).

Firstly, the locally collected cultivar is sown on a plot measuring 600m^2 and a lot of self-pollination takes place, 400 to 500 ears (see diagram), The S1's thus obtained are placed under observation and evaluated. A.F's take place on some ears from each line, thereby giving S2 lines. All the S1's of native origin with a good yield and high tolerance to mildew and smut are retained. At the same time the early S1's are isolated and retained.

The S1's are then crossed several times, thus producing the P1 populations which will be tried in peasant farmers' environment and elsewhere. The early S1's are also crossed several times in order to obtain the early version of our local populations which will be tested in drought-prone conditions and elsewhere.

This, briefly is the method of purification used and the results obtained. Even if the purification method is not strictly applied to sorghum, groundnuts and cowpeas, it is still true that it is always the early cycle that is used in plant improvement for drought control.

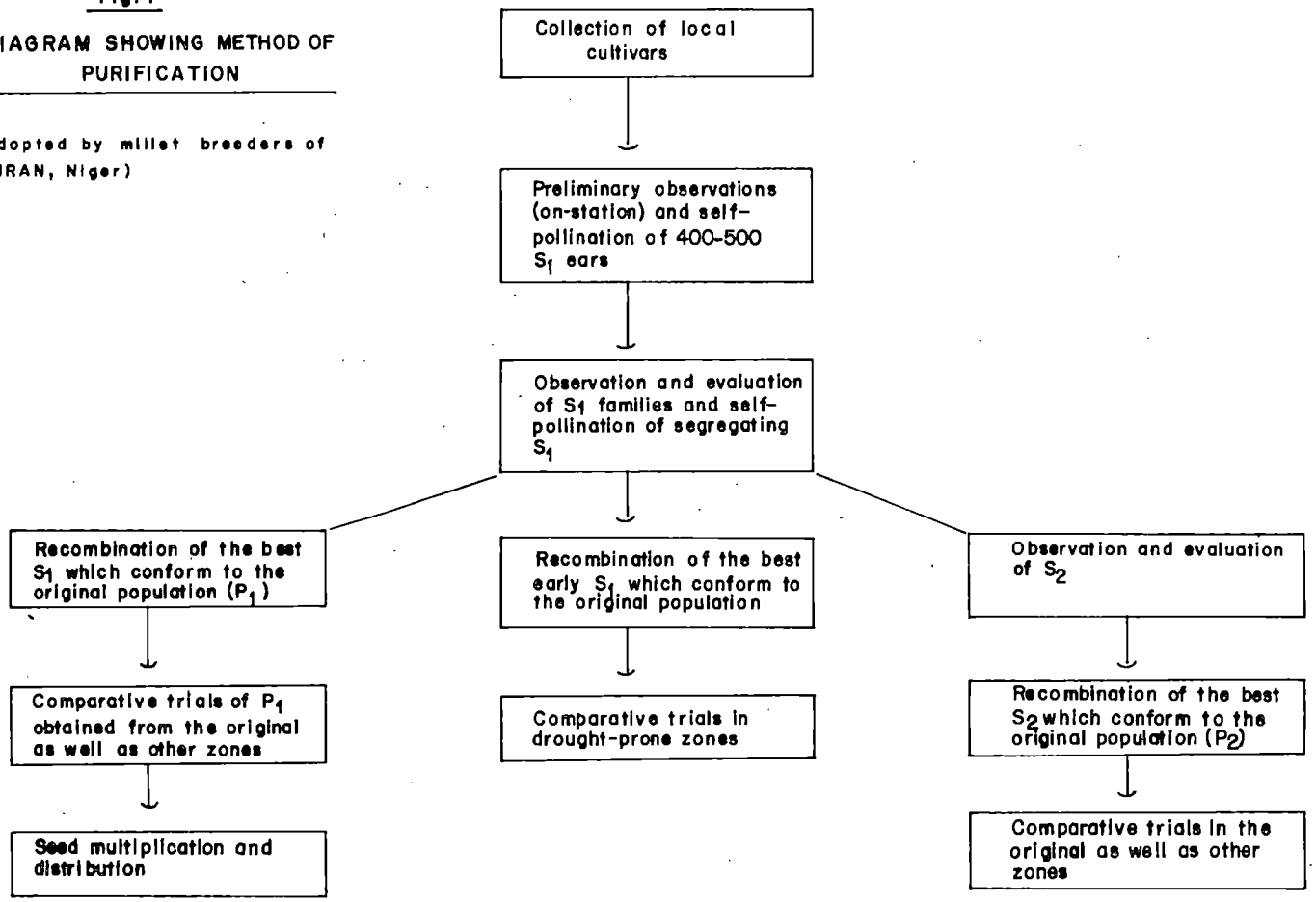
The use of early gene-pools

Drought being erratic, it is recommended that large-based genetic populations should be created. This was undertaken between 1978 and 1984 by the INRAN-ICRISAT cooperative programme, which developed 5 gene-pools among which were; the early pool, intermediate and long cycle; from which were obtained the ITMV series. These gene-pools were made to preserve great genetical variabilities of the different agronomic characteristics making it possible to stand bio-climatic hazards, including water stress. The "random mating" method is applied as described by Andrews and his collaborators in 1977 and proposed by M.N. HARRISON for maize improvement in Kenya. This method consists of taking as pollinating agent a "bulk" of an equal mixture of seeds of the different genotypes concerned. The lines of this bulk are then alternatively sown with the lines of the different genotypes composing it. This mixture lasts 3 to 5 cycles. If all goes well, at the last cycle, the new genotypes thus obtained will bear no morphological differences from the bulk itself, showing that a satisfactory union has taken place.

Fig. 1

DIAGRAM SHOWING METHOD OF PURIFICATION

(Adopted by millet breeders of INRAN, Niger)



The varieties obtained from these gene-pools are shown in Table 2.

Table 2. Characteristics of varieties brought to perfection at Tarna (Maradi) by the joint INRAN-ICRISAT programme. (Specific of the northern zone).

Varieties	Cycle 50% FL	Yield (kg/ha)
ITMV 8001	68	1044
8002	62	1021
8003	70	927
8302	65	1184
8004	67	1058
8303	64	1027
8301	67	1263
8306	69	890
8304	64	1076
8305	69	912
8401	68	1144

Why choose a short-cycle in drought control strategy?

The studies undertaken on the relative yield/cycle of 50% ear emergence during water-stress had shown a strong negative correlation between these two varieties. This study was carried out on four local millet populations, the Ba-angoure', the Moro, the Tamangagi and the Ankoutess (G. Jada 82). This study shows that the time between sowing and 50% of ear emergence and between sowing and 50% of flowering was, on the average, extended respectively from 6 to 8 days. This means that drought tends to extend the vegetative cycle of our plants (millet) rather than shorten it. The cycle is altered and this is variable from one population to the other; thus, the time between sowing to 50% flowering has been extended among the Tamangagi populations (10 days), gamoji (9 days) and guerguera (8 days) (see Table 3).

Table 3. Time of emergence and flowering of local millet populations.

Local Populations	Time elapsed from sowing to			
	50% Emergence		50% Flowering	
	1981	1982	1981	1982
Ba-Ang	59.69	67.34	63.90	70.24
Ank.	60.00	67.03	65.70	72.31
Gamo Ji	57.79	67.23	62.00	71.88
Tamangagi	58.29	68.00	63.75	72.31
Guerguera	59.83	68.33	68.48	71.15
Bazaoune	61.71	68.24	68.15	71.84
Moro	55.13	61.00	59.63	63.45
Average	57.34	64.35	62.40	67.62

Table 3 shows the 50% ear emergence cycle and flowering among the local populations under consideration whilst among the ankoutess populations of the ba-anoure', the moro and the bana oune, it varied between 6 and 7 days. This shows that grain development takes place especially during flowering, as the time between sowing to 50% flowering was extended on average by only 5 days whilst from sowing to 50% ear emergence this time was extended by 7 days (Table 3). Generally, a strong negative correlation R277.48 exists between the yield (y) and the cycle (X) (See Figs. 1 and 2).

This means that the longer the cycle the lower the yield. In 1982, a particularly dry year (285.6 mm), only lines with a 50% ear emergence cycle between 52 and 66 days after sowing gave an appreciable yield 1325 kg/ha to 816.66 kg/ha (see Table 4 and graphs 1 and 2). This was the same in 1985 (341.7 mm) (See Table 5 and graphs 3 and 4).

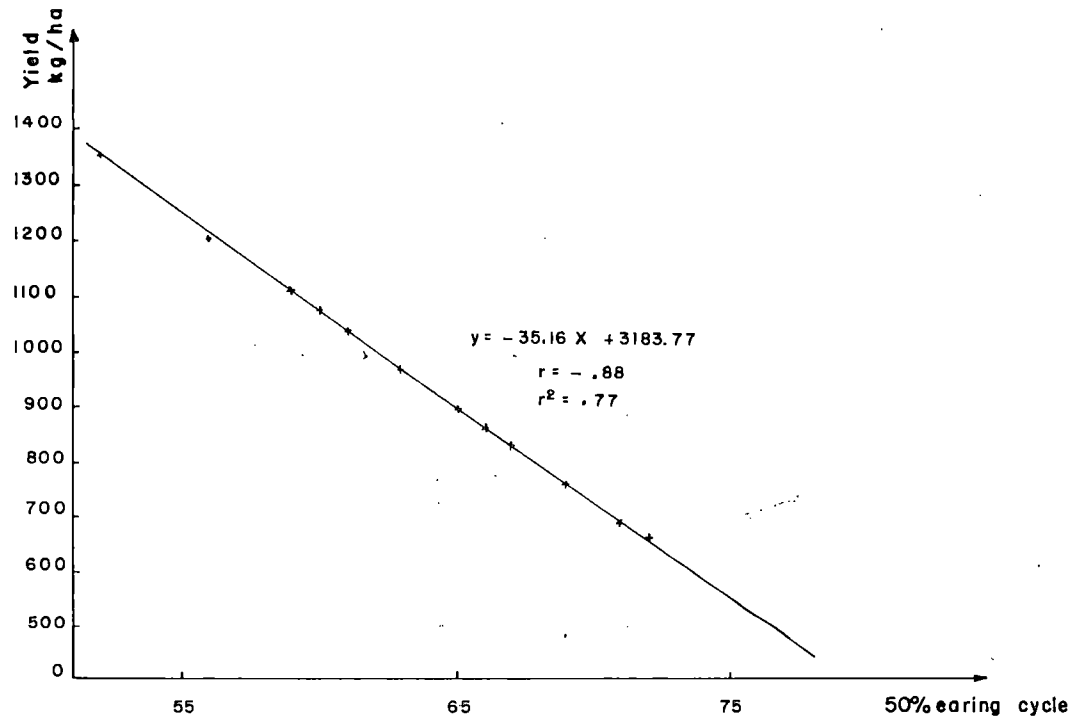


Fig. 1. Relationship between cycle and yield in millet under drought (1982 cropping season)

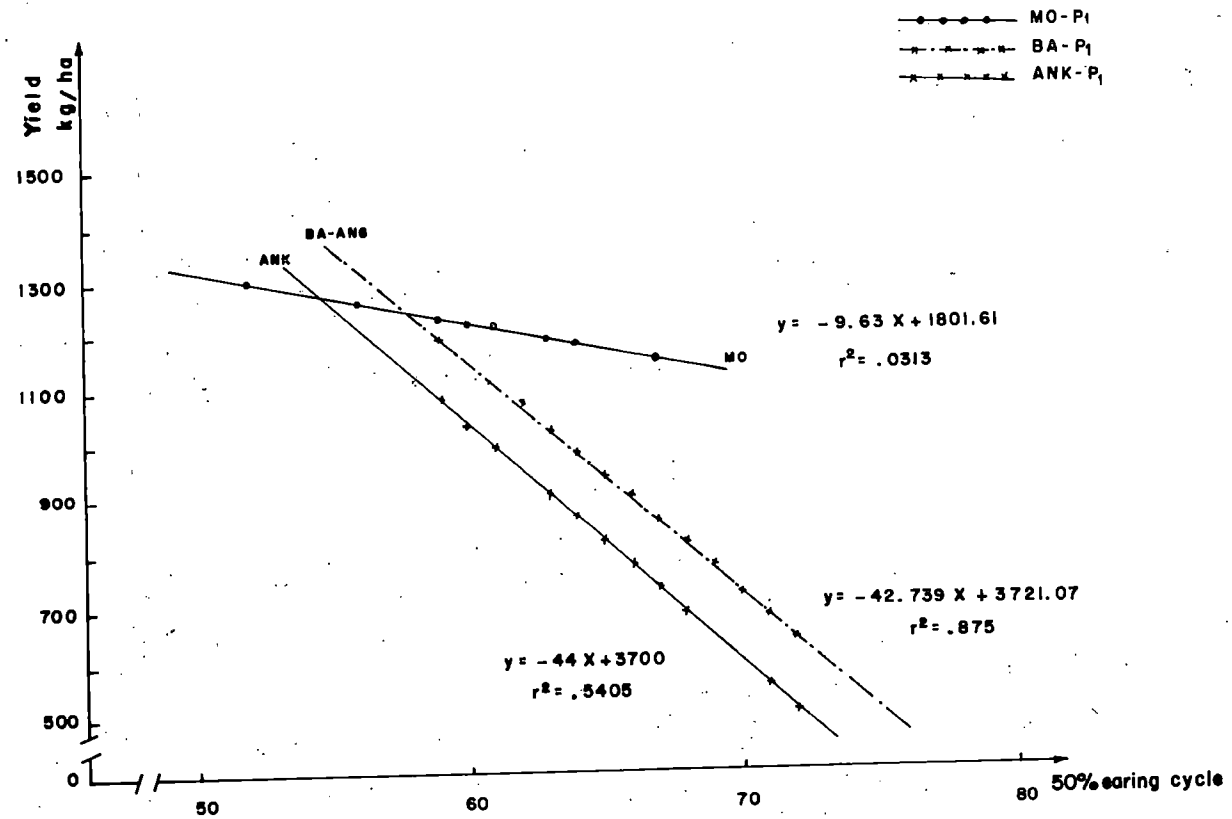


Fig. 2. Relationship between cycle and yield of purified local populations under drought (1982 cropping season).

Table 4. Mean average yields of lines in relation to their cycle (average of 4 populations) during the 1982 cropping season.

50% ear emergence cycle	Average Yield (kg/ha)
52	1325
56	1000
59	1151.85
60	1233.33
61	970.83
62	991.66
63	1182.40
64	1174.44
65	886.21
66	816.66
68	731.24
69	696.29
70	749.99
71	632.63
72	538.89
77	500.00

1985 Cropping Season

4 (Year)	X(50% ear emergence cycle)
1355.45	52
1204.81	56
1109.33	59
1074.17	60
1039.01	61
1003.85	62
968.69	63
933.53	64
898.37	65
863.21	66
828.5	67
792.89	68
757.73	69
722.57	70
687.41	71
652.25	72
476.45	77

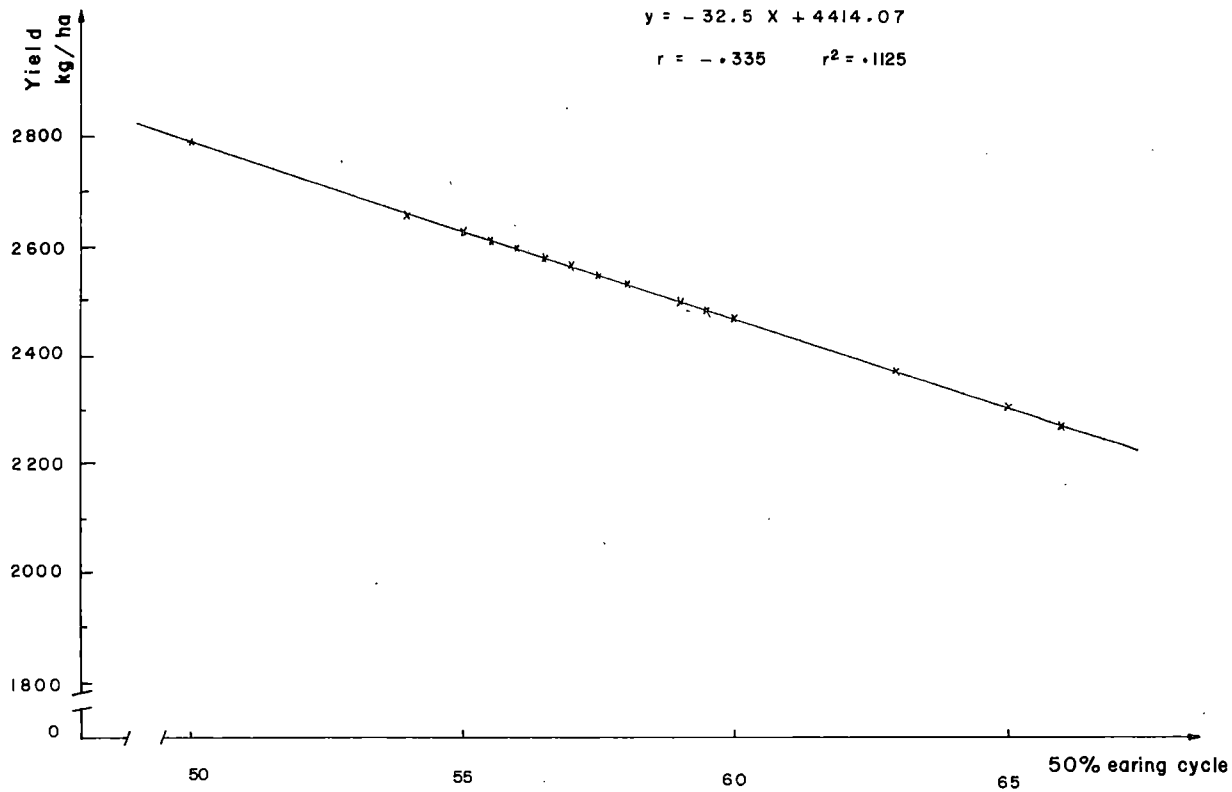


Fig.3. Correlation between cycle and yield in millet (1985 cropping season).

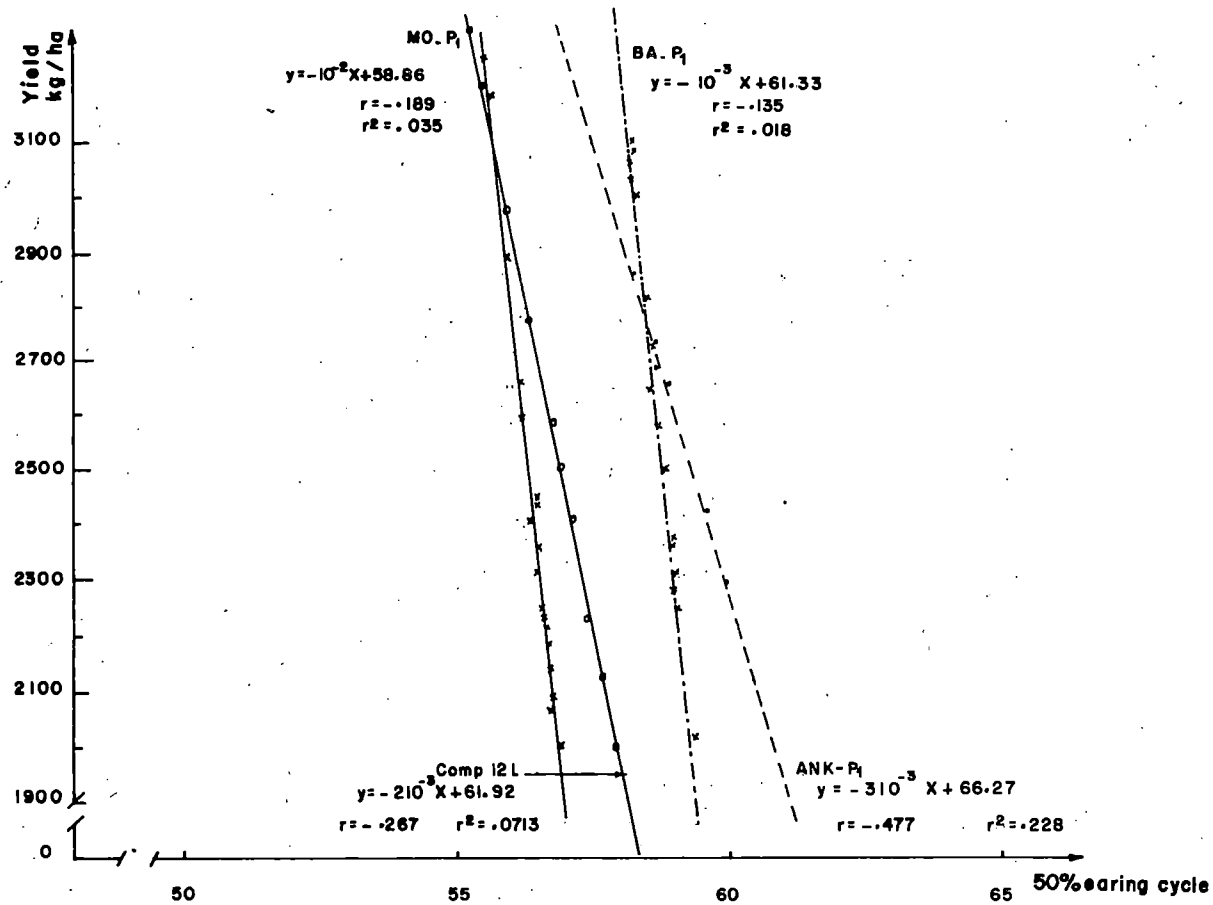


Fig.4. Correlations between 50% earing cycle and yield in purified local populations and their composite 12 L (1985 cropping season).

RESULTS OBTAINED

Millet

Based on precocity, a number of refined populations (early varieties) were developed and tested in the low rainfall zones as well as the early varieties proposed by the joint INRAN-ICRISAT programme, i.e. the ITMV series. This test showed that on all the trial sites, the early varieties outclassed the local reference check in yield, and the best varieties were Ank.-Pl with 1005.63 kg/ha. ITMV 8304 with 981.43 kg/ha and the Moro-Pl with 973.75 kg/ha; for an average rainfall of 277.05 mm; followed by varieties HK-BT-T with 933.75 kg/ha whilst the local variety produced only 902.4 kg/ha (see Table 5) or 11.47% less than Ank.-Pl and 8.66% less than ITMV 8304 and N/O-Pl for an average difference of cycle from 2 to 6 days.

Sorghum

Although no selection on drought resistant sorghum has been effective, because of the lack of adequate irrigation material, under this study, efforts have been made to carry out trials on early varieties, although in general the sorghum from Niger is early enough (90 days) and so resists drought by avoiding it. Efforts in the introduction of a hybrid have been made and the Sudanese hybrid Hageendural has shown a remarkable adaptation to drought in sand dunes by out-classing the local adapted varieties. (Table 6).

Groundnuts

The same strategy based on precocity had been used for the groundnut programme. The early varieties introduced such as Chico and the 796 as well as the drought resistant varieties like the 55.437 and the 57.16, selected elsewhere, have served as basis in the launching of a development programme of varieties adapted to our conditions. Important results were obtained not only in the study of the varieties, but also in the creation of early and resistant varieties to drought, year after year. In order to find a solution to the fluctuating situation of the yields of the lines retained and crossing due to the length of the rainy season, two selection groups were considered - the selection group of Tarna 2 for its resistance to drought and the Tarna P.R. group for precocity, the first based on strain and the second on crossing. The results of the study show that all the strains under study (within a 3-year period) were more resistant than the 55-437 which, is the reference check, but the most interesting are strains T.176-83 and T.177-83 with respective average pod yields of 605 kg/ha and 684 kg/ha with the reference check producing only 271.5 kg/ha (see Table 7).

Table 5. Trials in Northern Low-Rainfall Zone
Average yield of early varieties of millet in low rainfall zone

	CHETIMARI ZR	D. TAKAYA ZR	GUIDIGUIR ZR	TARNA MI	CHERI DA	YAGAGI ZR	OURFANE MI	CHIKAL NY	X	CYCLE 50% EP.
HKB-Tif.	1220	920	310	1770	340	1900	660	350	933.75	66.
HKB3	780	1060	610	1575	610	1740	630	330	916.87	65.6
MORO-PI	760	1100	690	1780	870	1470	630	490	973.75	65
ITMV 8304	670	1230	540	1680	960	1370	730	670	981.25	66.75
HKP	1070	570	380	1765	1060	2050	850	270	1001.87	67.00
ANK.PI	640	1140	580	1815	1080	1630	620	540	1005.63	70.50
Local	990	190	520	1635	890	-	460	430	902	72.50
Rainfall (mm)	261	292	245	341	316	-	226	258,4	227,05	-

Table 6. Mean average yield of early varieties of Sorghum in the trial sites.**

Locations Varieties	TARNA	MAGARIA	KOLO	KALA-PATE	KONNI	X
B.DF.	2333 (79)	1360 (80)	816 -	732 (84)	698.24 (74)	1187.84 (79.25)
E.M.	2303 (65)	456 (67)	254 -	183 (89)	1063.15 (73)	851.83 (73.5)
N.G.K.	3096 (74)	1395 (73)	798 -	419 102	584.2 71	1258.44 80.00
B.G.	2162 (87)	1246 (57)	842 -	409 (104)	765 (75)	1084.8 (80.75)
B.H.	2557 (72)	1482 (67)	798	447 (97)	842 (74)	1225.2 (77.5)
A.J.B.	2215 (77)	513 (57)	575 -	126 (93)	(75) (75)	(75.5) (75.5)
Terra	2737 (73)	632 (73)	421 -	549 (100)	891.22 (70)	10.46.04 (79.25)
Ref. Check.	2373 (72)	969 (57)	91 -	496 (91)	937 (73)	1053.2 (73.25)

** The figures in brackets show the 50% flowering cycle. This test shows that varieties B.D.F., NGK and BH have been the best with respective yields of 1187.84 kg; 1258.44 kg and 1225.2 kg/ha and have about the same 50% flowering cycle, 79, 80, and 77 days or (to seven days longer than the local reference check) with a production of between 12.8 to 19.5% more than the latter.

Table 7. Average Yield of Groundnuts - Lines 83 (kg/ha)

Lines	1983	1984	1985	X
T 176-83	483	154	1178	605
T 177-83	448	245	1361	684 6
T 178-83	435	202	698	445 0
T 179-83	438	46	432	305 3
T 180-83	392	189	771	450 6
55 437	-	42	501	271 5

Cross-breeding showed that the F5s in particular were not only compared for resistance with the 55-437, but also for precocity with the 796. The 55-437 variety is adapted to any combination although being the most popularized variety. Consequently, only the crossing of VSP seems to be interesting in the two mentioned cases, that is resistance and precocity (See Table 8).

Table 8. Pod yields of the different types of crossing studied.

Crossing	Pods kg/ha	Grains kg/ha
USP	1301	866
UN	850	569
UJ	1078	723
UB	1101	768
UR	942	634
UL	861	537
55-437	1225	842
Reference check 796	1058	698

For groundnuts in general, the useful season does not go beyond 35 flowering days. Early flowering seems to be the most important factor (thus interest in the 796).

Resistance to drought, especially at the end of the cycle (where interest is in the 55-43 and the TS 32 - 1) allows for yield improvement in haul, pods and grains. This makes it possible at least to minimize earth-loss due to the effect of precocity.

Cowpeas

For the cowpea programme, variety TN-88-63 is the reference check resistant to all soil-climatic hazards including low rainfall; thus it is found in all the comparative trials. After a three-year (81-85) trial period, results show that the best varieties in low and average rainfall conditions are: TN 80-70, TN 27-80 and TN 78-80 with a yield of more than 1 tonne and a cycle almost that of TN 88-63 (52 days) whilst the longer cycle varieties had very low yields about 26.98%, in comparison with the average yield of early varieties (See Table 9).

Table 9. Yield of best local cowpea varieties collected in 1980

	Cycle		Yield (kg/ha)
	50% flowering	50% Height growth	
TN 80-80	52	74	1077
TN 27-80	52	74	1048
TN 78-80	52	73	1010
TN 88-63 (T)	54	74	961
TN 97-80	62	79	790
TN 49-80	56	77	780
TN 113-80	55	76	712

Consequently, 5 days of difference in the cycle could result, in case of stress, to a decrease in yield of about 27%. Promising results have been obtained in the different test sites, and the results are as follows (See Table 10).

Table 10. Yield (kg/ha) of the different varieties TN tested at the sites

Locations Varieties	Tarna	Bengou	Kolo	Ouallam	Magaria	Moyenne
TN 88-63	749	746.5	712	527.5	431.5	633.3
97-80	220.5	1004	712	276	160.5	482.6
119-8	543	703.5	530	311.5	492.5	516.1
78-80	1005.5	975	853.5	526.5	530.5	774.6
49-80	438.5	890.5	572	430	190.5	504.3
27-80	988.5	980	766	471.5	572	745.6
80-80	1099	932	823.5	642	464.5	792.2
113-80	416	946.5	359.5	535.5	262.5	504.0

The early varieties such as TN 78-80, 27-80 and 80-80 produced 21.7% more than the reference check, TN 88-63. It has therefore been observed that precocity is one of the most important criteria for selection in order to overcome the effect of water-stress.

GENERAL AGRONOMY

Agronomy has contributed a lot in research on resistance, drought and the adaptability of new agronomic material developed by research through traditional multi-locational tests and trials carried out in large plots in the low rainfall zones,

In station trials, two basic concepts have been adapted; they are :

a. Rain-water conservation
b. The efficiency of water-management

For water conservation, a test using simple and tied ridges on traditional flat ground was carried out with sorghum in 1984 and in 1985. Insufficient rainfall in 1984 (200 mm) made any yields impossible but it was observed that sorghum stayed longer in tied ridges. The 1985 results confirmed the 1984 results, because with tied ridges the yield was considerably higher than with other trials (see Table 11). These results confirm those found in Burkina Faso by a research team from Purdue University in collaboration with IRAT scientists like Dr. Nicou.

Table 11. The effect of ridging on sorghum yield

Method of tilling	Yield sorghum kg/ha
Flat (traditional)	1,740
Simple ridges	2,010
Tied ridges	2,120

It is however necessary to repeat here that tied ridges are only effective in clayey and heavy soils.

For efficient water-use, a system of mixed cropping millet/cowpeas (intermediate cycle) is being tested. However, it is still too early to confirm these results. In any case, it seems that inter-cropping would allow for better water use (see Table 12).

Table 12. Effect of intercropping on grain yields

	Miillet	Cowpeas
Millet	670	-
Cowpeas	-	260
Millet/Cowpeas	580	90

CONCLUSION

It is certainly true that the study of drought resistance is complex. However, from the field results obtained in Niger, a conclusion has been drawn emphasizing the importance of precocity in drought control. Studies on the cultivation systems and on ridging are presently underway in order to look for the best ways to economise water. Interesting results have already been obtained. The task, however, is an uphill one, for if studies on physiology, pedology, genetics and agronomy have striven to show the different factors for drought resistance, when can one hope to have a plant "prototype", a synthesis of all these factors? We hope that with international collaboration this prototype will be produced in the very near future.

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8. NIGERIA

IMPROVEMENT IN THE PRODUCTIVITY OF FOOD GRAINS IN DROUGHT-PRONE AREAS OF NIGERIA.

J.Y. Yayock, Olupomi Ajayi, S.K. Karikari and J.J. Owonubi
Institute for Agricultural Research
Ahmadu Bello University
Samaru, Zaria
Nigeria.

ABSTRACT

The drought-prone areas of Nigeria span four major ecological sub-divisions: Southern Guinea, Northern Guinea, Sudan and Sahel savanna zones. Sorghum, Millet, Cowpea and Groundnut are grown in all ecological zones. Maize cultivation had been concentrated mainly in the wetter Southern Guinea until about a decade ago when the bulk of production moved to the Northern Guinea and Sudan zones.

The ecological zones most frequently affected by drought are the Sahel and Sudan which lie in the northern-most parts of the country. Production of crops in these semi-arid regions, even in normal years, is threatened by the unpredictable start of rains which adversely affects the establishment of seedlings and forces the farmer to plant the same field several times. Sudden cessation of rains towards the end of the crop growth cycle and before full grain maturity is attained also frequently hampers production. Recently, drought stress, mainly due to uneven distribution and decreasing total amounts of rainfall, have become the crucial consideration in determining the level of grain production in Nigeria.

Work at Nigeria's agricultural research institutiuons on the improvement of grain crops includes the development of high-yielding cultivars which are variously adapted to the different ecological zones, including those areas of the savanna that are drought-prone. In particular, the Institute for Agricultural Research (IAR) at Samaru has developed several crop varieties with relatively short maturity periods which can escape stress in drought years. The institute has also evolved agronomic practices aimed at ensuring greater productivity of the various crops as an added insurance against crop failure during drought years.

This paper highlights work undertaken in Nigeria and notably at the IAR, Samaru, towards boosting food grains production in the drought-prone areas. Areas of research gaps related to dryland agriculture in Nigeria are also highlighted.

INTRODUCTION

Nigeria occupies a land mass of about 924,000 km^2 between latitudes 4 and 14 degrees north and longitudes 2 and 15 degrees east. The country has an estimated human population of 100 million, about 70% of which depend on agriculture for their livelihood. The population of livestock includes an estimated 12.5 million heads of cattle, 12 million sheep and 24 million goats most of which are found in the northern parts of the country. The climate is characterised by distinct wet and dry seasons. The mean annual rainfall, potential evapo-transpiration and the length of the growing season across the country are shown in Fig.1. Because of the varied total rainfall and length of the growing season from north to south, a wide range of farming systems is practised involving many different crops. Of the major ecological sub-divisions (Fig.2), the Sudan and Sahel savannas are the most frequently-affected by drought, although the Northern Guinea and less so, the Southern Guinea, may also be occasionally affected.

The soils of the semi-arid regions of Nigeria are mostly young with limited profile development. They are derived mainly from aeolian material overlying basement complex and in many cases, from sedimentary deposits. The top soils are notably sandy and low in organic matter, usually less than 0.5%. The clay fraction is characteristically low, rarely exceeding 20%. The cation exchange capacity is also low and most often falls below 5 meg/100g of soil. The structural stability of the soil is generally poor and the consequent surface compaction tends to enhance run-off and erosion. In this regard, it is rather fortunate that the low total rainfall received annually in the drought-prone areas generally mitigate against excessive run-off and erosion.

The level of crop production depends on a variety of sociological, technical and climatic factors, including land tenure, input availability, labour, rate of adoption of research findings, commodity pricing and marketing as well as the overall state of the weather in any one year. While social and technical problems may be corrected or, at least, moderated with relative ease, especially if backed by appropriate Government policies, conditions of unfavourable climatic factors in any given year largely remain a limitation to crop production. This is especially so because crop production in Nigeria is almost wholly rainfed. This implies that the availability of sufficient water at appropriate times is a most crucial climatic factor determining the type and productivity of crops. Temperature is important only for the relatively small hectarage on which irrigation is practised during the dry season.

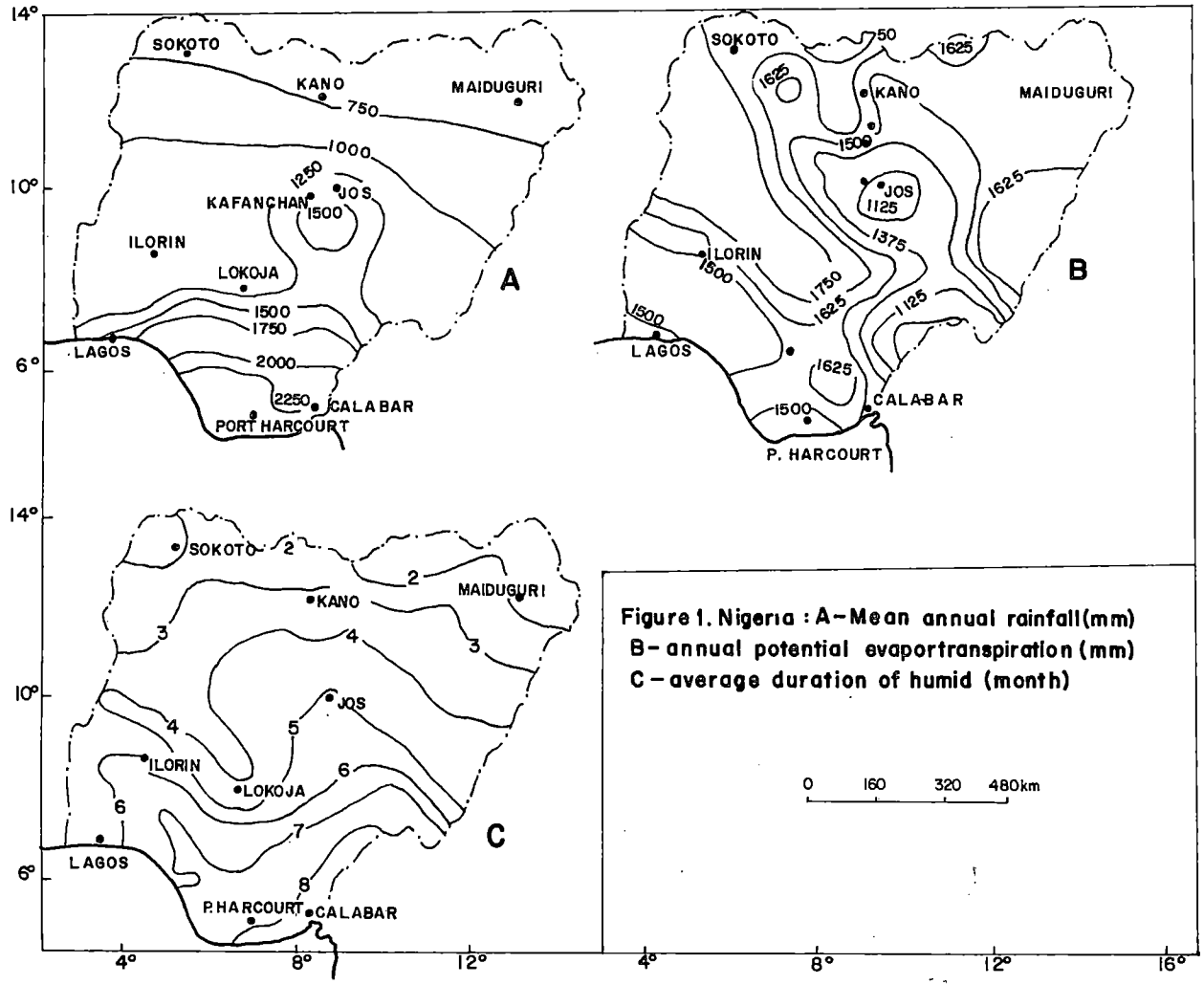

Figure 1. Nigeria : A – Mean annual rainfall (mm)
B – annual potential evaportranspiration (mm)
C – average duration of humid (month)

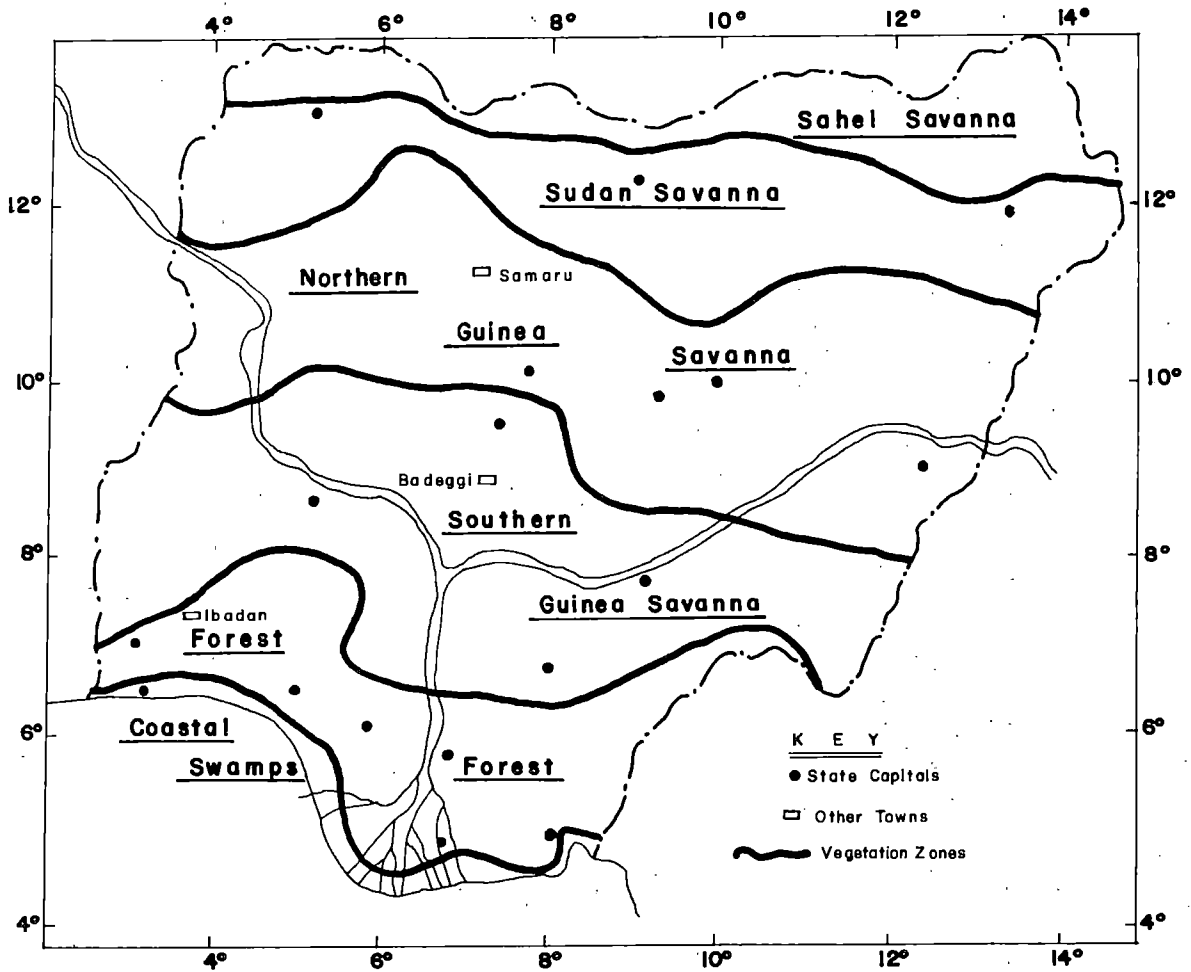

Figure 2. Major vegetation zones of Nigeria

Drought is caused by either low and inadequate total rainfall, its distribution pattern especially when drastically different from the normal, or by a combination of both. The occurrence of severe drought during the periods 1941-44, 1947-49 and 1960-62 whose effect has been largely persistent since the early 1970s, has threatened not only the total output of crops, but also the confidence of a large number of farmers to grow certain previously adapted crops. The persistent nature of drought and the increasingly adverse weather have necessitated the re-orientation of the various agricultural research programmes towards finding the means of coping with and improving on the performance of both traditionally adapted and newly introduced crops.

ZONATION OF MAJOR GRAIN CROPS

The cultivation of sorghum, millet, maize, cowpea and groundnut in Nigeria is primarily for human consumption. However, sizeable proportions of these grain crops, notably the cereals, go to the livestock industry, particularly poultry. In terms of land area and total grain output, sorghum and millet are the most important cereal crops in Nigeria, occupying 44 and 37% respectively, of the total land devoted to cereals (Table 1).

Table 1. Production figures of major food grains of drought-prone areas of Nigeria ('000 tons).

Crops	1970	1975	1980
Sorghum	3500	3437	3800
Millet	2300	3200	2300
Maize	1200	1000	1550
Groundnut	1175	280	570
Cowpea	na*	189	850

* Data not available.

Sorghum

About 90% of the total land grown to sorghum is in the savanna ecological zone, half of which is persistently threatened by drought. Sorghum is relatively more drought resistant/tolerant than maize but less than millet. This feature favours the highest production of sorghum in the Sudan and Northern Guinea where it is one of the principal food crops. Mean annual rainfall in sorghum-producing areas of Nigeria varies from 1270mm in the southern parts to 510mm at the fringes of the Sahel. Although the crop thrives well on soils in high-rainfall areas of the Guinea savanna, its performance further north, under decreased rainfall, is better on heavier soils in depressions and flooded plains. Except in the Sahelian zone, most areas of the savanna have at least 10% of the cultivated land devoted to sorghum. The planting date for sorghum is governed principally by the time taken to mature, the onset of rains and the length of the growing (wet) seasons. In essence, the sowing date is chosen so that seed-set occurs as the weather becomes dry. Both local and improved photo-sensitive and late-maturing cultivars are sown with the early rains and delays invariably result in heavy yield losses. Improved non-photosensitive and short duration cultivars are sown much later in the season when the rains are well established. Early sowing of sorghum not only enables the young crop to capture most of the mineralised nutrients (especially nitrogen) accumulated in the soil through the dry season, but it also minimizes the possible damage from shoot-fly, stem borers and weeds. The optimum spacing and plant population vary from one place to the other depending on cultivar, soil fertility status and the total amount and period of the rainfall. The ideal population densities under Nigerian conditions are estimated at 30,000 plants/ha in the Sahel zone and 50,000 plants/ha in the Northern Guinea.

Millet

Millet is the second most important cereal in the savanna region of Nigeria and particularly in the Northern Guinea, Sudan and Sahel zones. The low moisture requirement of millet, its ability to withstand long periods of drought and to tolerate high temperature makes it admirably suited to the drier semi-arid environment of the extreme north of the country. The seeds germinate with less moisture than most other crops and thrives well with an annual rainfall of 280 - 410 mm and generally requires less than 760 mm. This crop is important for bridging the 'hungry gap' between finishing the previous year's grain stock and harvesting the next crop. It is early-maturing, requiring not less than 120 days to mature.

Traditionally, gero millet is the first crop sown at the commencement of the rainy season. Since sowing takes place at the time the ground is still hard, only rudimentary land preparation is possible. Under wetter soil conditions which occur in the Southern Guinea savanna, it is possible and advantageous to properly cultivate the land before planting millet.

Maize

Maize is the most widely grown cereal crop throughout Nigeria. Although it has been shown that the crop has its greatest production potential in the savanna ecological zone, its traditional areas of production have been in the wetter Southern Guinea and forest zones. The high potential of the crop in the Northern Guinea is attributed mainly to higher solar radiation and other favourable growth factors. Although the Sudan and Sahel are endowed with an abundance of solar energy, the rainfall situation is such that there is presently little cultivation of maize in these zones, except under full irrigation during the dry season when pollination and seed-set are impaired by unfavourable temperatures. Whether under rain-fed or irrigated conditions, maize production is achieved through improved crop husbandry practices, including particularly the choice of seed, sowing date and population density.

The national mandate for the genetic improvement of maize rests with the National Cereals Research Institute based at Badeggi, which, in collaboration with the International Institute for Tropical Agricultura, IITA, Ibadan, has developed a range of high-yielding cultivars. The IAR has also developed varieties with medium maturity and which are adapted to the higher latitudes of the Northern Guinea and Sudan savannas. The most promising varieties in the drought-prone savanna include SZV/1, 2, 4, 5 and 6 which average yields are over 4 tons of grain/ha.

Groundnut

The traditional groundnut-production areas of Nigeria lie north of latitude 9 degrees and mostly in the Northern Guinea and Sudan zones. Until the early 1970s, Nigeria was a major exporter of the crop. Since then, the country has experienced a series of groundnut failures due to variable causes and notably dry weather and rosette disease. Cultivation of groundnut is currently confined largely to the southern fringes of the sudan and the northern guinea zones.

Cowpea

Cowpea constitutes an important source of vegetable protein in the diet of Nigerians, providing over 57% of protein from leguminous sources. An estimated 80% of the cowpeas produced comes from the savanna and notably the Northern Guinea and Sudan zones. The crop is subject to heavy disease and insect pest attacks particularly when grown in such humid environments as the Southern Guinea and forest zones. Cowpea has, therefore, remained a Northern Guinea, Sudan and Sahel savanna crop, despite threats of frequent droughts. Furthermore, the greater amount of solar radiation and the better drying conditions in the northern, relative to the southern parts of the country, favour the cultivation of the crop.

Planting of cowpea is timed so as to ensure that it comes to maturity after the rains have stopped to ensure effective grain filling and clean seeds at harvest. Because of the complex of insect pests and diseases associated with cowpea, it is imperative that the crop be protected by chemical sprays irrespective of the cultivar used, the level of crop husbandry employed or the location.

IMPROVING PRODUCTION PRACTICES

At the moment, most direct food production activities in Nigeria are in the hands of small-scale farmers who constitute the bulk of the farming population. The varieties of crops which they grow are inherently low-yielding and do not readily respond to improved technology and particularly high rates of fertilizers which are necessary for increased production. However, such local varieties are highly adapted to the environments where they have been selected over the years. Some of the varieties have become largely tolerant to certain insect pests, disease organisms and parasitic weeds, while their grain types and cooking qualities are readily accepted by the people. In sorghum, the tall stems which characterise locally adapted varieties are needed by farmers particularly in very dry areas as a substitute for wood in building houses, for construction of fences and for cooking.

While such local crop varieties might have been adequate in the past in meeting the subsistence and other simple needs of the peasant farmers, they have now clearly become unsuitable due to changing social, economic, political and technical circumstances. For example, with increasing human population the development of new tastes and eating habits as well as changing climatic conditions in the recent past, there has been a demand for the development of higher-yielding crop varieties of enhanced quality which are resistant or tolerant to drought.

In order to satisfy such changing demands, the various agricultural research institutions in Nigeria notably the IAR, Samaru, are required not only to evolve specific agronomic packages aimed at improving crop production in general, but also to conduct research on specific drought-related problems. Among on-going research related to increasing food and fibre productivity in Nigeria's drought-prone areas, are the following :

(a) Hydrological, physical and chemical characterization of savanna soils and diagnostic surveys of farming systems aimed at maximising the use of natural resources.

(b) Evaluation of historical weather incidences as a tool in short-term forecasts of the on-set and total amount of rainfall.

(c) Lysimetric and empirical studies of crop water-use under both rainfed and irrigated agriculture.

(d) Breeding of short duration and drought resistant/tolerant crop varieties, incorporating resistance/tolerance to major insect pests and diseases.

(e) Development of soil and water management techniques, including tillage, mulching and soil improvement by natural deposition.

(f) Development of water-saving techniques, especially in irrigated agriculture, including shelters and varied irrigation and channel lining designs

(g) Harvesting of solar energy for use in agricultural systems, including grain and forage drying, conservation and storage.

(h) Development of agronomic practices as are appropriate to low rainfall, fragile soils and drought-prone conditions, including appropriate tillage, population density, timeliness of farm operations and intercropping patterns that ensure against total crop failure.

RESEARCH INTO CLIMATIC CHANGES

Because of the over-riding effects of weather on crop production, considerable emphasis has been placed on studying the climate-crop relationships especially with regard to water use. The requirement of the various major grain for water, from planting to harvest, have been determined within Nigeria's Northern Guinea zone (Table 2). Continuous monitoring of weather elements has confirmed the decline of the total rainfall from the 1960s to date (Fig.3). The increasing dryness of the air manifests itself in higher temperatures and evapo-transpiration rates during the growing/rainy season. The dry seasons are also becoming more dusty, with estimates of annual dust deposition now in the order of 250 kg/ha (Fig.4). The increased frequency and density of dust over-pass during the dry season, affects the productivity of irrigated crops.

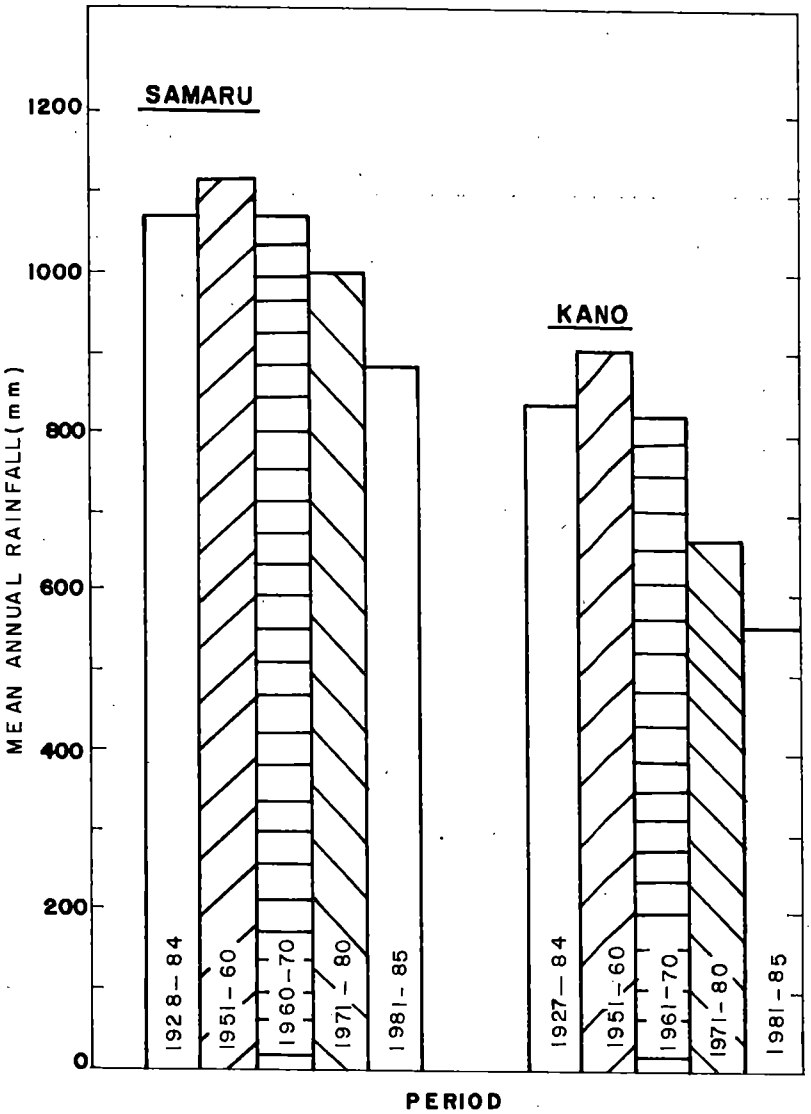

Fig.3. Progressive decline in total annual rainfall at Kano and Samaru (Nigeria) for the period 1927-85

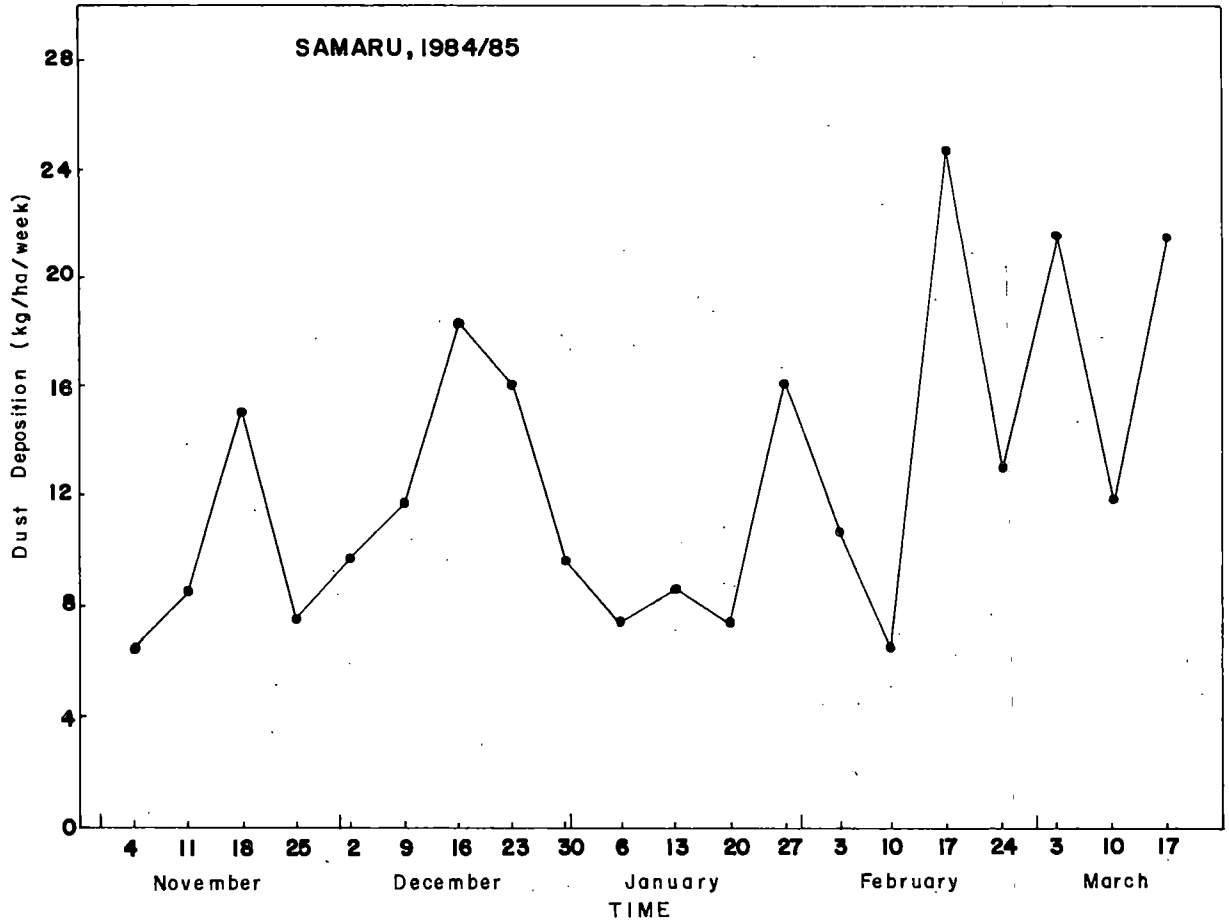

Fig.4. Pattern and rate of dust deposition at Samaru during the dry season of 1984/85

Table 2. Seasonal lysimetric water-use (ET), potential evapo-transpiration (ETo) and ET/ETo of some major grain crops in the drought-prone savanna zone of Nigeria.

Crop	ET (cm)	ETo (cm)	ET/ETo
Cowpea	47.2	64.2	0.74
Groundnut	43.8	59.1	0.74
Maize	48.6	56.5	0.86
Millet	33.0	40.2	0.82
Sorghum	66.6	93.9	0.71

ACHIEVEMENTS IN FOOD GRAIN BREEDING

Sorghum

The most common land races of sorghum in Nigeria are Kaura, Farafara and Guinea which are grown as rainfed crops and the Chad race which is restricted to the Lake Chad basin and contains both the rainfed types and a specialised type locally referred to as 'Masakwa'. The Masakwa is grown during the dry Harmattan season on clay soils where the fields are flooded during the rains and the residual moisture is sufficient to mature a crop without any form of supplementary irrigation. The broad characteristics of the four land races are briefly summarised in Table 3.

Table 3. Characteristics of Nigerian land races of sorghum.

Land Race	Species	Characteristics
Kaura	Durra-Caudatum	High-yielding with excellent combining ability
Farafara	Guinea-Caudatum	Early maturing; drought tolerant; high-yielding; with preferred white grains
Guinea	Guinnense and Conspicum	Very adaptable and hence widely cultivated.
Chad	Durra-Caudatum	Early maturing.

Intensive and fairly exhaustive collection in the semi-arid extreme northern parts of the country has yielded about 145 local germplasm accessions and sand dune sorghums. These are mainly the semi-dwarf to semi-tall Warsha type of Farafara race and early Kauras. These new accessions of very short season and drought tolerant/resistant sorghum have been classified and described and are presently being used in various crosses to develop new improved types.

Breeding work has led to the development of varieties which are suited to specific ecological zones. Table 4 shows some of the short-duration sorghum cultivars which have been developed and are presently under cultivation in most of the semi-arid areas of Nigeria. The varieties KSV 4, 11, 12 and 15 are recommended for areas with annual rainfall of less than 600 mm, while KSV 2, 5, 7 and 8 are for areas with less than 750 mm annual rainfall. All eight cultivars are non-photoperiod sensitive and are moderately to completely resistant to *Striga hermontheca*.

Table 4. Improved high-yielding short-season varieties of sorghum developed and released for production in the Sahel and Sudan zones of Nigeria.

Variety	Maturing Period (days)	Potential yield (t/ha)
K.S.V. 4	110	3.5 - 4.5
K.S.V. 11	105	4.2 - 4.7
K.S.V. 12	105	4.0 - 4.7
K.S.V. 15	90	3.5 - 4.0
K.S.V. 2	143	2.0 - 2.5
K.S.V. 5	140	2.5 - 3.0
K.S.V. 7	145	3.0 - 3.5
K.S.V. 8	140	3.0 - 3.5

Millet

Most of the early research on millet improvement was focussed on gero millet, but a lot of attention is now being paid to the other types. Like sorghum, no truly drought resistant varieties of millet have been developed, but several early-maturing and drought tolerant gero cultivars are presently available for production in the drought-prone Sudan and Sahel savannas (Table 5).

Table 5. Early/medium-maturing varieties of gero millet suitable for production in drought-prone areas of Nigeria.

Variety	Maturing Period (days)	Yield Range (t/ha)
S.E. 2105	70-85	1.5 - 2.8
S.E. 2106	70-85	1.4 - 2.9
S.E. 10	70-85	1.5 - 2.8
S.E. 361	70-85	1.3 - 2.5
S.E. 13	70-85	1.5 - 2.6
Dwarf Composite	70-81	1.2 - 2.5
Bristled Composite	70-85	1.3 - 2.5
Ex-Borno	70-85	1.5 - 2.5
INMV - 12	70-85	1.5 - 2.5
INMV - 10	70-85	1.4 - 2.5
Local	Above 85	1.1 - 2.0

Groundnuts

Of the varieties of groundnut currently available to farmers in the savanna ecological region, several are well suited to arid conditions, particularly on account of their relatively short maturity period and incorporated tolerance to drought and particularly rosette disease, (Table 6). Average yields are in the range of 1500-2500 kg/ha, depending on the level of management. Although cultivar RMP-12 is more adapted to the Guinea savanna by virtue of its longer maturation period, it is also well suited for cultivation in the southern fringes of the Sudan zone, especially when sown early.

The varying maturity cycles, together with disease tolerance/resistance among the improved varieties has resulted in the expansion of the land area cultivated to the crop beyond the traditional boundary of latitude 9 and 12 degrees north. As a consequence, more groundnut is presently grown in some of the more southerly locations than hitherto. In addition to the use of suitable varieties, timely planting of groundnut at enhanced population densities have consistently proved crucial in maximising yields.

Table 6. Early/medium-maturing groundnut varieties selected for the drought-prone areas of Nigeria.

Variety	Maturity Period (days)	Yield Range (kg/ha)	Range
RRB	95-110	2000 - 3000	Tolerant to drought and low rosette inoculum pressure.
55 - 437	95-110	2000 - 3000	Drought tolerant.
K1236-80	95-110	2000 - 3000	Rosette susceptible
Spanish 205	95-100	1500 - 2000	Drought tolerant.
RMP-12	120-130	1900 - 2500	Rosette resistant.

Cowpea

For the cowpea improvement programme, six cultivars of relatively short maturity periods are currently available for cultivation in the drought-prone areas of Nigeria (Table 7).

Table 7. Early/medium-maturing cowpeas recommended for the drought-prone areas of Nigeria.

Variety	Maturity Period (days)	Yield Range (kg/ha)
IAR 176B	70-75	1200-2450
IAR 341	70-75	1400-2100
Ife Brown	70-75	1170-3000
IAR 335	70-75	1400-2550
IAR 355	70-75	1200-2500
IAR 48	70-75	1050-2520
TVX - 3236	70-75	1200-2500
IT 82E - 60	64-70	900-1500

OTHER IMPORTANT FOOD GRAINS

The increasing harsh weather, changing tastes and eating habits as well as the increasing human population pressure have encouraged the introduction and adaptation of several other grain crops which add to the food supply in the drought-prone areas of Nigeria. Such important grain crops include wheat, barley, soyabean, sesame and sunflower.

Wheat

There is evidence to show that wheat has been grown for many centuries under irrigation in some northern parts of Nigeria, usually in 'fadama' areas and river-bottoms. The local varieties were generally late-maturing, tall and possess low tillering and yielding abilities and low grain protein. From 1959 the Nigerian Government first took a serious interest in the crop. Because of its requirement for low temperatures, wheat is only cultivated under irrigation during the cold, dry Harmattan period between latitudes 10 and 14 degrees north which falls mainly in the Sudan and Sahel ecological zones. The current land area cultivated to wheat is about 17,000 hectares out of a total planned area of 324,000 hectares.

Wheat varieties currently recommended for cultivation under irrigation in semi-arid areas include Tousson, Florence Aurore 8193, Sonora 63, Lee X NIOB and Siete Cerros. Under recommended cultural practices, the grain yield of these varieties average 3.4 tons/ha.

Barley

All the barley used by industry in Nigeria today and particularly the breweries, is imported. Work on the development of barley production was started at the IAR, Samaru, in 1976. Like wheat, barley is grown under irrigation during the dry season in areas between latitudes 10 and 14 degrees north. Many exotic materials have been screened and several varieties identified which are well adapted to semi-arid irrigation conditions. Among such varieties are Zephr, Tellus, Ark Royal, Bernice, Anazar, Trumphf, Ketch and Athos. The yield potential of these varieties is between 2-3 tons of grain/ha.

Soyabean

Traditionally, soyabean has been grown in Nigeria, mostly in the Southern Guinea savanna. At least six long-season introduced varieties have been available for a number of years, among which is the popular Malayan which once occupied as much as 95% of the total hectarage of soyabean. This means that the growing of soyabeans in the relatively drier Northern Guinea had not been possible because the cultivars are late-maturing. With the recent development by the IAR, Samaru, of medium-maturing varieties such as Samsoy-1 and Samsoy-2, it is now possible to grow soyabeans in the Northern Guinea and areas to the southern fringes of the Sudan zone.

Sesame

Sesame has been traditionally grown in the Guinea savanna, and recent work has shown that the crop can be successfully cultivated as far north as the northern fringes of the sudan zone which have become unsuitable for most crops. Among suitable sesame varieties recently developed at the IAR, Samaru, are Sase-1, Sase-2 and Sase-3.

Sunflower

The need for obtaining another oilseed crop to complement groundnut has motivated research into sunflower production. The crop was once cultivated rather widely in the semi-arid Sudan zone and it is known to be tolerant to drought. However, although the potentials for sunflower as a crop are high in the drought-prone areas of Nigeria, sunflower has so far received little research attention.

RESEARCH GAPS

Ecological Management

A prime requirement for maintaining agricultural production, particularly in the fragile areas prone to drought, is the ability to keep existing arable lands in usable form. Land degradation and, sometimes serious desert encroachment, have been observed in the parts of Nigeria most prone to drought. The situation is further aggravated because of the presence of millions of cattle in the area most prone to drought. The lack of surface vegetation poses serious problems of erosion, thus making doubtful future use of the land especially if and when the rainfall situation improves. Research should aid in finding adapted cover plants and in evolving management methods to stabilize and conserve the soil, soil water and vegetation.

Land Use and Agro-Forestry

There is at present no research on agro-forestry in the savanna areas of Nigeria,except projects which relate to alley cropping. Urgent research requirements in this area include the identification of multi-purpose local or adapted tree species and the development of appropriate technologies that will maintain or increase agricultural productivity while at the same time retaining shade and improving the soil.

Predictability of Drought

Analyses of historical climatic data have so far failed to show any obvious pattern of drought which could be used as a guide to forecast future occurrences. However, in subsistent and marginal agricultural areas, it is important to be able to predict drought, even if for only a few months, before its effects become evident. There is, therefore, an urgent need to identify local characteristics of rainfall that can be directly related to the occurrence of drought.

In preliminary assessments of rainfall characteristics in Nigeria, it has been shown that the north-south orientation of the time of onset and cessation of rains can be utilised as a fairly effective tool for forecasting. The relationship of the position of the intertropical convergence zone to the timing, amount and stability of annual rainfall are currently the most urgent requirements of our drought prediction effort.

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DISCUSSION

Ndunguru

Is there any undesirable effect that has been observed on sorghum varieties developed by removing the photosensitivity?. Have you observed any relationships between photosensitivity and Striga resistance?.

Nwasike

There is no adverse effect of developing non-photosensitive varieties of sorghum because the benefit is that these varieties are able to mature within the available rainfall of 760 mm instead of maturity based on day length irrespective of non-availability of rainfall.

Muleba

OAU and ECA had organised a conference on desertification and drought. An African document dealing with the overall economic development in Africa has been prepared and is being presented to the UN special session in New York on critical African development problems. So the problems you have just raised in this paper are being taken care of.

9. MAURITANIA

STATUS, PRIORITIES, AND RESEARCH NEEDS OF AGRICULTURAL PRODUCTION IN THE DRY LANDS OF MAURITANIA.

Diarra Mamadou
Director General, CNRADA
B.P.22
Kaedi, Mauritania.

INTRODUCTION

The Islamic Republic of Mauritania covers 1,031,000 km^2 and lies between 16 and 25 degrees latitude North and 5 and 16 degrees longtitude South of the African continent.The population estimate in 1985 was 1,630,000 inhabitants. In the year 2000 this will go up to 2,500,000 inhabitants, concentrated in the towns (more than 70%) and mainly made up of farmers. Mauritanian agriculture is limited by very low rainfall throughout the country. The southern part of the country which receives more rain has a mean annual average of 350 mm. The irregular distribution of often torrential rainfall makes the production of food crops uncertain. The rainy season extends from July to October and is very short and lacking beneficial rains. The dry season lasts 8 months and includes a period of relative coolness (from October to March) and a very hot period, from March to June.
Taking into account these conditions which do not favour agricultural development activities, the government of Mauritania has understood the need to join efforts with the other neighbouring countries sharing the same agro-climatic situation, within the framework of the sub-regional and regional organizations.

Thus, as early as 1972, Mauritania became a member of the OMVS (Senegal River Basin Development Programme), CILSS in 1973 and other organisations such as the CEAO (Economic Community of West Africa), ECOWAS and WARDA, etc.

In an under-developed Sahelian country, the role of research in general and especially agricultural research, is very important for the achievement of development objectives. This was the over-riding factor in the creation in 1974 of the National Centre for Agricultural Research and Agricultural Development (CNRADA) of KAEDI.

PRESENT STATE OF RESEARCH

Well before independence, the Agricultural Department in collaboration with the services in charge of development in the sub-region, were already doing research. With independence, and thanks to the cooperation between Mauritania and France, IRAT had carried out research work of a highly scientific and technical nature in the sub-region.

The creation of the National Centre for Agricultural Research in 1974 was with the gradual occurrence of drought in our country; a fortunate coincidence, although the latter was not the cause. On the contrary, it was the result of a spontaneous awakening of our leaders to urgently improve and promote agricultural production in general.

The CNRADA is in charge of organizing, executing and disseminating all activities relating to agricultural promotion. It is made up of four technical departments in charge of specific research programmes. These are the Rice Production Department, the Food Crops Department, Pre-extension Services and the Fruits and Market Gardening Department.

The research programmes are designed to achieve three main objectives laid down by the National Government. These objectives are :

1. Food self-sufficiency
2. Land restoration and improvement (preservation of natural resources)
3. The return and settling of populations on their specific land areas.

To achieve these objectives, agricultural research results should be transferable to and acceptable by our peasant farmers. Research subjects given below shall be reinforced within this framework if they already exist or be created if this has not been done, so as to guarantee better use of resources:

a) Soil science and fertilization
b) Irrigation and agro-climatology
c) Mechanization and agricultural engineering
d) Crop protection
e) Fruit tree planting and market-gardening
f) Agrarian systems and pre-extension
g) Plant improvement
h) Agro-pastoralism and forage
i) Planning and management.

AGRICULTURAL REGIONS

On the basis of aridity, the following four agricultural regions can be recognised in Mauritania:

- Semi-arid zone with about 500 mm of useful rain (Administrative region of Guidmakha).

- Arid zone with 225 to 500mm of useful rain (TRARZA - BRAKNA - GARGOL - ASSABA).

- Semi-desert zones with 100 to 225 mm of useful rain (TRARZA-OASIS).

- Raw mineral zone with less than 100 mm of useful rain.

Parallel to food crop cultivation which demands fertile soil and plenty of water, new agricultural methods such as irrigated agriculture are being set-up and developed in all the regions at the same time with the traditional crops (rice, market-gardening fruits and fodder).

The different types of soils, the cartographic units, give five types:

Mineralized soils (desert soil on rocks or sand without vegetative cover)

Slightly changed soils (pre-desert soils, rocks or sands containing vegetal terrain of climatic origin or sedimentary

Isormorphic soils (brown and fertile soils)

Hydromorphic soils (argillaceous soils compact and periodically flooded).

FARMING SYSTEMS

Four cultivation systems are presently practised in the Senegal Valley:

a) Dryland farming (millet, cowpea, water melon): low rainfall, very dry lowlands.

b) Semi-irrigated cultivation done on the fertile banks of the river with water being provided through rainfall, floods or infiltration, - sorghum, maize and vegetables.

c) Recessional agriculture: growing of sorghum, maize, and cowpea during the dry season on neither rain nor irrigation but solely on the water-reserve of the soil after much flooding in the rainy season.

d) Irrigated agriculture: rice, maize and legumes are, except market gardening, a recent introduction, thanks to the development of irrigated zones (small and large areas).

Extensive animal husbandry is practised with these systems and the harvest leftovers (by-products) are used for direct grazing, in the dry season or during harvesting, a principal cause of damage done by animals on crops and construction works.

Despite the areas under cultivation this year (about 5000 km^2), food production is still very much below the average. In a normal year (before 1968), production of basic cereals did not exceed 90,000 tons/per annum. However, thanks to the immense areas still available in each of the above-mentioned zones (desert, sub-desert, sahelian and recessional agricultural zones), there are hopes that appropriate developments will be undertaken, supported by the construction of two large dams,

Diama and Manantali, on the Senegal river, provided that water is available and that it is possible in the river valley to have double or even triple production cycle.

Table 1. Cereal demand in tonnes.

Years	Population	Cereal needs in tonnes
1980	1,451,000	189,000
1985	1,642,000	247,000
1990	1,900,000	247,000
1995	2,171,000	259,000
2000	2,480,000	322,000

Table 2. Productive Areas.

Food Species and Systems	Areas under Cultivation (ha)	Yields in kg/ha	Production in tonnes
Rainfed cultivation millet, sorghum, cowpeas, water-melon.	81,000	350	28,300
Rain-farming, dams lowlands - sorghum, millet, maize.	48,000	500	24,000
Recessional agriculture - sorghum, maize, cowpea.	48,000	550	26,400
Irrigated agriculture rice, maize, wheat, sorghum.	4,310	2,390	10,300
TOTAL	181,310	-	89,000

Consequences

Food dependency is becoming more and more pronounced resulting in a growing need to import up to 75% of our needs, as shown in Tables 1 and 2.

THE PRODUCTION SYSTEMS

Research programmes dealing with improvement possibilities of agricultural systems (rainfed and irrigated) and trials conducted in experimental stations, at the regional level and carried out in rural areas, have made it possible to obtain precise information on traditional systems of agriculture.

The following systems have therefore been observed in the production process of food crops.

The Oases

Oases are characterized by the presence of a water-table just near the surface. This permanence of the water-table as well as its proximity to the surface is made good use of for date cultivation which does not need irrigation. As for food and fodder crop cultivation, watering by hand is often done. The very low or inexistent rainfall has no influence on production which is wholly for local consumption (wheat, maize, sorghum, and legumes).

In Mauritania, there are about 350 oases covering 6,000 hectares. Date palms are estimated at more than 1 million, producing yearly about 16,000 tons of dates. A Date Research Station attached to the CNRADA is resuming activity and will soon be fully operational, whilst an entomology laboratory set up through FAC funding (French Aid and Cooperation) in Nouakchott, is carrying out research on the main pests attacking the date crop in Mauritania.

Recessional Agriculture

The floodable lands (about 150,000 hectares) are only cultivable when the water level falls and this is only on a small portion, well-watered by floods on 35-50,000 hectares yearly. With this system, the crops are totally dependent on water stored during the rainy season. Sowing is done only after drying up of the land during the cooler period of the dry season. The crops, needing neither rain nor irrigation, use the soil water reserve.

The system of rainfed cultivation

The rainfed crops (millet, sorghum, maize, cowpea and legumes) depend on rainfall and the reserve water of the soil (lowlands and outlets from the hills).

The real rainfed cultivation system

Contrary to the other systems, this system wholly depends on rainfall. Certain species and early varieties (water-melons, cowpeas, millet), produce seeds only in soils watered by well distributed rainfall in a normal year. Their active vegetative period is reduced to about 45 days in KAEDI and between 60-75 days towards the south. Under this system, the available land (Dieri) is abundant, but success is minimal.

The Irrigated System

This is one of the most important systems, thanks to the development policy being implemented by the three states (Senegal, Mali and Mauritania) to ensure the permanent presence of fresh-water. Valley rice cultivation is the main activity here.

All of these systems, oases, rainfed, recessional agriculture are practised extensively, over-exploited, often not even capable of satisfying the needs of the fast growing rural and urban populations. Some, dependent on rain, are risky and produce little.

Although productive, recessional agriculture uses up only a small part of the flood water available. The irrigated systems are equally productive but rarely make a head-way because of the difficulties encountered with major development (damage of development works, high costs of maintenance and equipment). The evolution of agricultural production shows that the needs are much higher than production which follows neither in quality nor in quantity and which, unfortunately, remains dependent on climatic hazards.

Despite research experience on different varieties, trials, introductions, seed selection and production, despite the very good results obtained in fruit growing and market gardening, and in rice cultivation, although certain varieties might be ready for mass release, agricultural production and crop yields remain low. This is also true for food crops where sorghum, millet, maize and cowpea varieties have for many years been tried by the CILSS Member States.

The role of research in the face of the present situation is very important. Food self-sufficiency can only be obtained through reliable results provided by research which are adaptable to our conditions; even though research alone cannot accomplish this task.

RESEARCH NEEDS

Research and development exchanges, in an organized and well-structured set-up, has become more and more urgent. Such a system requires the following inputs:

- The financial resources necessary for the implementation of the defined objectives.
- The necessary infrastructure and equipment.
- Coordination between sub-regional and national research institutions:
    - a) Better information between researchers.
    - b) Avoid all duplication
    - c) Make good use of the research findings of other scientists.

- More responsibility and motivation to the researcher in accordance with the quality of the work carried out.
- A training policy for researchers as the cornerstone of all research activity.
- A more realistic approach to research as far as agriculture is concerned.

Recently, a document produced by CILSS reminded us of the competition between research and development projects, in the allocation of funds and other resources. This is so because in certain countries agriculture is seen as being more important than research even though one is complementary to the other; research remains the basis for development.

RESEARCH PRIORITIES

Considering the determining factors of agricultural production in our states in general, and in Mauritania in particular, research priorities are as follows:

- Food crops
- Irrigation: agro-climatology
- Plant protection
- Production systems
- Cultivation methods
- Soil fertilization
- Agricultural pasture-land
- Conservation and protection of the Eco-system
- Research on soil-water plant relations.

DISCUSSION

Mfutakamba

(i) Based on the statement of the speaker on water research, could he elaborate briefly on the areas of water research to which he refers? Is it water quality or water for irrigation?.

(ii) What selection criteria does the Mauritanian government utilise in a viable irrigation system, for instance, based on -

(a) site approval data
(b) cost analysis data
(c) systems designs considering irrigation systems available
(d) outline cost analysis versus crop residue values.

Diarra

(i) Water for irrigation.
There is a well-drilling programme being implemented by the Ministry of Hydraulics to meet the consumption needs of humans and livestock with the possibility for village cooperatives to undertake market gardening.

(ii) The essential criterion is the well-known DIAMA DAM, being constructed by OMVS. There are other criteria less important such as earthen anti-salt dams on the river to prevent sea water from going up and salting the fresh water of the river.
The irrigation systems, the selection of site and costs depend therefore on the availability of water, its proximity to useable lands and the costs of irrigation.
Unfortunately our research has not yet carried out economic studies on these activities. The Mpourie State Farm which specialized in rice production, thanks to a cooperation agreement with the People's Republic of China, had undertaken this kind of economic studies. Since 1981 nothing has been done in this regard.
Therefore, I regret I cannot describe the cost and production ratio. A specialized commission will, however, very soon publish its conclusions on this matter.
To come back to the criterion of selection of the various irrigation systems, I would like to say that the dam enables fresh water to be permanent in the Senegal River all year round. Through pumping, some cooperatives for market gardening, rice production, or food crop production, depending on the areas, the villages or the proximity of these villages to the river, undertake gravity irrigation. Size of farms: 5 ha maximum:

- By pumping the water to a suction tank and from the tank to tertiary irrigation channels;

- Gravity irrigation in state farms: its 1500 ha and 20 ha in small districts.

Blum

Since the recent severe drought in some of the African countries made the locally adapted landraces extinct, what do you use for seed when you wish to resume farming after drought?

Diarra

Three strategies have been adopted :

a) Conduct a joint mission with the Department of Agriculture in the zones where the conditions are still better, in order to take stock of the best producing sorghum, millet and maize fields. Collect the best ears and obtain from these ears, seeds to be multiplied by contractual farmers.

b) We have noted that maize producers, for example, select the best maize ears which they sell. Maize is a crop highly appreciated by the population and consumed green so that only the ears which are not representative are presented for planting. Maize tends to be downgraded. To avoid this, we have decided to buy or collect the best ears which we treat and use for research needs in order to obtain good seeds.

c) Importation of improved sorghum seeds from the arid regions of USA (Arizona), within the framework of research collaboration between us and Arizona University. For example, 1 ton of improved sorghum seeds will arrive at Kaedi from Arizona (USA) before June 18, 1986.

10. TANZANIA

AGRICULTURAL RESEARCH STRATEGIES TO PROMOTE DRYLAND AGRICULTURE IN TANZANIA.

F.M. Shao
Chief Research Officer
Ministry of Agriculture &
Livestock Development
P.O. Box 9071,
Dar-es-Salaam, Tanzania.

INTRODUCTION

Tanzania is a vast country (939,701 km^2), located just south of the equator. Except for the coastal belt, most of the country lies between the altitudes of 1000 m and 1500 m above sea level. The country is rich in surface waters which are potentially valuable for both agriculture and energy development. Soils vary from the rich volcanic soils of the mountain slopes to the good soils of the river valleys and the moderately productive clayey soils which characterize the majority of the land area. The climate of the country is very variable and has great influence on crop and livestock production and the distribution of population.

Agricultural research strategies to promote dryland agriculture in Tanzania will have to involve a number of research institutions including the Directorate of Research and Training and the Ministry of Agriculture and Livestock Development which is the coordinator, the Tanzania Agricultural Research Organization (TARO), the Uyole Agriculture Centre (UAC), the Tropical Pesticides Research Institute (TPRI) and the Tanzania Livestock Research Organization (TALIRO) which are the implementers. The Sokoine University of Agriculture also conducts some agricultural research. Linkages with Extension and Technical Services must also be established in order to ensure that the end products of research reach the farmer.

Realizing the complexity of the systems, the National Agricultural Policy of 1982 directed that Agricultural Research must be problem-oriented and dynamic to cope with the changing demands of the sector. Specifically, the policy emphasized :

i. The maintenance of strong coordination at all levels;
ii. Focus on Agro-ecological Zones;
iii. Adoption of a farming systems research approach;
iv. Provision of adequate finance;
v. Maintenance of a national data bank; and
vi. Priority to consolidation of existing institutions.

This paper will discuss the research strategies to promote dryland agriculture in Tanzania in line with the National Agricultural Policy and in consideration of the agro-climatic conditions of the country.

CLIMATE

The climate of Tanzania varies from tropical to semi-arid to temperature types and is influenced by variations in altitude which affect both rainfall and temperature.

Based on rainfall patterns, the country may be divided into four climatic belts as follows:

(i). A northern coastal belt (about 180 km wide from Dar-es-Salaam to Kenya border), with two rainy seasons and yearly average rainfall of from 1,000 to 1,500 mm.

(ii). The northern and southern highlands where rainfall ranges from 750 - 1,250 mm. Here the main rainfall occurs between December and April.

(iii). A 90 km wide area bordering lake Victoria with an annual yearly rainfall of 750 - 1,000 mm, well distributed throughout the year.

(iv). A broad area including the South-eastern coastal belt and the greater interior plateau where rainfall ranges from 250 to 750 mm per year.

Despite the general patterns indicated above, rainfall is however highly erratic in regard to both timing and amount in most of the country.

AGRO-CLIMATIC TYPES

Gommes and Houssiau 1982 identified seven major agro-climatic types of growing seasons (GS) as shown in Figure 1. These are useful for determining where different crops should be grown.

(i). The S Type or Southern Highlands type (proto-type Mbeye) is unimodal and has the most reliable rainy season in the whole country. The season starts from mid-November in its most northern part (Mpanda) and mid-December in the South (Ruvuma) and ends in mid-April, lasting 130-140 days. The climate is ideal for water demanding crops (maize, finger millet and bananas) and also for wheat and beans due to the lower temperatures. In this GS, two areas depart somewhat from the prototype. S2 are the Kyela plains where the GS lasts from mid-November to mid-June (200 days). Here the dry season is not well marked and the lowlands are well suited for rice and purely tropical crops like rubber, cocoa and oil palms. The S3 is the Mahenge - Iringa area which gets very heavy rains in March/April often resulting in flooding but with less reliable rainfall in February. The season extends from December to May, about 150 days. This extreme climate is due to the Sout-eastern monsoon and appears to be well suited for rice.

(ii). The C-type or the Central-type (prototype Singida) is characterized by unreliable rainfall throughout the season. It is definitely unsuitable for water demanding crops with a very high risk of dry spell at mid-season (February). This climate is only suitable for sorghum and bulrush millet and drought resistant tuber crops (sweet potatoes and cassava). The Prototype covers C1 - the central regions of

Tanzania, with GS from early January to mid-March (about 80 days); C2 - The Southern lowlands of Mtwara and Lindi. with GS from January to mid-April (about 100 days) and C3 - a transitional climate between the C and S-type. Here rainfall reliability increases towards the west and the GS runs from December to mid-April. Maize could be grown successfully in these areas, in about 60% of the year.

(iii). The B-type or bimodal type (prototype Dar-es-Salaam) is characterized by unreliable rainfall throughout the season(s) with two peaks in the end of November - early December and April with a B-type. In these areas, the planting of maize at least during the short rains is not successful. Very short cycled drought resistant crops (cassava and some perennial crops) are recommended. Some areas of this zone are also suitable for grazing (Serengeti, part of Monduli and Handeni District).

(iv). The T-type or transition (prototype Kilosa) is intermediate between unimodal and bimodal 9C and B-types). The season lasts 130-160 days but the first three months suffer from very unreliable rainfall especially in the East and the West. The central part (Mbulu) enjoys orographic rains and low temperatures. The onset of rains is between November and January. Drought resistant crops are recommended after the rains and water demanding crops at mid-season in order to benefit from the water accumulated in the soil. Some of the major wheat farms are located in this area at the higher elevations where beans and the temperate vegetables will do well. In the lowland, the crops suited for the C-type are recommended.

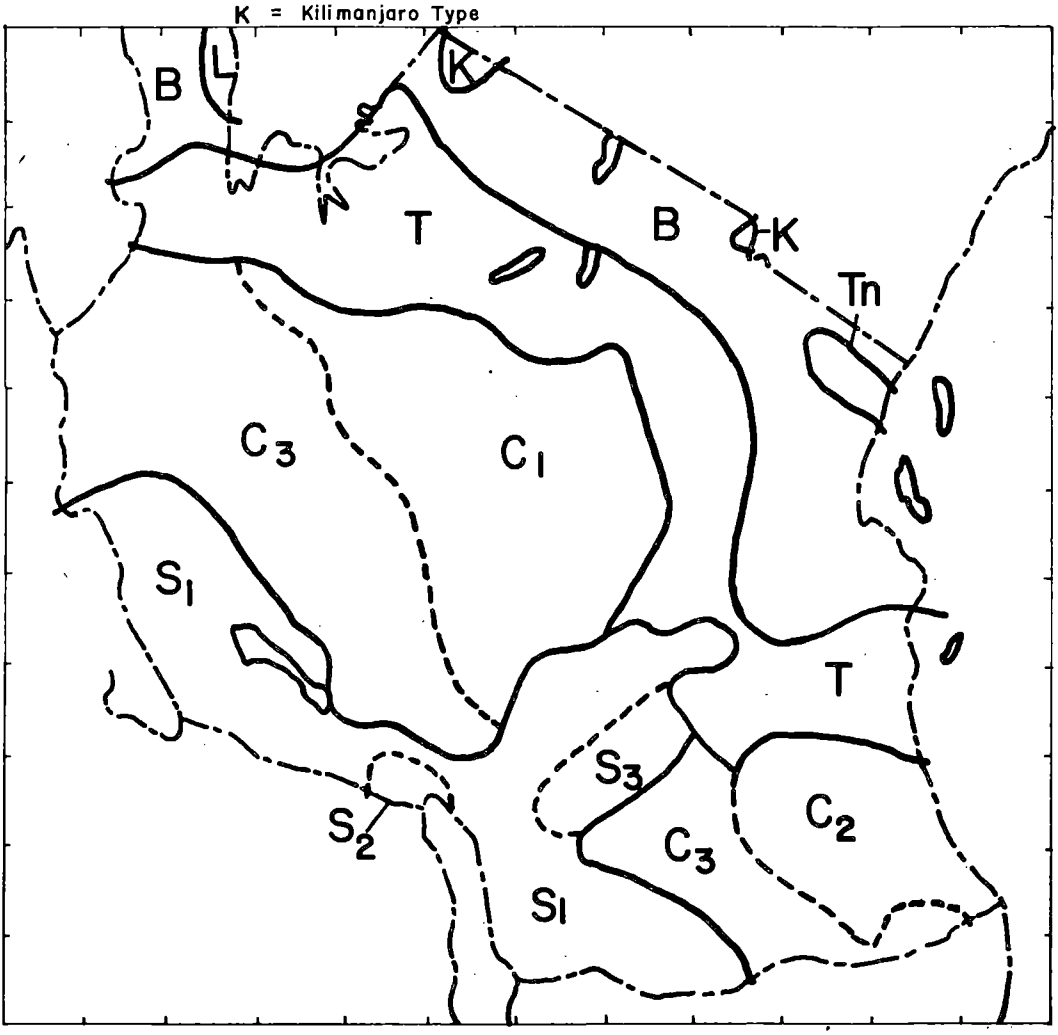
(v). The L-type or lake type exhibits a rather long Gs of 230 days from early October to late May. This is closely related to the B-type but the first rains are much more reliable than the B-type. Maize and rice grow satisfactorily during both seasons but the field drying of the crops planted early is difficult because of the short dry season (January-February).

(vi). The Tn-type or Tanga type is the most unusual type with the driest period during January and February and more than usual rains falling from July to September. The main rains (March to mid-June 90 days) are suited for water demanding crops. Post maturity losses due to difficulty of drying the grain in the field may be experienced. However, at higher altitudes, two maize crops can be grown, the first maturing late December and the second in early June.

(vii). The K-type or Kilimanjaro type (prototype Rombo). The east facing slopes of Kilimanjaro benefit from both the North-eastern (November) and South-eastern (March) airstreams (Coults 1969). The resulting GS truly bimodal and suited for two water demanding crops a year. Beans and finger millet and maize are grown respectively for the first and second rains. The highlands of Tarime enjoy similar type of climate with the short dry season being less clear.

Figure 1 : Agro-climatic Types of Growing Seasons (GS) in Tanzania

S = Southern Highland Type
C = Central Type
B = Bimodal Type
T = Transition Type
L = Lake Type
T = Tanga Type
K = Kilimanjaro Type



Agro-ecological Zones

Tanzania has also been divided into twenty agro-ecological zones (Samki et al 1981) mainly on the basis of soil types and climate. This paper is based mainly on the agroclimatic types because it is strongly believed that rainfall variability plays the major role in agricultural production in Tanzania.

LAND USE

Of the 48.7 million hectares of potential arable land in Tanzania only about 9 percent is presently being cultivated. This is only 5 percent of the total land area (88.36 million). Table 1 shows the land use categories.

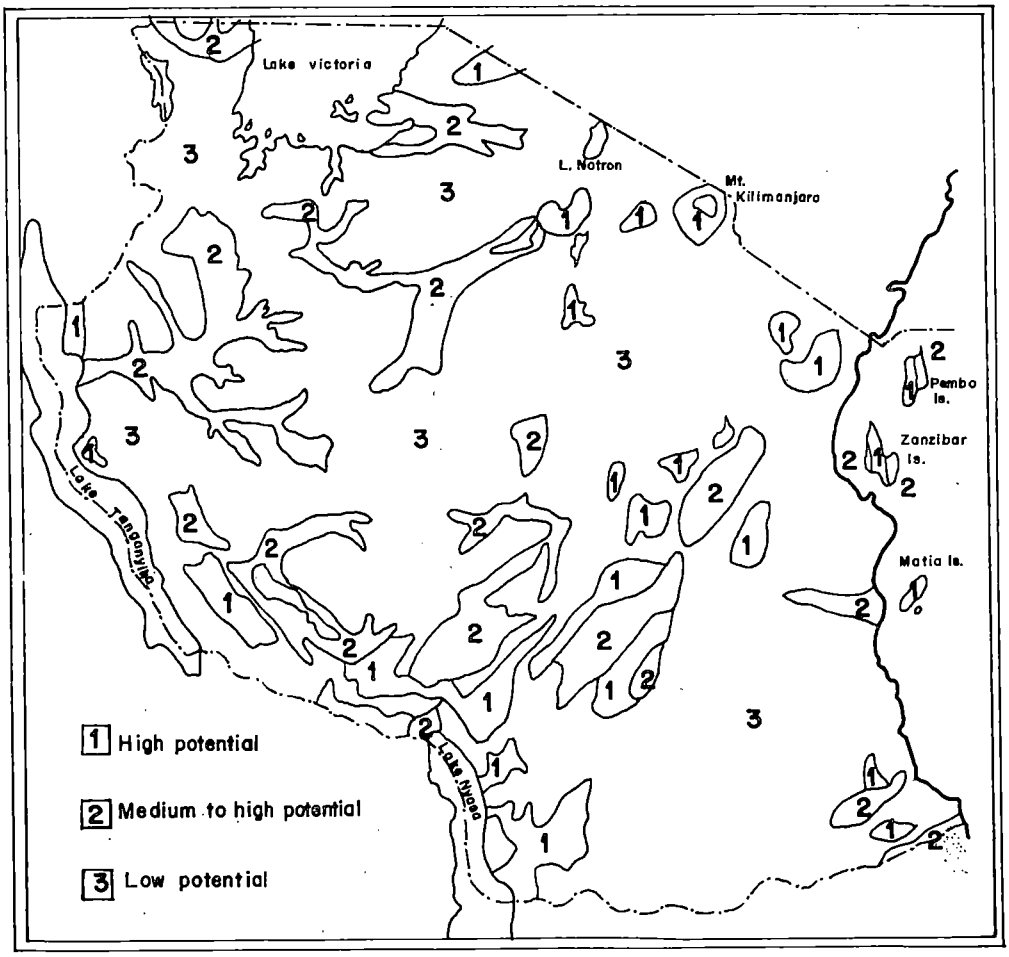
Table 1. Land use categories in Tanzania.

Category	Area ('000 ha)	Percentage of Total Area
Cultivated land	4,465	5.1
Small-holders	3,880	4.4
Large-holders	585	0.7
Grazing	44,245	50.1
Forest/Woodland	38,050	43.0
Urban, Swamps	1,600	1.8
Total	88,360	100.00

Source: Tanzania Agricultural Research Resources Assessment 1984.

Based on climate and soils, the quality of land also varies. Figure 2 shows the land use potential of the country. About 67 per cent of the total population (estimated to be 21 million people) live in the high potential areas, mainly in the mountains and highlands. Agricultural expansion into the medium and low potential less fertile and semi-arid areas is possible but it will require significant amounts of inputs to conserve and increase soil productivity.

Figure 2: Land Use Potential of Tanzania



Source: Agricultural Research Resource Assessment 1985.

PRINCIPAL CROPS PRODUCTION

The major crops grown in Tanzania with areas cultivated, total production and yield per hectare for 1983/84 are shown in Table 2.

Table 2. Major crops grown in Tanzania

Crop	Area Planted (ha)	Production (tons)	Average Yield (kg/ha)
Maize	1,920,000	1,920,000	1,000
Sorghum & Millet	1,000,000	700,000	700
Rice	285,000	360,000	1,265
Grain Legumes	478,000	239,000	500
Root Crops	903,000	1,589,000	1,760
Wheat	58,600	71,500	1,220
Coffee	220,000	55,000	250
Cotton	450,000	148,500	330
Tobacco	23,347	14,000	604
Tea	18,548	15,195	819
Sisal	56,043	46,187	824
Cashewnuts	-	48,340	-
Pyrethrum	-	1,705	-

Source: Tanzania Agricultural Research Resource Assessment 1984.

Most of the crops are produced by small-holder farmers and the rest by state farms and very few private farms. As will be seen from the Table, yields per hectare are rather low and production has been declining over the years. Some of the factors affecting production and methods to promote dryland agriculture will be discussed.

CROP RESEARCH AND PRODUCTION IN THE ARID AND SEMI-ARID AREAS

In the dryland areas of Tanzania, (rainfall 250 to 750 mm) low production of crops is frequently attributed to "drought". According to Berry et al 1972, drought was defined as a joint product of man and nature, related to both the variability of climate and man's degree of adjustment to such conditions. Mascarenhas (1968) observed that localized and sometimes widespread food shortages due to adverse weather conditions are no recent plagues in Tanzania and Gommes and Houssiau 1982 warned that their frequency had increased in recent years. According to Riise (1971) and Morth (1973), above normal rainfall were common in the sixtees. This attracted farmers to move from drought resistant crops mainly bulrush millet and sorghum which were well adapted to the local conditions to maize which has now become the cereal of preference despite repeated crop failures.

Gommes and Houssiau 1982 assessed the probability of yield reductions in maize and sorghum due to water stress and came up with four major yield reliability classes shown in Figure 3:

(i) reliable for maize.
(ii) marginally reliable for maize but reliable for sorghum
(iii) reliable for sorghum only
(iv) marginally reliable for sorghum and reliable for grazing.

Van de Vyvere and the Crop monitoring and early warning project in 1981, under very conservative assumptions of farming practices and percentage of land used, made the following estimates of potential cereal production in tons per reliability classes:

(i)	Wheat and Finger Millet (above 1,500 m)	280,000
	Maize	2,200,000
(ii)	Maize, Sorghum & Bulrush Millet	1,100,000
(iii)	Sorghum & Bulrush Millet	3,000,000
	Total	6,580,000

They concluded that if cash crops are included as well as cassava and sweet potatoes in class III, rice in suitable areas and improved inputs, Tanzania would be able to be self-sufficient. Research on maize, sorghum and millets and rice is very active in Tanzania and it is believed that with improved varieties of these crops, and improved technological packages of inputs, it is possible to realize on-farm yields of 4 tons/ha for maize and rice, and 3 to 3.5 tons/ha for sorghum and millet in pure stands. Taking the hectarages under these crops in Table 2 and if we could attain the above yields per hectare, we would have produced 7,680 tons of maize which is more than three times the potential estimated by Van Vyvere et al. Similarly, we would be able to produce 8,000,000 tons of sorghum and millet and 1,140,000 tons of rice.

Some of the major constraints to increased production in these areas are inadequate rainfall distribution coupled by the fact that farmers still prefer to grow maize even under these conditions; for sorghum and millets, losses due to birds (*Quelea quelea*), lack of varieties coupling bird and drought resistance with acceptable grain quality and susceptibility to high post-harvest losses, and the low prices offered to these crops are the major constraints to increased production.

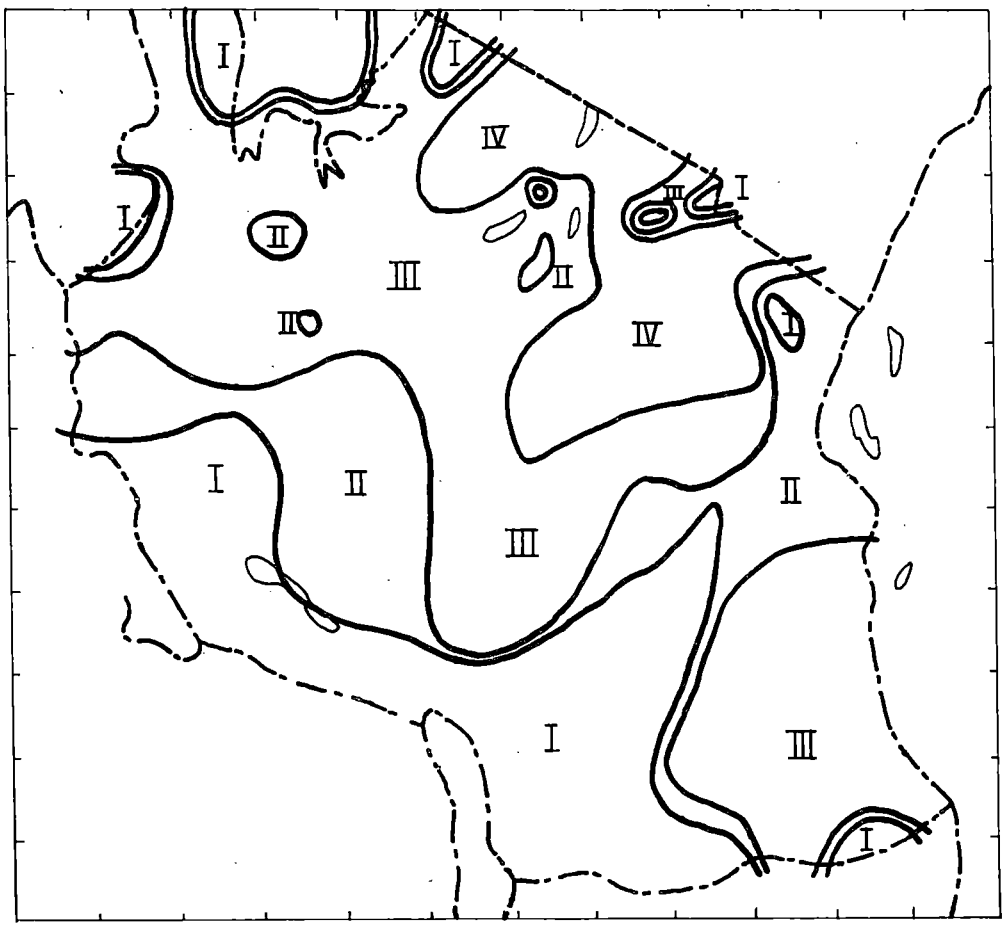
Figure 3: Major Grain Yield Reliability Classes for Tanzania

I = Reliable for maize

II = Marginally Reliable for maize, Reliable for Sorghum

III = Reliable for Sorghum

IV = Marginally Reliable for Sorghum, Reliable for Grazing



Realizing these limitations, Government policies have emphasized the growing of drought resistant crops, sorghum and millets. Two varieties of improved sorghum which have been developed, Serena and Lulu have had some problems. Serena, a brown seeded variety, is high yielding and has some resistance to bird damage but it is not readily accepted by farmers because of its high tanin content which makes it bitter. Lulu, a white seeded variety, is more acceptable to farmers but it is highly susceptible to grain mould and bird damage. Another white seeded variety "Tegemeo" is more resistant to grain mould and is high yielding but its grain quality is low. Future research priorities include the development of varieties coupling bird and drought resistance with acceptable grain qualities for food and storability.

Research will also continue improving on the short-term crops of maize which may be grown in these areas. So far two varieties, Katumani and Kito are available.

It is also recommended to introduce test and evaluate new crops and species which will offer potential for increased production in the dry zone and identify new species which will have potential as additional cash crops or food crops with improved security for production. So far no such introductions have been done successfully but attempts have been made. Guar and Jojoba are some of the candidates that are being tried.

Along with the development of the improved varieties consideration must be given to the multiple cropping systems practised by the farmers in those areas and the availability and applicability of the improved packages of recommendations. Thus, in the semi-arid areas, leguminous crops like cowpeas, green gram pigeon peas, bambara nuts and root crops, especially cassava, are often intercropped with the cereal crops. Development of suitable varieties of these crops is the major pre-occupation of the grain legumes and the root and tuber crops improvement programmes.

Research needs to implement the above programmes, include sufficiently trained manpower, adequate financial resources both local and foreign, (only 0.5% of our GDP is used on Agricultural Research) research facilities such as laboratory, chemicals, transport and library/scientific information services. Some of these are pre-requisites in establishing a sound indigenous research system to address the problems of the farmer and make any recognizable break-through that could effectively be applied to a locality. Collaboration and cooperation with Regional, National and International Research Institutions involved in dryland research is highly desirable in order to learn the methodologies and share the tools and information that are common.

LAND AND WATER MANAGEMENT

Land and water management methods that will increase crop production in the arid and semi-arid areas include:-

- The development of soil management methods that will retain rainfall in the soil, including water storage and use.
- Establishment of crops in such ways that will lead to efficient use of the water.
- Proper management of grazing land to ensure production of healthy livestock.
- Introduction of new tree species or shrubs that may have potential as fodder for livestock and for soil conservation.

SOIL AND WATER MANAGEMENT

Since the arid and semi-arid areas of Tanzania have low rainfall which is also highly erratic, the management of rainfall in these areas is therefore very important. These include methods to increase the availability of rainfall by surface modification e.g. ridging and tie ridging, practiced to some extent, in the western cotton-growing areas on the hill sand type of soils. These practices optimise the use of the rainfall for cropping.

Rainwater in the form of surface runoff could also be harvested and stored in simple dams, ponds and tanks. Surface waters from rivers could also be collected and used for irrigation. Despite the country's high potential in surface waters, these have not been exploited fully for irrigation. There are only a few irrigation schemes (120/318 ha). Major limitations here are the high level of technology involved and the large amounts of financial resources required.

CROP MANAGEMENT

In addition to developing soil management methods to retain rainfall, it is important to establish crop management techniques which will lead to efficient use of water. Such natural practices as tillage techniques, time of planting, methods of planting, plant densities and geometry, weed control, crop sequence and intercropping, etc., are some of the methods that can be adjusted to increase moisture availability. On tillage it has been observed that some of the techniques used in the Great Plains of North America can be adopted for our conditions in East Africa. In Tanzania the wheat research and production programme has used the chisel plough as a first tillage operation, effectively trapping the first heavy rains in the mini-basins created by course rough cloudy surface. This process virtually eliminated runoff and erosion on both the flat and undulating topography in the areas of 450 mm rainfall. In sorghum and millets plant population studies at TARO Ilonga, have recommended low plant densities in the drier areas and high densities in the high rainfall areas. On-station research is conducted on most of the cultural practices involving some of the prominent crops especially sorghum, millet, maize and cowpeas. More work in these areas particularly involving on-farm diagnostic survey on-station research and on-farm testing is needed.

MANAGEMENT OF GRAZING LAND

It is known that grazing land takes about 50% of the total land area (Table 2) and most of this land is in the arid and semi-arid areas. Tanzania has also one of the largest livestock herds in Africa (12.9 million cattle, 5.9 million goats, 3.7 million sheep, 23 million, chickens and 40,000 pigs). This great resource is however not well managed to realise its full potential. In the 1985 Tanzania Agricultural Research Resource Assessment, it was observed that for cattle, sheep and goats the major constraints are range and herd management. Others are pest and disease control and access to water.

Land tenure is probably one of the major factors limiting sound management of range lands in Tanzania. The main forms of land tenure are customary land tenure, communal land tenure, leasehold and rights of occupancy. In practice, most of the agricultural and range land is held under the customary and communal systems. Under this system the major problem is to determine the correct carrying capacity vis-a-vis the herders' objectives and their concern for the system's stability. In recent years, Government emphasis on crop production in the dry zone may have led to overstocking in the remaining land.

Measures to improve grazing land include review of the existing communal systems and design of alternative grazing schemes to be tested under communal conditions, collection, introduction and screening of drought resistance fodder plants, studies of practices to improve water infiltration on grazing lands and on-farm trials to determine effective stalking rate in the communal grazing systems.

AGROFORESTRY

Generally, this is a system of land management in which trees are grown together with agricultural crops and or simultaneously or sequentially with animals interacting on the same unit of land in such a way as to sustain overall production of the system. The tree crops may have potential as fodder for the livestock, for wood and/or timber and for soil conservation. Some leguminous tree crops e.g. Leucaena with potential for nitrogen fixation may also be grown. The semi-arid areas of the country comprising the Masai pastoral range land in Arusha, Dodoma and Singida and some parts of Western Tanzania - Mwanza and Shinyanga, have undergone severe deforestation, soil erosion and desertification. In these areas, agroforestry can play an important role in improving soil fertility and minimizing land degradation by erosion. Fuel wood and building materials can also be increased as well as fodder. The major problem in these areas is that land is communally grazed even after harvest of crops. This partly explains why in a recent proposal in collaboration with the International Council for Research in Agroforestry it was agreed to introduce agroforestry technology in the miombo woodlands. However, where it is applicable in the semi-arid areas, it is encouraged to grow trees and shrubs for soil conservation and fodder. Some of these may also serve as cash crops e.g. Jojoba which does well in the semi-arid areas of the USA.

FARMING SYSTEMS RESEARCH

Examples have been given of the dryland technologies (e.g. the Serena and Lulu varieties of sorghum) that have not been readily acceptable to farmers in the dryland areas of Tanzania. In order to overcome such disappointments on the part of research, dryland technology development should therefore aim at producing technologies that will be acceptable to the majority of the small farmers, with possibilities of improving their overall socio-economic conditions. This implies the Farming Systems Research (FSR) approach. This approach was endorsed in the Tanzania National Agricultural Research Policy of 1982. However, the FSR is not a substitute for commodity oriented or multidisciplinary on-station research. It is meant to complement on-station research by identifying farmer problems which need investigation, on and off-station. Ghodake and Hordake 1981 described a whole-farm modeling for assessment of dryland technology. They described a farm systems or a whole-farm system as an interwoven mesh of soil, plants, animals, implements, workers, other inputs and environmental influence with the strands held and manipulated by a person called the farmer, whose preference and aspirations attempt to produce output from the inputs and technology available to him. It is the farmer's awareness of his immediate natural and socio-economic environment that results in this farm system.

In their model, they view the need for technology development on the basis of existing level of output, level of income, resources use patterns and environmental factors. They term this a "bottom up" approach for assessment as it stimulates the farmer's behaviour but it does not directly involve the farmer at the grass root level in goals, skills, attitude and preference and also his physical environment in terms of farm resources, institutional infrastructure and alternative technologies.

A Farming Systems Research Programme was started in Tanzania in 1982 in accordance with the National Agricultural Policy. It took into consideration the large size of the country and identified three zones, the Central zone covering the semi-arid area (C + T types), the Northern zone covering the highland area of Kilimanjaro and Arusha and the Western zone covering the Western cotton growing area of Mwanza and Shinyanga. Due to limited financial resources the programme has not been able to operate in the Western zone. In the Central zone the FSR team has collaborated very closely with the maize, sorghum and millet and grain legumes Research Coordinators at Ilonga Research Institute. It has evaluated the stock of past experimental results and recommendations for relevance to farmers' situation in the zone. In particular, it has helped farmers to adopt a short-term newly released variety of maize 'Kito' which has been highly acceptable by the farmers in these areas during the short rains.

Overall, the success of the FSR approach requires greater collaboration and cooperation between the biological scientists, the FSR social scientists, the Extensionists and the farmers within national and regional policies. The establishment of networks to standardise the methodologies is also highly desirable. It is recommended (Shao 1985) that in implementing the FSR approach we have to integrate it into the existing commodity-oriented on-station research programmes.

DISCUSSION AND CONCLUSIONS

The desirability to improve dryland agriculture in Tanzania has been constantly expressed by politicians and high level policy makers and has been the major challenge to Agricultural Research Scientists, Extensionists and farmers. Researchers have been eager to develop dryland technologies for the semi-arid areas while policy makers and extensionists have been emphasizing the need for farmers to adopt such technologies in the drought stricken areas. However, there has been some missing link between the researcher, the extensionist and the farmer's preferences. This has been noted in the developed sorghum varieties Serena and Lulu which have not been readily accepted by the farmer. The Farming Systems Research is the key to solving such problems.

The studies of Gommes and Hossiau which have identified the agro-climatic types of growing seasons may play a major role to exploiting the potential of the dryland areas of Tanzania if the appropriate technologies developed for those areas are utilized. Government policies must, however, play a key role in enforcing the adoption of such technologies as against those of the farmer's preference.

Rehabilitation and maintenance of the dryland areas of Tanzania is also a major pre-requisite for any recognizable production from the dryland areas. The land and water management programmes and the Farming Systems Research approach includes the resource efficient farming methods which may apply not only to Tanzania but on a regional basis. There are common strategies, materials and methods that could be applied in the region to solve the problems of drought and the frequent shortages in the area. The recently established Southern African Centre for Coordination in Agricultural Research (SACCAR) for the SADCC countries based in Botswana with Regional Sorghum and Millets improvement programme in Bulawayo, Zimbabwe and the proposed Land and Water Management and Grain Legumes Improvement Programmes have this goal. Similarly, the SAFGRAD/ICRISAT-funded Eastern African Sorghum and Millets Programme with headquarters in Nairobi, has the same goals. It is hoped that these programmes will establish the necessary networks in collaboration with national governments to attain the required goals.

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THE STATUS, PRIORITIES AND RESEARCH NEEDS TO PROMOTE DRYLAND FARMING IN DROUGHT PRONE AREAS OF UGANDA.

Vincent Makumbi Zake and Joseph Oryokot
UAFRO, Sorghum and Millet Unit
Serere Research Station
P.O. Soroti, Uganda.

INTRODUCTION

Agriculture in Uganda constitutes the most important sector of Uganda's economy. It provides employment for over 80 per cent of the country's population which is over 15 million people. This population is increasing at the rate of 3.1 per cent per annum. The rural population consists predominantly of subsistence farmers (GNP per capita US $280, 1982).

Agriculture accounts for the total domestic output and over 60 per cent of government revenue (Ministry of Planning Records, 1982).
The country's policy places emphasis on self-sustenance in food resources whilst improving production of export crops and livestock. The importance of food crops such as maize, sorghum, finger millet, banana and root crops compared to cash crops has increased tremendously over the years (Table 1).

Uganda is well supplied with water compared with most countries in Africa. Fifteen per cent of the total surface is open water and most of the country can expect more than 750 mm of rainfall. Besides the great lakes on the boundaries - Victoria, Albert and Edward, the branches of Lake Kyoga ramify through the centre of the country from south to north. For crops established from seed, one month is considered a drought month if the rainfall expectation is less than 50 mm for more than once in four years. Uganda is dependent on rain-grown crops. Being on the Equator, rainfall is distributed between two rainy seasons one in the first half of the year and the other in the second half. These two seasons merge into one rainy season as one moves north or south of the Equator. This distribution is favourable to perennial crops. Bananas and coffee are cultivated extensively in the southern half of the country.

Efforts to increase food production through agricultural research were already established by the late 1930s and early 1940s in East Africa. Collections and introductions were already being made in Uganda during the same period and sorghum breeding at Serere began in 1954 (Dogget, 1982). Established centres of Research namely, Kazwanda, Namulonge and Serere, coordinated sixty-four (64) district variety trial centres, scattered all over the districts of Uganda in the eleven established agricultural zones which were determined on rainy seasons, amount of rainfall per annum, altitude and the basic agricultural and livestock management activities (Table 2).

Table 1. Production of the principal crops in UGANDA

CROPS	AREA HARVESTED (1000 ha) 1983	AREA HARVESTED (1000 ha) 1984	YIELD (kg/ha) 1983	YIELD (kg/ha) 1984	PRODUCTION (1000 Mt) 1983	PRODUCTION (1000 Mt) 1984
Cereals, Total	958	1005 F	1630	1607	1562	1615 F
Maize	340 F	385 F	1324	1299	450	500 F
Millet	360	360 F	1667	1667	600	600 F
Sorghum	230	230 F	2043	2043	470	470 F
Rice	20	20 F	1250	1250	25	25 F
Wheat	8	10 F	2125	2000	17	20 F
Roots and Tubers, Total	686 F	690 F	3805	3819	2610 F	2635 F
Potatoes	30 F	32 F	6667	6406	200 F	205 F
Sweet potatoes	156 F	158 F	4872	4937	760 F	780 F
Cassava	500 F	500 F	3300	3300	1650 F	1650 F
Pulses, Total	492 F	492 F	856	856	421 F	421 F
Beans Dry	380 F	380 F	947	947	360 F	360 F
Other Crops						
Groundnuts (in shell)	120 F	120 F	833	833	100 F	100 F
Sesame seed	80 F	80 F	475	475	38 F	38 F
Seed cotton	450*	528*	73	118	33*	62*
Cotton seed	22*	40*	-	-	-	-
Coffee	219*	220 F	877	927	192*	204*
Tea	5 F	6 F	500	500	3*	3 F
Banana Plantain	410 F	420 F	3400	3410 F	-	-
Sugar cane	32 F	32 F	11875	12121	380 F	400 F
Tobacco	1 F	1 F	2300	2500	2*	3 F

Note: * Unofficial figure
F FAO Estimate
- None, in negligible quantity

Source: FAO Production Yearbook 1984.

Table 2. Agro-climatic Zones of Uganda

Zone	District	Agricultural System
Zone I	Busoga/Bukedi	Banana, Millet and Cotton System with outliers of the main coree-banna system.
Zone II	Bugisu/Sebei	Montane system: Arabica coffee, bananas (wheat and maize in Sebei).
Zone III	Teso	Teso system: finger millet, cotton and cattle keeping (mixed agricultures).
Zone IV	Karamoja	Pastoral system - cattle keeping.
Zone V	Lango/Acholi	Northern system: finger millet, cotton, tobacco (some mixed agriculture also).
Zone VI	West Nile/Madi	West Nile system: basic agriculture like Zone V but predominance of cassava as staple food.
Zone VII	Bunyoro/Toro	Arabica and Robusta coffee and banans system: Montane system: heterogenous agriculture but basically bananas, coffee and tea.
Zone VIII	Ankole	Montane system in the west: Pastoral to the east: Arabica and Robusta coffee, tea, bananas and cattle.
Zone IX	Kigezi	Montane system but with larger annual crop acreage than other montane system. Sorghum is major staple. Arabica coffee, tea.
Zone X	Lake Victoria Crescent	Main Robusta coffee and banana-system: Robusta coffee, bananas, tea, sugar and cocoa.
Zone XI	Northern Buganda	West extension of the banana -millet - cotton system, but now largely taken up by big ranching projects.

Source: Planning Cell, Ministry of Agriculture.

The establishment of the multi-locational testing sites and ancillary services for screening of varieties and testing other technological packages over a wide range of environments, has played an important role in the development of cotton, groundnuts, sorghum, finger millet, livestock, pasture and ox-cultivation. Unfortunately, however, all the centres of research do not have established sub-research stations in drought-prone areas of the country to provide the right applicable, acceptable recommended packages for use by farmers of the areas. Research stations which provide wide adaptable research information are established in very different ecological zones not comparable to drought-prone areas in Uganda.

SEMI-ARID ZONES OF UGANDA

In Uganda, the areas considered as dry are those receiving a rainfall probability of 500-1015 mm with a 9:1 confidence limit. Areas which exhibit this phenomenon include Karamoja, the country around the north eastern end of Lake Albert, the Kazinga Channel flats between Lakes Edward and George; a belt from south Ankole to west Masaka. In the second half of the year, this belt extends to include south-east Kigezi and the whole of Masaka to the shore of Lake Victoria and to Lake Kyoga. The rains are typically in torrential, violent convective storms. Karamoja is the largest single semi-arid region in Uganda, occupying an area of 20,125 km^2. Typical settlement areas in the central part of the region where most Karamojong live receive 600-700 mm. The difference is however greater than average figures imply, for Karamoja is highly susceptible to such poor distribution of rainfall that actual crop failures occur due to drought. Heavy stocking rates exaggerate the situation causing heavy soil erosion. Thus, agricultural production, using existing technologies and crop varieties in these areas has become very marginal. Most of the year, Karamoja is extremely dry and hot.

The infiltration rate of rain for bare soil is rarely greater than 20 mm per hour, yet a large proportion of the rainfall occurs at rates greatly in excess of this. The problems of dealing with the high intensities of tropical rainfall are acute in all parts of Uganda but particularly so, in areas where rainfall received during the main season, is often inadequate or badly distributed. In many areas, run-off is high and the potential evaporation rate each month equals or exceeds the total rainfall (Farbrother and Munro, 1970). According to Rowland (1983), since 1978, Karamoja has been experiencing crop failures and it was only in 1982 that there was abundant rainfall. Every other year, poor or ruined crops have been experienced in many areas of Karamoja. In the previous decade, reasonable or good years tended to alternate with poor years. The Karamojong have one chance per year to produce food and a very long and hungry wait if that should fail. Most other parts of Uganda, however, have higher mean annual rainfall and two crop growing seasons each year. Accurate estimates of average monthly evaporation shows the probability and severity of drought periods. Table 3 shows rainfall and surface evaporation observations for selected sites.

Table 3. Mean monthly totals and mean annual rainfall (mm) and estimates of evaporation from open water (mm per month in brackets) in selected sites in Uganda.

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL TOTAL
SERERE	36.9 (195)	59.1 (179)	111.2 (190)	200.6 (160)	165.4 (155)	101.4 (143)	106.6 (132)	160.8 (148)	131.1 (165)	161.3 (180)	129.4 (179)	50.6 (188)	1442.0
MUBENDE	46.1 (152)	60.1 (141)	102.6 (162)	190.9 (133)	93.4 (132)	48.2 (145)	47.4 (139)	119.1 (138)	220.5 (133)	170.0 (142)	193.2 (131)	51.7 (143)	1152.0
KASESE	24.5 (155)	47.5 (155)	73.9 (156)	135.0 (147)	97.1 (179)	49.3 (146)	41.5 (139)	75.8 (144)	96.2 (151)	112.0 (156)	135.0 (144)	48.5 (156)	1204.3
MBARARA	56.5 (128)	62.2 (119)	92.6 (127)	130.2 (101)	63.8 (123)	21.5 (138	24.4 (139)	68.6 (134)	99.3 (134)	123.5 (126)	153.2 (111)	67.3 (120)	983.1
KABALE	64.9 (118)	82.7 (111)	142.6 (124)	150.2 (105)	90.6 (101)	29.4 (108)	18.7 (128)	57.0 (126)	96.0 (123)	199.3 (125)	127.5 (105)	91.3 (108)	994.9
NEBBI	15.3	24.6	64.5	93.3	87.1	75.5	113.1	142.7	136.2	130.5	104.3	27.6	1022.4
KATONGA FOR STN	24.6	36.4	78.9	132.6	143.1	72.0	69.0	96.8	80.3	131.6	108.9	30.4	1110.0
KOTIDO	7.8	24.7	96.2	76.0	87.9	80.7	115.8	82.1	31.9	49.8	46.4	19.5	709.2
KANGOLE	7.3	19.8	48.9	101.6	98.4	59.5	103.8	88.2	63.5	58.2	44.0	14.5	701.9

Due to violent, torrential rainstorms, low penetration rate, high run-off and rapid evaporation, soils in Karamoja consist of undifferentiated lithosols; topographic vertisols and ferruginous tropical soils which occur in large areas as a complex co-dominant with black clays and also a complex co-dominant with lithosols. Kigezi and the eastern extension of Ankole have abundant ferrallitic soils which are mainly yellowish sandy clay and sandy loams. Sheet erosion following the violent rainstorms has stripped off the top soil in many parts of Karamoja. In the drier regions where over-grazing is intense, sheet erosion is widespread, gully erosion spectacular and grassland and tree savanna have changed to arid tree and shrub steppe. Severe dry seasons prevent maintenance of good permanent vegetative cover. In this connection, lands for communal grazing in Ankole are easily eroded due to hard compact topsoil that develops and cannot absorb the first rains. Indiscriminate burning which is extensive and fierce in Kigezi and Ankole grazing areas have also encouraged sheet erosion.

FOOD PRODUCTION

Sorghum is widely grown all over Uganda especially in the dry short grass areas in the north and east and is particularly important in the drought prone Karamoja and Kigezi. In Karamoja, Sorghum occupies over 80 per cent of the total food crop hectarage. It is estimated that half of the total production of sorghum in Uganda is produced in Kigezi and Karamoja. In Kigezi, sorghum assumed great importance in the mid-1930s due to labour requirements in finger millet, more sensibility of soil fertility under conditions of land pressure and rainfall distribution. Sorghum is an important staple and grows not only in Karamoja and Kigezi but also in many parts of Uganda, especially Teso and Acholi. Bulrush millet which is often associated with drought tolerance has assumed recognisable importance in Karamoja. Other crops grown include sunflower, tepary beans, pigeon peas, grams, cucurbits and cowpeas. The hoe is the most common tool for land preparation although ox-cultivation is practiced. In Karamoja, it is estimated that 50 per cent of the settlements have ox-ploughs especially in areas where cattle are owned. Cattle herding is an important activity.

Besides three months of seasonal rainfall and the quite unpredictable erratic and unreliable rain, constraints to agricultural productivity in drought-prone areas of Uganda include social taboos like sex division of labour, nomadic and cattle rustling behaviour in Karamoja and absence of oxen in field operations in Ankole. Being famine striken areas, availability of seed is a problem in lean periods; the seed is eaten and often the distributed seed by food relief agencies is unsuitable to the environment. Due to poor communication arising from lack of transport facilities, lack of extension personnel to work in remote areas and long distance settlements, agricultural advice to farmers is lacking. Soil conservation , soil moisture measures and crop rotation are not

practiced especially in Karamoja. Cattle is reckoned by numbers rather than quality leading to overgrazing and extensive soil erosion. There is serious shortage of ox-ploughs. Animal diseases are rampant. The district variety trial centres which are in these areas are testing the varieties developed in more favourable areas for adaptation in the drought-prone areas. More importantly, the range of crops tested is narrow and do not include some important types.

RESEARCH ACTIVITIES AND PRIORITIES

Under these circumstances, the Sorghum and Millet Research Division at Serere is taking a serious approach to improve crop production in these areas. Bulrush millet composite 2 (SC 2) has been released to Karamoja and its performance is commendable. Although the sorghum variety Seredo is popular among farmers in Karamoja and it has wide adaptation, the station has embarked on the development of drought escaping or tolerant sorghum varieties. Valuable sources of early maturing and drought tolerant lines which were identified from the sorghum germplasm have been exploited to produce progenies that flower within a range of 50 to 60 days and to produce a reasonable crop. The progenies have been identified in the 3KXs, 72Xs, OZXs and lZXs and were screened in Karamoja during the first rains of 1985. Materials for drought prone areas received from the Eastern Afrian Co-operative Regional Sorghum and Millet Improvement Trials, were also tested in Karamoja and Kigezi. Results of their performance have not yet been received. Nonetheless, the performance of 3Xs and 7ZXs at Serere indicated progress (Table 4) towards early maturity. Selections 3KX 73/4 and 72X 407/2 have given consistent good yields across sites. In view of providing proper direction in selecting suitable sorghum varieties for Karamoja and Kigezi, segregating early generations (preferably F_2s) of sorghum need to be sent in those particular environments.

The Karamoja Seed Scheme, a department of the Church of Uganda, besides multiplying seed, has carried out crop introductions and variety testing of both traditional and exotic crops. Multiplied seeds include sorghum, maize, bulrush millet, groundnuts, cowpeas, local Hyacinth beans (**Lablab niger**) grams, bambara nuts and sunflower. Introduced crops include wheat. Limited agronomic work has been done by the scheme on planting dates; spacing and plant populations; intercropping and relay planting. No research has been carried out on soil management and soil moisture conservation. While almost all trials were invariably conducted without irrigation, fertilizers, pesticides or tractor cultivation, the number of trial sites used were few and many of the crops failed or were badly damaged due to drought and diseases.

Table 4. GRAIN YIELD, PLANT HEIGHTS AND DAYS TO FLOWER OF 36 GRAIN SORGHUM VARIETIES GROWN AT SERERE (6 x 6 EARLY MATURING SORGHUM) TRIPLE LATTICE FIRST RAINS, 1983

Entry	Grain yield (g/ha)	Plant height (cm)	Days of flower
7ZX 376/2	3.5	160	70
7ZX 378	11.0	145	69
3KX 76/8	11.2	170	50
3KX 79/1	31.7	165	49
Serena	46.3	155	60
3KX 79/6	25.2	155	49
3KX 72/1	25.2	140	49
7ZX 389/1	1.7	140	72
3KX 71/1	22.0	155	50
7ZX 379/2	1.9	185	67
3KX 74/3	56.7	195	56
3KX 76/6	32.3	155	49
7ZX 380/2	32.8	190	64
3KX 76/2	21.3	150	50
7ZX 382	1.8	125	67
7ZX 385	30.6	155	63
3KX 72/2	26.1	110	49
3KX 73/4	31.8	165	51
7ZX 387/2	15.4	130	63
7ZX 388/2	14.5	135	63
3KX 76/5	28.3	135	50
E 525 Ht.Reduction	56.0	160	62
3KX 71/4	15.9	145	49
3KX 79/3	15.3	135	47
7ZX 389/1	16.3	145	66
3KX 76/9 Brown	38.6	140	48
7ZX 391	21.6	150	61
7ZX 396/2	13.0	200	65
Seredo	45.5	180	63
3KX 73/1	47.3	160	91
7ZX 407/2	51.9	195	60
3KX 79/2	-	-	-
3KX 76/7	57.3	155	50
Kafiranum x Simila	72.6	180	55
Kafiranum x SB65	50.4	180	55
3KX 80	25.0	155	53
LSD (P=0.05)	13.3	41.75	3.39
CV%	28.1	16.3	3.6

Success in distributing seeds to the farmers by the Scheme depends on the success of the rains. The Scheme is highly successful with Sorghum. Limited ox-cultivation training is carried out by the Catholic Church in Karamoja.

Foremost among priorities to promote dryland agriculture in Uganda include:

a) The establishment, in the short run, of:

(i) sub-stations to handle dry lowland research. These should be mandated to cater for all areas below 1100 m.

(ii) a sub-station to handle dry highland research, to cater for all areas above 1100 m.

b) The establishment of farming systems research in these dry areas, where agriculture is done nearly on low input levels. For data obtained from these sub-stations to be relevant, knowledge of these farmers resources, priorities and constraints is a prerequisite so that research in these sub-stations should be aimed at problem solving.

c) Co-operation with other countries or international crops programmes is important for the exchange of information and materials. These would save on time and resources, considering that a lot of information is already available internationally on dryland farming.

Considering the difficult conditions that prevail in these arid regions, the main areas of research thrust are:

1) Varieties: The development of adaptable varieties to these environments in overall performance. The national sorghum programme has made a lot of progress in breeding materials suitable for Karamoja. In Kigezi due to the length of the growing season, rationing of sorghum is common. The sorghums grown are rationing types, these are of low quality. Research needs to be focussed on quality improvement of these rationing sorghums.

2) Multiple cropping: Surveys done in Karamoja have shown multiple cropping as a fixed feature of agriculture (Rowland, 1985).Sorghum is inter-

cropped with maize, cowpeas,sunflower and cucurbits. Research is desirable to identify sorghum genotypes which lend themselves best to intercropping. In the same vein is the desirability of identifying intercropping systems which provide the highest product per unit area.

In Kigezi most crops remain for nearly six months in the fields, and therefore only one crop is possible. To enhance the productivity of this region, research should aim at relay cropping. Crops such as beans are being relayed with sorghum or sorghum with maize. Research should focus on identifying stages at which the relay crop is planted to minimise its effect on the first crop's yield.

3) Planting dates: This is of importance especially in Karamoja and other similar environments. Poor crop estalishment results from wrong planting dates and yields are similarly affected or missed. Research should aim at establishing ideal planting dates in view of the total farming system. Compromises made should not grossly affect crop performance.

4) Crop/Water relations: Research has to determine individual crop water requirements. This will allow for correct plant populations both in mixtures and sole crops. Trials done in Karamoja with sorghum have shown that crop population is critical especially in drier years (Exp. Report, 1975).

5) Soil moisture conservation: The determination of effective soil moisture conservation measures is a prerequisite. Work by the Karamoja Agricultural Project has indicated that simple bunds make a difference between a good and poor crop. A suitable hardy pasture grass could be planted to form grass bunds. This may be grassed on during the dry seasons.

The heavy torrential rains that fall in Karamoja cap soil lead to loss of moisture and soil. This is promoted by cultivation especially by oxen. Experimental work should aim at minimal tillage to reduce the soil cropping and encourage water infiltration.

6) Soil nutrient conservation: Soil erosion is serious in both Karamoja, related environments and Kigezi. As pointed above,strip cultivation, bunding and minimal tillage can reduce erosion in the flat dry regions. In Kigezi these measures are not enough and terracing has been practiced by farmers. Research needs to be carried out on how to improve these terraces and to enable them last longer.

CONCLUSION

In order to reduce the frequency of famine in Karamoja and boost the agricultural production in drought-prone areas, suitable technology through establishment of a Dryland Research Station and Soil Conservation Department by the Ministry of Agriculture is needed for introducing, collecting, evaluating, testing of diversified crop, grass, tree (especially fruit) germplasm to minimise risks and encourage maximum productivity. Crop diversity through germplasm introduction must be a continuing and an integral part of the project. Serere should continue to provide materials that are drought tolerant, to the stress environments by testing germplasm, and testing segregating early generation crops, and screening varieties in the existing trial sites. Furthermore, the dryland research institution will look into traditional farming methods, introduce cropping implements, investigate crop rotation, use of manures, trash and fertilizers, intercropping, planting dates, tillage methods, tie-ridging and mulching, spacing and plant population.

It is hoped that with the establishment of the Dryland Research Station suitable technology for development of adaptable varieties, soil and moisture management under conditions of low erratic rainfall, high evaporation rates, low infiltration rates and water holding capacity will be provided to substantially boost agricultural production in the drought-prone areas of Uganda.

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12. ZAMBIA

PRIORITIES AND RESEARCH NEEDS IN THE SEMI-ARID AREAS OF ZAMBIA.

K. McPhillips, W. Veldkamp and B.K. Patel
Mt. Makulu Research Station
Post Bag 7,
Chilanga, Zambia.

INTRODUCTION

The semi-arid parts of Zambia are characterized by a mean annual rainfall of between 600 and 800 mm. The area includes the Gwembe Valley, the Lunsemfwa Valley, the Central and Southern parts of Western and Southern provinces. Altogether, the area covers about 11 million hectares which is 15% of the country. There is a considerable difference in elevation. The Gwembe Luangwa and Lunsemfwa valleys lie at an elevation of 300 to 900 mm, while the rest of the semi-arid areas lie between 900 and 1300 mm above sea level like most of Zambia.

CLIMATE

Using 70% probability data, showing results for 7 out of 10 years (Veldkamp et al 1984), a few representative meteorological stations indicate the rainfall distribution in the region (Table 1). These data show a range in growing season between 80 and 110 days, a growing period characterized by rainfall exceeding half of the potential evapotranspiration including a period of pure soil storage. Using mean values (FAO 1978), the number of days of growing period range between 135 and 153 days.

For the same station, the probability of a dry 10-day period with less than 30 mm rain is shown in Table 2. These data show that within the growing season 3 to 5 dry 10-day periods occur, so that a total of 30 to 50 days have low rainfall in 7 out of 10 years. In some parts, more than 50 days of the growing season can experience drought.

Table 1. Rainfall at 70% probability and potential evapotranspiration (in mm) for some representative meteorological stations.

		SINAZEZE GWEMBE		KATONDWE (LUANGWA SOUTH)	MISSION SOUTH	LIVINGSTONE		SESHEKE	
		P	PET	P	PET	P	PET	P	PET
Nov	20-30	7	44	0	43	11	47	11	48
Dec	1-10	13	45	20	42	20	48	23	46
Dec	11-20	36	45	20	40	35	47	30	44
Dec	21-31	33	44	34	39	30	46	23	43
Jan	1-10	31	44	27	39	26	45	23	45
Jan	11-21	22	44	23	39	23	44	22	45
Jan	21-31	37	42	25	37	43	41	35	42
Feb	1-10	39	40	19	34	30	38	26	39
Feb	11-20	36	38	29	33	26	35	28	37
Feb	21-28	21	38	15	35	9	37	11	38
Mar	1-10	23	39	14	38	14	42	17	42
Mar	11-20	15	39	0	39	4	44	6	44
Mar	21-31	0	36	0	38	0	42	0	41

P = rainfall, 70% Prob. PET = Potential Evapotranspiration.

Table 2. Probability in % of a 10-day period with less than 30 mm rainfall.

		SINAZEZE GWEMBE	KATONDWE MISSION (LUANGWA SOUTH)	LIVINGSTONE	SESHEKE
Oct	20-31	96	93	83	82
Nov	1-10	78	77	66	61
Nov	11-20	74	80	66	61
Nov	21-30	61	67	70	61
Dec	1-10	39	40	37	36
Dec	11-20	35	43	17	43
Dec	21-31	30	20	33	36
Jan	1-10	26	40	40	39
Jan	11-20	30	43	30	36
Jan	21-31	22	33	17	18
Feb	1-10	26	40	33	25
Feb	11-20	26	27	43	39
Feb	21-28	35	50	60	54
Mar	1-10	43	53	53	50
Mar	11-20	48	67	66	57
Mar	21-31	70	83	83	82

In the lower elevated valleys high temperatures are recorded, meaning that evaporation losses are high. During the growing season, the mean maximum monthly temperatures range between 29 and 31 degrees centigrade. The parts at higher elevation are slightly cooler; they, however, experience some frost during the dry season (July).

SOILS

Some of the soils, especially the loamy alluvial soils along the tributaries of the Luangwa river, in the semi-arid zones, have a high available water holding capacity (AWC), but this is quite rare. The heavy textured vertisols have relatively little problems in drought conditions but they may flood during the rainy season. Most soils in the semi-arid zones are sandy. Those in the western parts are Kalahari sands, probably of fluviatile origin. Their fertility is very low and only under hydromorphic conditions can crops be grown. In the Southern province, the soils are characterized by a loamy sand or sand topsoil/subsurface over a depth of several decimeters, underlain by a heavier textured subsoil. Drought in the early stages of growth, or in case of shallow rooting crops, can seriously hamper crop production on such soils. In the Gwembe valley, colluvial sandy loam soils are common. Their AWC is rather low.

Whereas most soils are slightly acid to neutral, alkaline soils have been found in a few places. Some of the vertisol areas (Mambova swamps in Southern province) are believed to consist of alkaline clay soils. In the Luangwa and Gwembe valleys alkaline clayey river terraces have been observed. These soils tend to erode easily. Saline soils are rare and are found in the driest parts, mainly, e.g. near Chirundu.

Agricultural soils can be found along the tributary rivers in the Luangwa valley and on the youngest river terrace along the Zambezi river in the Gwembe valley. These soils are relatively close to open water and especially in the latter case irrigation can be considered.

RESEARCH PRIORITIES

In the semi-arid zone the research programme has been geared to the problems of high temperature, low and erratic rainfall, and high evaporation rates. The search has been not only for better methods of husbandry but also for new and alternative crops which may give greater returns to the farmer.

As the unfavourable climate and soil conditions have resulted in low living standards of the local people, the main effort of the experimental work has been directed to :

- checking the local crops which are not high yielding, and testing new varieties with a view to obtaining greater drought resistance/tolerance and higher yield potential.

- looking for alternative food crops which might be more productive than those presently in use.

- testing different methods of water conservation.

- finding the optimal management for high yields of cotton and investigating other alternative cash crops.

Crops under investigation include :

- Maize
- Sorghum
- Bulrush millet
- Pearl millet
- Cotton
- Soyabeans
- Beans
- Guar
- Cowpeas
- Sunflower
- Safflower
- Sesame
- Wheat
- Rice
- Bambara nuts.

Physical management has included :

- tied-ridging (to conserve rainfall)
- rotavating (to break surface crusts)
- Mulching.

Intercropping trials have also been initiated.

RESEARCH PROGRAMMES AND CONSTRAINTS

Staff shortages and lack of continuity has restricted progress. The programme of work has been very much a stop/go situation with no long-term objective. However, some progress has been made in the release and introduction of new varieties of maize, sorghum and millet, specifically adapted to the agro-ecological conditions, and cotton as a cash crop has been successfully introduced into the valley areas. Wheat and rice production on the seepage zones of the river areas are also showing promise. Cashew nut research has been initiated.

Virtually no work has been undertaken on integrated animal enterprises within the farming systems context and this requires urgent study as cattle, goats and fish enterprises all form part of the traditional agricultural systems. Physical measures to conserve rainfall have only proven of limited benefit at the individual level. The use of tied ridges has been advocated in the valley area and although of undoubted benefit in some seasons, the incidence of high intensity short duration storms often lead to periods of waterlogging, as the

valley soils have low infiltration rates. This has necessitated, in some seasons, the breaking down of the ties in order to ensure drainage when the crops are obviously suffering from the effects of waterlogging. The labour burdens imposed by this practice have made it unpopular with farmers and other solutions need to be investigated.

Further research endeavour must be preceded by a detailed examination of the traditional systems practised by local groups. People living under such harsh environments maintain a complex and often fragile equilibrium with nature, and the consequences of change are often difficult to predict.

Even apparently small changes can have a disproportionate potential for possible negative effects. The interactions of farming enterprises are such that a single discipline approach must be avoided.

The major constraint to production in the semi-arid zone is by definition, lack of adequate moisture for full season crops. The primary objective therefore is to conserve and achieve effective utilisation of the existing rainfall. While much can be done by individuals, the problem is best tackled by planning on a catchment area basis. This will involve not only Government intervention at a national level but even inter-Governmental agreements between neighbouring states. The setting up of an international body to review and recommend the best technical solutions to catchment area conservation of both rainfall and other water sources in the area is a prerequisite to farm planning on a district basis. The research branch of the Department of Agriculture maintains close cooperation with the international institutes such as IITA, CIAT, ICRISAT and CIMMYT, and local testing of international nurseries is a major feature of the work programme. Zambia also fully participates in the Regional SADCC Agricultural Research Projects (SACCAR).

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DISCUSSION

Persaud

What are the criteria used to define the three agro-ecological zones in Zambia?

Patel

Rainfall and broad soil classification. Rainfall in terms of length of the rainy season. The semi-arid region has a rainfall of approximately 600 mm while the growing season lasts only about 110 days.

Hulugalle

What crops suffered most from water logging under tied ridging?

Patel

Mainly maize, this was experienced with the main hybrid variety of maize (SR 52) being grown.

Gonda

Have you been dealing with the intercropping system studies in Zambia, can you give us the best intercropping system?

Patel

Not yet. Results are only indicative because trials have only been conducted for the past two seasons.

Johnson

What has been your experience with Bambara groundnuts? Did you find them as a species to be more drought tolerant than other grain legumes?

Patel

Yes, especially in the Kalahari sands. They have been grown traditionally in the region since historical records are available.

Kanyenji

You stressed the need for research programmes to tie up with the traditional usage of the crop involved. How does your sorghum improvement programmes tie up with traditional utilization of sorghum in your country?

Patel

Traditionally, both sorghum and millet are used for brewing and for food. The sorghum and millet improvement keeps in mind the quality of uses for which they have to cater for.

Muleba

In your paper you were reporting rainfall ranging from 600 mm to 900 mm. I would like to know what type of drought problems you experience. Is it for distribution, late starting of rains, early cessation of rain or a combination of any two or all three of these factors?

Patel

All the three mentioned patterns have been experienced, i.e. late start of rains, poor distribution pattern of rains, early cessation of rain as well as long breaks in the rainfall patterns.

PLENARY SESSION

Summary of Discussion

The need for an integrated study of past and present issues on agricultural development in Africa as the foundation for developing a food security research agenda was emphasized. It was also pointed out that the food policy/security concepts like "Food First", "Food Self-sufficiency", "Food Self-reliance", "Food Security", should be clearly defined before undertaking any research on the food problem in Africa.

A few of the causes of Africa's agrarian crises of 1970-85 were highlighted. The main thrust was on the need for national and sub-regional food security studies, allocation of public expenditure on agriculture to develop prime movers of agricultural development (human capital, research, infrastructure, etc.), strengthening of the institutional base, research in export crop performance, keeping pricing policy of food crops in perspective in relation to technology generation, human capital improvement and strengthening agricultural institutions to achieve multiple objectives.

Three basic challenges facing food and agriculture in Africa from 1986 to the year 2000 were discussed. These include the food production-population race, the poverty-hunger and food security battle, and the rural employment imperative. It was emphasized that background issues, namely, food security concepts, project or policy level of analysis, and political sensitivity should be examined and debated before food security research priorities are spelt out at the household, village, national or regional levels. Finally, research priorities were discussed under the following main areas: Efficiency in agricultural production, Marketing, Food consumption and nutrition, Managing foreign exchange, Grain reserves and food aid; International trade and national and sub-regional policy options.

During the discussion, questions raised included the role of social scientists in food security research, the kinds of research priorities to be considered where food marketing is not well developed, priority to research in high potential areas vis-a-vis in resource poor areas, food crops vis-a-vis cash crops research, irrigation potential in semi-arid areas, study on the movement from farming systems research to resource management; relative and overlapping concepts of food security; kinds of food strategies, food security policy on the basis of comparative advantages and the farm level micro linkages in food security research.

It was commented that the role of social scientists was to collect general information, conduct consumption surveys, study the marketing margins, grain storage, cost aspects of food availability, etc. The main area in food marketing research is marketing margins of commodities. It was mentioned that high research priority should be given to high potential areas rather than poor natural resource regions. The question of

food crop vis-a-vis cash crop research should be resolved on the basis of national priorities. It was emphasized that food security policy should look at international trade opportunities and work on the principle of comparative advantage.

Other issues such as food production on the basis of comparative advantage, emphasis on food production oriented strategy rather than distribution and marketing strategies, attracted much of the participants' attention during the discussion. It was stressed that food self-sufficiency should have high priority in national development plans in African countries especially due to high uncertainty and risks experienced in international political relationships. This point is well presented in the Lagos Plan of Action of the Organization of African Unity

In addition to intensification of production in high potential areas, efforts should be continued to develop arid and semi-arid areas to increase food production to feed the growing populations in the affected countries.

It was also pointed out that food marketing systems are not well developed in most of the African countries. Food strategies should therefore emphasize the distributional aspect of food security in these countries.

Strategies for strengthening regional research cooperation were discussed, while important considerations for promoting research networks were outlined. Regarding crop productivity under drought stress, lack of adequate production of biomass in the sudan savanna and sahelian zones tends to limit the use of mulching as a water conservation alternative. It was stressed that research should provide the technological possibilities for conserving water in order to influence farmers to shift their current strategy to intensify their agricultural activities by integrating crop and animal production systems. With regard to sustaining the generation of technology at regional level, the flow of technology has been shown to be both multi-directional and reciprocal.

Livestock losses due to drought was identified as a critical constraint to crop production. For example, water shortage for animals, limits the use of animal power. It was emphasized that making large amounts of hay during good rainfall years to sustain animals could be an effective policy alternative if labour resources were not scarce for farmers. Although animal production could complement crop production both in interrelated resource cycling and economic activity providing milk, meat, animal manure, power, etc., great care must be taken regarding the negative aspect of over-grazing which increases soil run off and induces desertification and drought. As regards optimum levels and stocking rates, more monitoring research is necessary since destocking is an unaccepted strategy by government and livestock owners. Viable options for pastoralists should be made available if stocking limits are to be improved. Research carried out in Northern Nigeria, Mali, Botswana, etc., indicate difficulty of changes - since range land producers have short-term objectives. The problem of how to get an animal which has suffered from drought to recover and produce again was raised. In order to reduce

overgrazing, it is necessary to consider technological options such as minimum tillage systems requiring less power. Conducive government policies such as, reducing or alleviating taxes during drought years, could facilitate recovery and post-drought rehabilitation of livestock.

There seemed to be a general consensus by participants on the development of stable, higher yielding and drought resistant crop varieties as the avenue of greatest promise for drought conditions in Africa. The paradox, however, is that while breeding for drought resistance is an urgent issue, this novel research activity is expensive since it requires much knowledge, equipment and infrastructural facilities. Plant breeders, agronomists, etc., in different national research programmes, need to be supported to improve their research capabilities. In this regard the following roles have been identified for regional programmes:

(a) To promote research cooperation for screening of breeding materials among NARS which are working on similar objectives. Sharing of facilities common to several neighbouring countries - suitable screening sites should be supported by regional programmes to solve specific problems; the major effort being to breed for drought tolerance. Any good material that can be identified could be distributed to all cooperating countries.

(b) To facilitate the flow of germplasm and technical information. In order to minimize duplication of efforts, research should not be limited to yield trials but should also include several advanced lines to be evaluated within the national crop improvement programmes. Activities of IARCs should concentrate on germplasm distribution, accumulation and distribution of information on new elite sources, such as materials resistant to diseases, drought, insects, etc. Selected regional nurseries for specific purposes like disease evaluation, etc., should be established on a regional basis.

(c) To facilitate the realization of these objectives, multi-disciplinary research teams consisting of highly qualified scientists from different national research programmes, should be linked.

(d) To promote short and long-term training at B.Sc.; M.Sc. and Ph.D degree levels. This area is absolutely essential in upgrading the staff levels of many of the NARS for long-term improvement of research capabilities in solving food grain production problems.

(e) To promote the improvement of experiment station management through specialized workshops and training for research administrators.

After considering the weaknesses of current national research programmes, the following research gaps have been identified:

- Lack of proper characterization of the environment and clear definition of the nature of drought problems in each major growing area, including identification of relevant traits for various environments and prioritizing such traits to restructure research strategies;

- Lack of adequate facilities for direct screening and acceleration of breeding material. Effective regional cooperation is necessary among SAFGRAD member countries, particularly to utilize good sites to screen drought tolerant lines;

- The absence of research geared towards increasing the cropping period in relation to fallow land as well as research in alternate cropping systems and intercropping to minimize risk of crop failure;

- Need for more research on soil types in relation to availability of water and crop establishment problems. Orientation of agronomic research should be more problem-solving, considering different farm conditions.

- Lack of resource base for quality research (inadequate qualified researchers, funding, and poor working conditions in many national research programmes).

RECOMMENDATIONS

Policy issues.

(1) The development of national food security systems (food banks) should be encouraged, and food security should have high priority in national development plans of African countries, which tend to suffer from high uncertainties and risks experienced by environmental stress and in international political relationships.

(2) It is noted that less than ten percent of government resources are allocated to the development of agriculture in most SAFGRAD countries. It was recommended that SAFGRAD, through the OAU/STRC mechanism, should play a catalytic role in sensitizing African governments to allocate more resources to agricultural research and development.

(3) It is recommended that greater emphasis should be placed on land use control and management practices. Increased research support is needed in soil-water conservation, integration of multi-purpose trees, food crops and livestock. There should be intensified crop research and production in areas of most stable and consistent rainfall, leaving sahelian and other low rainfall zones to cattle grazing.

(4) It is recommended that an agency should be encouraged and provided with the necessary support to coordinate environmental stress analysis in sub-Saharan Africa. This would provide a regional agroclimatic data base that would be accessible to all NARS.

GROUP I. CROP PRODUCTION

Summary of Discussion

To increase drought tolerance in food grain crops in semi-arid tropics, it is important to evaluate materials at representative sites. It may be necessary, therefore, to support and develop the facilities of sites in selected NARS. Identified sites would serve for evaluating and screening materials that could be available to all participating countries.

Breeding and improvement of food grain crops should be concentrated at locations where the soil, climate and physiography have been adequately studied. In general, climatic quantification should include the frequency, duration and intensity of drought periods in relation to development of plants, in terms of hydrological balance. Adequate long-term data base needs to be assembled. A central data repository unit is necessary to provide services to different NARS.

It was suggested that local sources of germplasm such as the Guinea sorghums are well adapted to semi-arid regions. Phenotypic alteration of these types of sorghum could be exploited even though these groups of sorghum are very difficult to improve or modify through breeding. Major phenotypic alteration can also be attained by using exotic varieties that possibly carry some Guinea traits. Improvement of the indigenous research capabilities of selected national programmes could enable breeders to develop and evaluate their own hybrids. It was reported that, in general, hybrids, compared to varieties, proportionately perform better in stress, compared to non-stress situations.

Several comments were made at the symposium about hybrid seed availability for the small farmer. It was pointed out that a local seed industry could evolve once suitable hybrids are developed. For example, Hageen Dura No.1, a hybrid developed in Sudan, currently being multiplied on a large scale by local seed companies. As to cropping systems, concern was expressed about pushing maize into marginal growing conditions, the semi-arid drought prone areas. In Southern Africa, in the traditional drier areas, farmers intercrop maize hybrids and sorghum varieties in order to minimize risks of crop failure. Considering similar practices elsewhere, particularly in drought-prone regions, there is need to establish intercropping systems of combining compatible varieties and hybrids of sorghum and maize or millet.

Cooperative regional sorghum improvement in Eastern Africa has been facilitated by SAFGRAD/ICRISAT programme through regional trials and nurseries, introduction of germplasm, organization of workshops and advice to the national programmes of the region. This region was defined to include eight countries - Burundi, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania and Uganda. Thirty-two released and promising varieties were identified (5 varieties for high elevation above 1800m, 8 varieties for intermediate elevation, 1500-1800m and 19 varieties for low elevation below 1500m).

It was pointed out that more emphasis had been placed on the utilization of conventional and traditional breeding methods. However, substantial amounts of hybridization activities are currently being carried out in the region: in Ethiopia, Sudan, Uganda and Tanzania. Although the advantages of hybrid sorghum had been demonstrated in these countries, it is only the Sudan that had moved hybrid sorghum from research station to large-scale seed and grain production. The percentages of grain yield increase of hybrids over varieties was reported to be higher under stress, indicating the superiority of hybrids in yield and stability across environments.

Discussion during the symposium showed that there was apparent tendency for national research programmes to develop their own hybridization programmes. It was pointed out that hybrids were only useful if growing conditions are good and require higher inputs such as fertilizer. Although the full yield potential of hybrids may need high inputs, the differences in yield between variety and hybrids become greater as growing conditions become harsher. The spin-off advantage of hybrids is that it would pave the way for a local seed industry to evolve. It was stressed that it was not productive to argue the variety VS hybrids issue in the abstract, but to develop good adapted hybrids and varieties and determine their value in a range of climatic situations.

Recommendations

Improvement of crop production under drought conditions without the modification of the environment is one of the most difficult tasks in scientific research. Solutions should come from multidisciplinary approaches to the problems of crop improvement.

Three major components involved are :

- Research for crop improvement.
- Conditions and facilities to undertake research.
- Education and training to strengthen appropriate manpower needs.

(1) It is recommended that existing knowledge should be used to identify research and management priorities focusing on issues relevant to specific drought prone situations. This symposium revealed that a significant amount of new knowledge has been generated in recent years and this knowledge can be used to improve crop production research in dry regions. Such research should continuously be done and supported.

(2) It is recognised that, although a certain amount of crop production technology has been developed, much more is required, considering the complexity and severity of the problems of production under drought stress. There is need to strengthen and

develop national programme research capabilities to tackle this important area. This should be done by various means, such as:

(a) strengthening collaborative research among national programmes, regional and international agencies.

(b) Identification of research areas that can be described as attracting donor support. Such areas include -

- plant breeding for dry areas.
- Basic research in the physiology of crops in dry areas.
- Research in the development of breeding methods for crops grown in dry areas.
- Capitalisation on an expansion of germplasm resources.
- Identification of the most appropriate locations to undertake research on drought resistance.
- Improvement of communications between scientists.
- Recognition of the importance of research in the area of post-harvest technology to minimize substantial crop losses.

In view of these tasks, expertise is needed in identifying needed facilities, the working environment and experiment station management in order to achieve quality research results. It is recommended that these needs should be quantified for donor support.

(3) The individual scientist has a key role to play to achieve these objectives. It is recommended that scientists be supported by:

(a) Identifying the appropriate manpower needed.
(b) Providing support through education and training.
(c) Providing encouragement by adequate personal compensation based on creativity.
(d) Improving living and research conditions.
(e) Providing adequate opportunities for interaction with other scientists.

The transfer of new technology to the farmer, depends on supportive government policies including market opportunities.

In order to strengthen cooperation among countries, a policy should be developed to facilitate movement of scientists, germplasm and breeding stocks throughout the African continent.

GROUP II. SOIL-WATER MANAGEMENT

Summary of Discussion

The African continent, although endowed with immense natural resources, has faced serious food crises since the last two decades. The continuous decline in per capita food production has been attributed variously to the drought, rapid population growth and degradation of the resource base for productive agriculture. Although these factors may have exacerbated the food crisis, the root of the problem lies in the neglect of the environment in general and improvement of soil fertility, conservation and water management in particular. Soil degradation has consequently become a major constraint to food production in semi-arid sub-Saharan Africa. Technology and methodology for improved soil fertility, conservation and water management are therefore urgently needed. In addition, development of an integrated production system which recycles resources and consequently conserves and optimizes available soil resources was suggested.

The drought that destabilized food grain production in many countries of Africa is not unique to the region. Although the droughts of the 1960s and 1970s of the Sahel received world-wide attention, more than 20 droughts have occurred since the 16th century in the same region. Previous patterns of climate seem to suggest that droughts occur in one or more regions of Africa every year. Two or more droughts affect large areas of the continent every decade while extremely protracted and widespread droughts occur about three times in a century, although the precise geographical area of incidence is not predictable. In general, the erratic pattern of rainfall distribution, as well as poor soil management techniques to conserve moisture, have also contributed to poor food grain production.

Initially, discussion centred around the need for rainfall record analysis in relation to crop production. With regard to utilizing long-term rainfall data, predicting the occurrence of "dry spell bands" within five to ten-day intervals, during the growing season, was proposed since such information could help farmers to decide on crop production activities and maximize the use of available moisture. The importance of water use efficiency through manipulating tillage practices, crop and other cultural practices, particularly in the semi-arid regions, was emphasized. It was also pointed out that water and soil conservation techniques could not be universal and need to be modified according to soil type, amount and pattern of rainfall. It was stressed that the problem of soil fertility constitutes a significant impediment to increased food production. Restoring the soil fertility poses important challenges for research and policy on resource management. Insufficient quantities of nitrogen and phosphorus also limit the production of semi-arid food grains.

A research study on characterization of soil Phosphorus (P) status, crop P resources, P removal and balance in different cropping systems, residual P effects, efficient use and effectiveness of different P sources (with particular emphasis on local phosphatic rocks, role of mychorryza, genotype and P level interactions, drought stress and P level interactions) need to be emphasized.

Similarly, research investigations on the characterization of soil Nitrogen (N) status, crop N responses, N removal and balance in different cropping systems, residual N effects, efficient use and effectiveness of different N sources, role of leaching and volatilization losses on the N balance, genotype x N level interactions, drought stress x N level and timing of application interactions need to be studied.

Different parameters of soil fertility in relation to drought were discussed. Low inherent fertility of soils in semi-arid tropics is partially due to total removal of crop residues for its competing uses as fuel, construction, livestock feed, burning, etc. It was pointed out that certain soils particularly those common in the semi-arid tropics (such as alfisols) are low in organic matter in general, and nitrogen, phosphorus in particular. In addition to incorporation of organic residue and developing appropriate cropping systems, the need for integrating livestock for traction, fuel and food, was emphasized.

It has been noted that the major option to sustain food production particularly in densely populated regions of the semi-arid tropics is the intensification of agricultural production of which livestock manure and other organic residue application is known to improve the physical and physio-chemical effect of soils in addition to the provision of nutrients

Recommendations

(1) Several tillage practices suitable to dryland agriculture are available and many of the techniques (ploughing, tied-ridges, etc.) have been successfully tested. It is recommended that energy efficient and conservative tillage systems, which improve soil structure, reduce weed growth, labour and fertilizer inputs, should be studied at the village level with appropriately designed on-farm trials.

(2) Attention must be given to soil fertility research and management, more particularly in relation to:

- harmonization of methodologies for soil fertility evaluation;
- basic chemistry of soils and their reactions to the addition of various fertilizers;
- problems of minor element toxicity and soil salinity; and
- crop residue and manure management research; priority should also be given to the development of local fertilizer resources and more particularly, to rock phosphate.

(3) Water is the most important constraint to crop production in the semi-arid zones of Africa. Conservation and efficient use of water are consequently critical to the development of a rational agricultural resource management system. Management systems which minimize runoff and erosion, and maximize water infiltration into the soil profile, should be given high priority. Research aimed at increasing the efficiency of rainwater utilization needs to be continued as well as that on the hydrology of surface and ground water. Rainfall pattern of several years should be examined carefully in semi-arid regions of Africa in relation to crop production.

(4) There is a need to intensify research on rural landscape management (anti-erosive control, water conservation) by considering traditional techniques and integrating agroforestry methods. Several ways and means have been suggested to minimize the evapotranspiration losses such as the removal of ineffective tillers, use of mulch, tillage practices, etc.

(5) Regional cooperative research could help to optimize human and natural resource utilization by linking more closely national, regional and international agricultural research and training institutions. Intellectual interchange among resource management researchers in their respective fields stimulates new ideas and creative solutions to difficult and complex problems and avoids pitfalls. Networking can enhance professional development by facilitating contacts among junior scientists and senior professionals. It can also promote a continuous flow of technical information and enhance the dissemination and adoption of research results. The management of soil and water in relation to food grain production would be the thrust of the suggested network activities.

It is recommended that SAFGRAD should facilitate the realization of such networks in order to enhance the application of soil and water management techniques among participating member countries.

GROUP III. FARMING SYSTEMS RESEARCH

Summary of Discussions

Fourteen papers on different aspects of farming systems research, FSR, were presented during the third and fourth days of the symposium. All except one of the papers dealt with different national approaches to farming systems research or aspects of FSR at the national level, and how FSR might be an appropriate research strategy to tackle the agricultural research problems associated with drier or drought-prone areas.

Participants generally agreed that the farming systems research approach was relevant and effective in drought-prone areas. It was suggested that in these high risk areas, fragile environments composed largely of subsistence agriculture, were very important to take note of the farmer's requirements and goals. Thus, it is important to emphasize the human elements, as occurs in the diagnostic and adaptive phases of FSR. Some of the lessons and results from FSR in the higher rainfall potential areas may be relevant in the drier areas. Participants felt that FSR in the drought-prone areas need to address the issue of management of the hazards associated with drought. There is a need to improve the farmer's options or numbers of options, while not leaving him open to higher risks. Management of risk in these areas is an important research topic.

Considerable discussion centred around how much emphasis should be given to FSR and commodity research. This issue was relevant because of the limited availability of funds, the general long-term nature of FSR, and the amount of manpower needed for it. Currently in East and Southern Africa, it was estimated that only 5% of the research manpower was involved in FSR. It was felt that 15 to 20% was probably a better partitioning (particularly if this meant 15 to 20% of each researcher's portfolio). Some participants suggested that separate FSR programmes could not only tax for more resources, but could also surface competition with other departments and this could impede the development of appropriate FSR. Rather, FSR could involve conventional researchers themselves, leading to integrated research and production systems in due course.

It appears that the requirements to undertake FSR may have been underestimated. The establishment of an FSR approach from scratch may mean the training of personnel at Masters and Doctoral degree levels. With the long learning curve of the FSR approach, it may take some countries up to 10 years to arrive at the stage of implementing such an approach.

Participants stressed that choosing the balance between the emphasis to be placed on diagnostic and adaptive research compared to commodity research, was something that could not be generalised for the drought prone regions. Some countries have a history of commodity research, the results of which have not been adopted by the farmer. In such countries, on-farm surveys and adaptive research are priorities. In other countries, the extent of commodity research is limited, and will need to be given priority, to generate technologies in response to farmers' needs and constraints.

Furthermore, it was stressed that livestock production is an important option and part of farming systems in drought-prone areas. It has high potentials for improving the productivity and the resource base of farming systems in these areas. Unfortunately, farming systems research effort has been mostly on cropping. There is a need to equally emphasize both cropping and livestock production systems in order to ensure complimentarity of resource cycling to sustain food production in the drought-prone areas.

It has also been recognized that intercropping systems, as practised by farmers, may be an efficient way of improving production and of better exploiting time, rainfall and other resources. Intercropping systems have a very important role to play in better management strategies for higher and more stable agricultural production in the drought prone-areas.

Finally, on the basis of experiences from semi-arid areas of many countries, the need to develop technologies which are sustainable under low resource management by farmers was stressed. A special accent, however, needs to be placed on the development of proper soil-water management and soil fertility improvement techniques. Tied ridging has been demonstrated as a promising soil-water management technique in drought prone-areas.

Recommendations

(1) The farming systems approach to agricultural research is recommended for developing relevant and sustainable food production systems in drought-prone areas, particularly in view of the complex risk-avoidance strategies that may exist and the special need for preventing further environmental degradation.

(2) More emphasis should be placed on research to understand the farmer's approach to risk management in the drier areas and the adjustment mechanisms used when drought occurs. Such farmers' mechanisms and technical solutions should be used as a point of departure for developing technologies to cope with drought.

(3) As drought may result in a degradation of the environment and losses in the resource base, it is recommended that research efforts place emphasis on conservation of the resource base, particularly soil and water conservation. Research should emphasize the development of systems sustainable in the long term.

(4) The crop/livestock interface and agroforestry are important components of farming systems in drought-prone areas which can play an important role in preventing environmental degradation, improving soil-water retention and increasing crop productivity. These topics are of special relevance to drought-prone areas and may hold considerable potential benefits for such areas. Ways need to be sought to better exploit the potential linkages between crops, livestock and agroforestry.

(5) Greater attention should be paid to aspects other than that of production. These aspects include the farmer's socio-economic constraints, marketing, storage, etc. Although a lot of programmes claim to have an FSR approach to research, many do not address important issues such as the decision-making strategy of the farmers. Studying such issues will lead to a better understanding of why farmers do not adopt apparently "good" technologies. These studies will also pinpoint policy and institutional requirements needed for the adoption of some critical technologies.

(6) All agricultural researchers must see themselves as part of the farming systems approach to research, particularly where the clientele, the farmer, is the same. By adopting the farming systems approach to research on the problems of food production as part of each researcher's portfolio, the apparent conflict and competition between commodity researchers and the on-farm researchers will be reduced. One method of moving towards this goal would be to avoid separating "farming systems research" from the other disciplines, conferences and meetings, but rather to have multi-disciplinary sessions.

(7) There is need to improve capabilities for the transfer of appropriate FSR methodology and technologies in the drought-prone areas of sub-Saharan Africa. It is believed that a symposium such as this one on drought will continue to be a very important process in this transfer. FSR training, workshops

such as those conducted by the University of Zimbabwe, are recommended (for commodity researchers as well as FSR specialists) and should also be developed for the francophone areas of sub-Saharan Africa.

8. FSR is, by nature, comprehensive, and this involves a long-term approach to the problems of realizing sustainable food production systems. With the harshness and variability of the environment of drought-prone areas in the semi-arid regions of sub-Saharan Africa, caution should be taken in the holding of expectations that envisage a "quick-fix", using FSR.

LIST OF PARTICIPANTS

1. Mesfin ABEBE
Assoc. Prof. of Soil Science
Debre Zeit Research Centre
P.O.Box 32
Debre Zeit
ETHIOPIA.

2. Akinola A. AGBOOLA
Soil Scientist
Department of Agronomy
University of Ibadan
IBADAN
NIGERIA.

3. Vas Dev. AGGARWAL
Cowpea Breeder
IITA/SAFGRAD
B.P. 1495
OUAGADOUGOU
BURKINA FASO.

4. Levi AKUNDABWENI
Cowpea Breeder
IITA
P.M.B. 5320
IBADAN
NIGERIA.

5. Gatachew ALEM
Research Officer
Institute of Agricultural Research
P.O. Box 2003
ADDIS ABABA
ETHIOPIA.

6. Richard A. AMABLE
Agronomist
IITA/Tanzania Project
Sokoine University
P.O. Box 3116
MOROGORO
TANZANIA.

7. Kwesi AMPONG-NYARKO
Agronomist
Crops Research Institute
P.O. Box 3785
KUMASI
GHANA.

8. Frank ANDERSON
Agricultural Economist
ILCA
P.O. Box 5689
ADDIS ABABA
ETHIOPIA.

9. Roberto ARIAS
CIMMYT Joint Coordinator
Ghana Grains Development Project
P.O. Box 1639
ACCRA
GHANA.

10. Andre BATIONO
Soil Scientist
International Fertilizer Development Centre
ICRISAT
B.P. 12404
NIAMEY
NIGER.

11. Taye BEZUNEH
Director of Research
SAFGRAD Coordination Office
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

12. Francis BIDINGER
Crop Physiologist
ICRISAT
Patancheru P.O. 502 324 AP
INDIA

13. Abraham BLUM
Agronomist
The Volcani Centre
Agricultural Research Organization
P.O. Box 6
BET DAGAN
ISRAEL.

14. A.E.O. CHABEDA
Chief Research Officer
Ministry of Agriculture
P.O. Box 30028
NAIROBI
KENYA.

15. Sansan DA
Sorghum Breeder
INERA
Farako Ba Station
B.P. 910
BOBO DIOULASSO
BURKINA FASO.

16. Seme DEBELA
General Manager
Institute of Agricultural Research
P.O. Box 2003
ADDIS ABABA
ETHIOPIA.

17. Alpha Oumar DIALLO
Maize Breeder
IITA/SAFGRAD
B.P. 1495
OUAGADOUGOU
BURKINA FASO.

18. Mamadou DIARRA
Director General
CNRADA
B.P. 22
KAEDI
MAURITANIA.

19. G.O. EDMEADES
Agronomist/Physiologist
CIMMYT
Londres 40
Apdo Postal 6-641
06600 MEXICO D.F.

20. Y. EFRON
Maize Breeder
CIMMYT/IITA
P.O. Box 5320
IBADAN
NIGERIA.

21. Carl EICHER
Agricultural Economist
Land Management Department
University of Zimbabwe
P.O. Box 167
Mount Pleasant
HARARE
ZIMBABWE.

22. Gebisa EJETA
Sorghum Breeder
Department of Agronomy
Purdue University
West Lafayette
IN 47906
U.S.A.

23. H. Johannes ENSERINK
Agronomist
63 Mauritshade
1092 AD AMSTERDAM
THE NETHERLANDS.

24. Peter ESELE
Research Officer
U.A.F.R.O.
Sorghum & Millets Unit
Serere Research Station
P.O. SOROTI
UGANDA.

25. L.K. FUSSEL
Agronomist
ICRISAT Sahelian Centre
B.P. 12404
NIAMEY
NIGER.

26. Brhane GEBREKIDAN
Maize Breeder
CIMMYT
Londres 40,
Apdo Postal 6-641
06600 MEXICO, D.F.
MEXICO.

27. B. GELAW
Maize Breeder
CIMMYT
P.O. Box 25171
NAIROBI
KENYA.

28. Jada GONDA
Millet Breeder
CNRA/TARNA/NARAJI
B.P. 240
MARADI
NIGER.

29. Vartan GUIRAGOSSIAN
Sorghum Breeder and Genetisist
OAU/SAFGRAD Regional Offfice
P.O. Box 30786
NAIROBI
KENYA.

30. A.E. HALL
Dept. of Botany and Plant Sciences
University of California
Riverside
CALIFORNIA 92521
U.S.A.

31. K.L. HAULE
Research Coordinator
Agric. Research Institute
MLINGANO
Private Bag NGOMENI
TANGA
TANZANIA.

32. G. HEINRICH
Agronomist
P.O. Box 10275
FRANCISTOWN
BOTSWANA.

33. Leyland R. HOUSE
Project Manager
SADCC/ICRISAT Sorghum/Millet Improv. Prog.
ICRISAT
P.O. Box 776
BULAWAYO
ZIMBABWE.

34. N. HULUGALLE
Soil Scientist
IITA/SAFGRAD
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

35. Jerry JOHNSON
SAFGRAD/ACPO
B.P. 146
MAROUA
CAMEROON.

36. R.K. JONES
Agronomist
ACIAR/CSIRO Dryland Project
P.O. Box 41567
NAIROBI
KENYA.

37. B.M. KANYENJI
Plant Breeder
NDFRS Katumani
P.O. Box 340
MACHAKOS
KENYA.

38. R.N. KAUL
Agricultural Engineer
Institute for Agric. Research
P.M.B. 1044
ZARIA
NIGERIA.

39. Yilma KEBEDE
Research Officer
Institute of Agric. Research
P.O. Box 103
NAZRET
ETHIOPIA.

40. J.M. KINAMA
Soil & Water Management Research Officer
P.O. Box 340
Katumani
MACHAKOS
KENYA.

41. Roger A. KIRKBY
Senior Programme Officer
Crops & Cropping Systems
I.D.R.C.
P.O. Box 62084
NAIROBI
KENYA.

42. S.K. KITHEKA
Agro-Meteorologist
N.D.F.R.S. Katumani
P.O. Box 340
MACHAKOS
KENYA.

43. J.F. KOAMPAH
Agronomist
P.O. Box 4000
KUMASI
GHANA.

44. Bernard KOUNDIANO
Agronomist
Ministry of Rural Development
B.P. 576
CONAKRY
REP. OF GUINEA.

45. Ono LELEJI
Plant Breeder
Department of Plant Science
IAR/ABU
P.O. Box 1044
ZARIA
NIGERIA.

46. K.O. MARFO
Food Legume Breeder
P.O. Box 52
NYANKPALA/TAMALE
GHANA.

47. A.M. M'ARIMI
Agronomist
Tana & Athi Development Authority
P.O. Box 47309
NAIROBI
KENYA.

48. J.K. MAVUA
Research Officer (Agric. Econ.)
NDFRS - Katumani
P.O. Box 340
MACHAKOS
KENYA.

49. L.M. MAZHANI
Senior Agric. Research Officer
Department of Agric. Research
Private Bag 0033
GABORONE
BOTSWANA.

50. Mulugetta MEKURIA
Research Officer
Institute of Agricultural Research
P.O. Box 2003
ADDIS ABABA
ETHIOPIA.

51. Joseph M. MENYONGA
International Coordinator
SAFGRAD Coordination Office
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

52. A. MFUTAKAMBA
Water Resources Engineer
P.O. Box 2271
Stanford
CALIFORNIA
U.S.A.

53. M. MITAWA
Principal Scientific Officer
TARO-Ilonga
P.O. ILONGA-KILOSA
TANZANIA.

54. E. MODIAKGOTLA
Agronomist
P.O. Box 10
MAHALAPYE
BOTSWANA.

55. Riungu M'RAGWA
Plant Breeder
NDFRS - Katumani
P.O. Box 340
MACHAKOS
KENYA.

56. F.N. MUCHENA
Soil Scientist
Kenya Soil Survey
P.O.Box 14733
NAIROBI
KENYA.

57. Watson MWALE
Maize Breeder
Private Bag 7
CHILANGA
ZAMBIA.

58. Stephen I.N. MUGO
Plant Breeder
NDFRS Katumani
P.O. Box 340
MACHAKOS
KENYA.

59. Lutta MUHAMMAD
Agricultural Economist
NDFRS Katumani
P.O. Box 340
MACHAKOS
KENYA.

60. Nyanguila MULEBA
Cowpea Agronomist
IITA/SAFGRAD
B.P. 1495
OUAGADOUGOU
BURKINA FASO.

61. D.K. MUTHOKA
Maize Breeder
P.O. Box 450
KITALE
KENYA.

62. Bruno J. NDUNGURU
Agronomist
SAFGRAD/FSR/BENIN
B.P. 3 - NDALI
R.P. BENIN

63. D.S. NGAMBEKI
Agricultural Economist
SAFGRAD/FSR/CAMEROON
IRA-NORD
B.P. 415 GAROUA
CAMEROON.

64. E.L.N. NGATUNGA
Soil Scientist
National Soil Service Project
P.O. Box 5088
TANGA
TANZANIA.

65. D.N. NGUGI
Agronomist
ICRAF
P.O. Box 30677
NAIROBI
KENYA.

66. E.C.K. NGUGI
Plant Breeder
NDFRS Katumani
P.O. Box 340
MACHAKOS
KENYA.

67. O. NIANGADO
Millet Breeder
B.P. 438
BAMAKO
MALI.

68. Robert NICOU
Agronomist
IRAT-CIRAD
B.P. 596
OUAGADOUGOU
BURKINA FASO.

69. Curtis R. NISSLY
Research Agronomist
USAID Kenya Mission
P.O. Box 30261
NAIROBI
KENYA.

70. Njoroge KIARIE
Maize Breeder
NDFRS Katumani
P.O. Box 340
MACHAKOS
KENYA.

71. B. NTARE
Agronomist
ICRISAT Sahelian Centre
B.P. 12404
NIAMEY
NIGER.

72. C. NWASIKE
Plant Breeder
IAR/ABU
P.M.B. 1044
ZARIA
NIGERIA.

73. A.P. OCKWELL
Agric. Economist
ACIAR/CSIRO
P.O. Box 41567
NAIROBI
KENYA.

74. C.E. OHIAGU
Entomologist
IAR/ABU
P.M.B. 1044
ZARIA
NIGERIA.

75. A.G.O. OKECH
Senior Research Officer
Ministry of Agric. & Livestock Development
Scientific Research Division
P.O. Box 30028
NAIROBI
KENYA.

76. A.D. OLANG
Agronomist
National Agricultural Research Station
P.O. Box 450
KITALE
KENYA.

77. W. OLUOCH-KOSURA
University of Nairobi
Dept. of Agric. Economics
P.O. Box 29053
NAIROBI
KENYA.

78. Joseph O.E. ORYOKOT
Agronomist
Sorghum and Millets Unit
UAFRO Serere Research Station
P.O. SOROTI
UGANDA.

79. Paul Abuto OMANGA
Plant Breeder
NDFRS Katumani
P.O. Box 340
MACHAKOS
KENYA.

80. A.F.E. PALMER
Agronomist
CIMMYT
P.O. Box 25171
NAIROBI
KENYA.

81. Bharati PATEL
Chief Agric. Research Officer
Mt.Makulu Research Station
P/Bag 7
CHILANGA
ZAMBIA.

82. J.M. PEACOCK
Cereal Crop Physiologist
ICRISAT Patancheru P.O.
Andhra Pradesh 502 324
INDIA.

83. Eugene R. PERRIER
Soil/Water Agronomist
ICARDA
P.O. Box 5466
ALEPPO
SYRIA.

84. Naraine PERSAUD
Soil Physicist
Dept. Soil and Crop Sciences
Texas A and M University
College Station
Texas 77843-2474
U.S.A.

85. Yves Coffi PRUDENCIO
Agricultural Economist
SAFGRAD/FSR/BURKINA
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

86. Joel K. RANSOM
Maize Agronomist
CIMMYT
P.O. Box 25171
NAIROBI
KENYA.

87. M. RODRIGUEZ
Maize Agronomist
IITA/SAFGRAD
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

88. Darrell T. ROSENOW
Sorghum Breeder
Texas Agricultural Experiment Station
Route 3, Box 219
Lubbock
TEXAS, 79401-9757
U.S.A.

89. J.M. ROOK
Economist
F.A.O. Food Strategy Project
P.O. Box 2
DAR-ES-SALAAM
TANZANIA.

90. G.T. RUNYORO
Agricultural Economist
Ministry of Agriculture & Livestock Dev.
P.O. Box 9192
DAR-ES-SALAAM
TANZANIA.

91. J.K. RUTTO
Senior Research Officer
Western Agric. Research Station
P.O. Box 169
KAKAMEGA
KENYA.

92. Sibiri SAWADOGO
Agro-Economist
INERA
B.P. 7192
OUAGADOUGOU
BURKINA FASO.

93. Boukar SEINY
Soil Scientist
IRA
B.P. 33
MAROUA
CAMEROON.

94. A. SHAKOOR
Plant Breeder
NDFRS - Katumani
P.O. Box 340
MACHAKOS
KENYA.

95. F.M. SHAO
Chief Research Officer & Plant Pathologist
Ministry of Agric. & Livestock Dev.
P.O. Box 9071
DAR-ES-SALAAM
TANZANIA.

96. K.L. SHARMA
Agric. Economist
Economics Department
University of Nairobi
P.O. Box 30197
NAIROBI
KENYA

97. Bir Bahadur SINGH
Grain Legume Breeder
IITA
P.M.B. 5320
IBADAN
NIGERIA.

98. Johal R. SINGH
Agricultural Officer
c/o Ministry of Agric. & Livestock Dev.
P.O. Box 30028
NAIROBI
KENYA.

99. L. SINGH
Soil Scientist
SAFGRAD/FSR/CAMEROON
B.P. 415
GAROUA
CAMEROON.

100. Leopold SOME
Researcher
INERA
B.P. 7192
OUAGADOUGOU
BURKINA FASO.

101. Mamadou SONKO
Soil Scientist
Institute Senegalais de
Recherches Agricoles (ISRA)
B.P. 3120
DAKAR
SENEGAL

102. Lamine TRAORE
SAFGRAD/ACPO
B.P. 2614
BAMAKO
MALI.

103. Stephen D. TURNER
Soil Scientist
Bureau Buitenland
Vrije Universitet
P.O. Box 7161
1007 MS AMSTERDAM
NETHERLANDS.

104. Anthony YOUDEOWEI
Entomologist/Publishing Editor
University of Ibadan
IBADAN
NIGERIA.

105. Corradom ZANCOCCHIA
Agric. Economist
FAI - Vialle Pilsuskly, 124
ROME 00197
ITALY.

SECRETARIAT

106. E. ADANLETE
Accountant
SAFGRAD Coordination Office
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

107. Mary Ann BRIGGS
Administrative Assistant
SAFGRAD Coordination Office
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

108. Yvonne MAGASSOUBA
Bilingual Secretary
SAFGRAD Coordination Office
B.P.1783
OUAGADOUGOU
BURKINA FASO.

109. Denis E. OUEDRAOGO
Information & Documentation Officer
SAFGRAD Coordination Office
B.P.1783
OUAGADOUGOU
BURKINA FASO.

110. Boniface SANOU
Translator
SAFGRAD Coordination Office
B.P. 1783
OUAGADOUGOU
BURKINA FASO.

111. Mildred D. TETTEY
OUA/IBAR
NAIROBI
KENYA.

ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research.
ACPO	Accelerated Crop Production Officer.
CERCI	Centre d'Expérimentation de Riz et des Cultures Irriguées (Burkina Faso).
CIDA	Canadian International Development Agency.
CILSS	Comité Inter-Etats de Lutte Contre la Sécheresse au Sahel.
CIMMYT	Centro Internacional de Mejoramiente de Maiz y Trigo (International Maize and Wheat Improvement Centre).
CIRAD	Centre International de Recherche Agricole et de développement(France).
CNRADA	Centre National de Recherche Agronomique et de Développement Agricole (Mauritania).
CSIRO	Commonwealth Scientific and Industrial Research Organization.
ECA	Economic Commission for Africa.
FAC	Fonds d'Aide et de Coopération.
FAO	Food and Agriculture Organization of the United Nations.
FSR	Farming Systems Research.
GDP	Gross Domestic Product.
GNP	Gross National Product.
IAR	Institue for Agricultural Research, Samaru (Nigeria).
IBAR	Inter-African Bureau for Animal Resources.
ICRAF	International Council for Research in Agroforestry.
ICARDA	International Centre for Agricultural Research in the Dry Areas.
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics.
IDRC	International Development Research Centre.
IFAD	International Fund for Agricultural Development.
IITA	International Institute of Tropical Agriculture.

ILCA	International Livestock Centre for Africa.
INERA	Institut d'Etudes et de Recherches Agricoles (Burkina Faso).
INRAN	Institut National de Recherches Agronomiques du Niger.
INSAH	Institut du Sahel.
INTSORMIL/CRSP	International Sorghum and Millet/Collaborative Research Support Programme (USAID).
IRA	Institut de la Recherche Agronomique (Institute of Agricultural Research), Cameroon.
IRAT	Institut de Recherches Agronomiques Tropicales (France).
IRRI	International Rice Research Institute.
IUFRO	International Union of Forestry Research Organizations.
NGO	Non-Governmental Organization.
OAU	Organization of African Unity.
SACCAR	Southern African Centre for Cooperation in Agricultural Research.
SADCC	South Africa Development Coordination Conference.
SAFGRAD	Semi-Arid Food Grain Research and Development.
SAREC	Swedish Agency for Research Cooperation with Developing Countries.
STRC	Scientific, Technical and Research Commission of the OAU.
TALIRO	Tanzania Livestock Research Organization.
TARO	Tanzania Agricultural Research Organization.
TPRI	Tanzania Pesticides Research Institute.
UNDP	United Nations Development Programme.

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MENYONGA, Joseph M.

AU-SAFGRAD