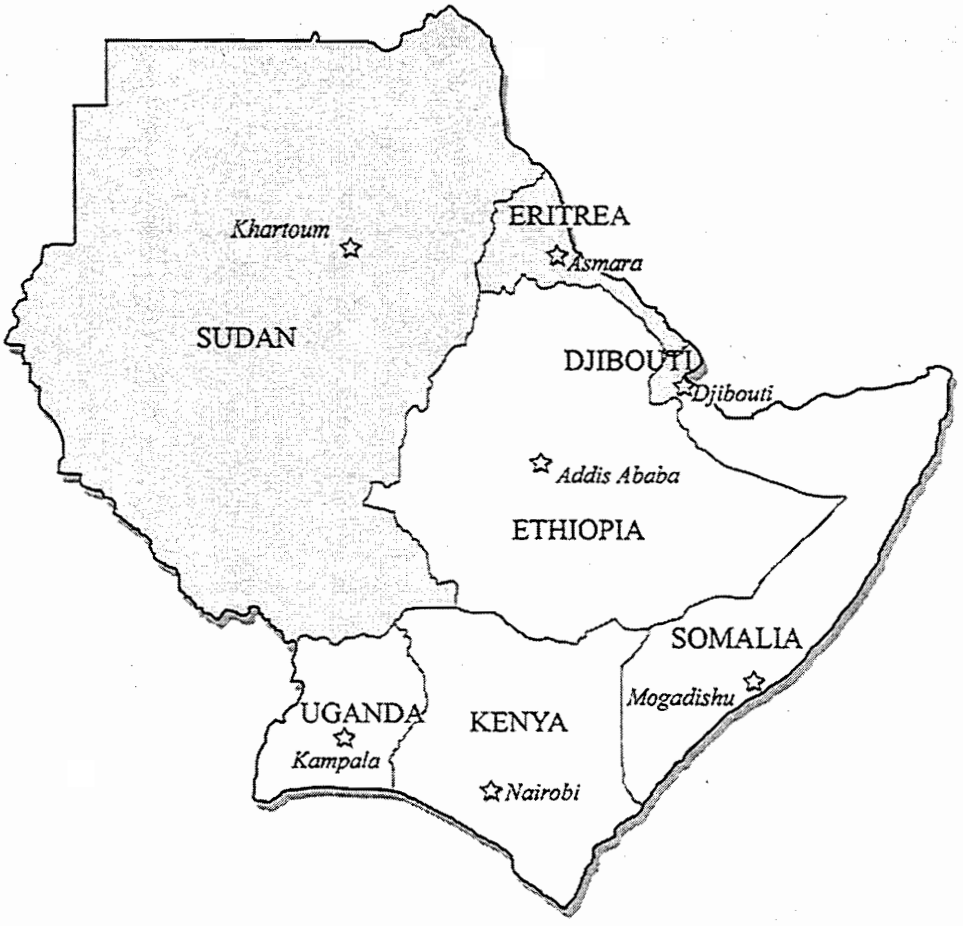
# Agricultural Technology for the Semiarid African Horn




# Vol. 3: Country Studies Djibouti, Eritrea, Sudan

## IGAD/INTSORMIL/USAID-REDSO

**February 2001**

The above three are the contracting agencies. This report does not imply approval or endorsement by any of them.

## IGAD (the Inter-Governmental Authority for Development)

IGAD (the Inter-Governmental Authority for Development) was created in 1986 in response to the recurrent severe droughts in the Horn of Africa. The Organization was then named The Intergovernmental Authority of Drought and Development (IGADD). Food Security and Environmental Protection were high on the regional agenda and in 1990 two regional strategy documents, one on environment and the other on food security, were developed. These regional strategies stressed the development of the region's Arid and Semiarid Lands (ASALs) which constitute more than half of the land area and are home for 20 million people, 13% of the population. The need for better inter and intra-regional networking for agricultural research was identified as a critical constraint in the food security strategy. This recommendation laid the groundwork for the creation of ASARECA in 1994 as a regional coordinating body for the commodity-based research networks of the region.

In 1996 the seven member states of IGAD (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan and Uganda) resolved to increase the level of their cooperation and expand the mandate of the Organization to include, the political and economic cooperation issues. With this new mandate came a list of 17 priority projects for the revitalized IGAD. A key to the success of this strategy has been the IGAD Secretariat's agreement to limit its role to intra-regional coordination and facilitation. The implementation of the 17 follow-on projects has been entrusted to one or more centers of excellence in the member states with technical support from one or more international centers. These projects, as earlier projects, are focused on sustainable development of the arid and semiarid lands.

The three volumes in this series are the output of one of the 17 follow-on projects. The three volume series from this project attempted to review the constraints and opportunities confronting the diffusion of new higher yielding crop technologies into the semiarid areas of the IGAD mandate area in the Horn. The first volume is a synthesis report and the following two each include three of the country reports

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# Agricultural Technology for the

# Semiarid African Horn


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**INTSORMIL**
**Grain Sorghum/Pearl Millet Collaborative Research Support Program**

**USAID/REDSO/ESA/AGR**
**U.S. Agency for International Development**
**Regional Economic Development Services Office for East and Southern Africa**



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# Prologue

The Inter-Governmental Authority on Development (IGAD) includes seven countries of the Horn of Africa, Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan, and Uganda. The fieldwork reported in this volume is part of an IGAD project to identify drought resistant crop varieties for the semiarid zones of the Horn countries. INTSORMIL has been developing new sorghum and millet cultivars and associated technologies in Africa with collaborative research for over two decades. So INTSORMIL submitted a proposal to undertake this study in the spring of 1999. Fieldwork commenced in November 1999.

In the first phase of this project, IGAD requested a diagnostic study to include all crop technologies for the semiarid zones. IGAD defined the objectives for country analysis as: describing the cropping systems; identifying technology successes, potential successes, and constraints; analyzing the adequacy of the national, regional, and international research systems; evaluating the extension systems especially the linkages with farmers and researchers; examining seed supply and crop marketing issues; identifying the role of women with regard to the present farming system and new technology introduction; and reviewing agricultural policies.

So the first phase of this research project is a broad diagnostic study focusing on the agricultural technologies that has been successfully introduced into the Horn of Africa and the steps necessary to rapidly introduce new crop technologies in the future. As requested, there is a strong emphasis on lessons learned and what needs to be done.

The three volume series is directed to those concerned with research policy directions and with the diffusion of new technologies. The study is expected to be of interest to donors, policymakers, research administrators, researchers and those involved with moving technology onto the farm.

The study was funded from the REDSO/ESA office of USAID in Nairobi, directed by IGAD, and implemented by INTSORMIL from Lincoln, Nebraska. A core team of five professionals was contracted by INTSORMIL with IGAD concurrence. The team was composed of an economist, a maize breeder, a pathologist, a dryland agronomist, and an anthropologist. IGAD contracted two national scientists in each of the countries except for Somalia. One was contracted to review research and one for extension in each country.

This Volume 3 is the third of three Volumes in the INTSORMIL series on the identification of potential technologies for semiarid areas in the Horn countries and includes the three country studies of Eritrea, Sudan, and Djibouti.

The country studies are based upon field visits and interviews by both a core team and national consultants. These country studies also include a bibliography of the relevant literature acquired in the field and in Washington, D.C. People interviewed are indicated at the end of each country report. The core team was multi-disciplinary and multi-nationality. Individual authorship is assigned to each country report. Reports by national consultants are cited in the references and are available from the authors. Further background details on the specific objectives of the study and the names of all the personnel on the core team and the national consultants are available in Volume 1.

The core team and the national consultants are grateful for the information provided by public officials, the private sector in general, and farmers of the semiarid regions in particular. This voluntary and enthusiastic participation of people in the region made this report possible. Expert editing and word processing assistance were provided by Mary Rice, Joan Frederick, Dottie Stoner, and Kimberly Jones.

# Djibouti

## Wadis and Herders in an Arid Land

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# Acknowledgments

**We are grateful for the substantial inputs of the national consultants Djamu Mahmoud Guelleh and Nabil Mohamed Ahmed and of others who provided substantial time and effort to orient and instruct us (see Interviews). Thomas Crawford provided substantial inputs on the editing and some of the conceptualization issues. Errors of omission or interpretation are our responsibility.**

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# Table

## Acronyms

| | |
|---|---|
| CNE | Comite National pour l'Environnement |
| DINAS | Direction Nationale de la Statistique |
| DJI | Djibouti |
| EIUD | Economic Intelligence Unit |
| FAO | Food Agricultural Organization of the United Nations |
| GDP | Gross Domestic Product |
| IGAD | Intergovernmental Authority on Development |
| INTSORMIL | International Sorghum and Millet Collaborative Research Program |
| ISERST | Institute for Advanced Studies, Scientific Research and Technology |
| NGO | Non-Governmental Organization |
| PANEO | Plan d'Action Nationale pour l'Environnement |
| PSSA | Programme Speciale pour la Securite Alimentaiare |
| PNUID | Projet Direction de l'Aménagement du Territoire et de l'Environement |
| P/ETP | Potential Evapotranspiration |
| UNSO | United Nations Sudano-Sahelian Office |
| USAID | United States Agency for International Development |

# Economic Conditions

The population of Djibouti is 636,000 (World Bank, 1999, p.232) with a per-capita income of approximately $800[1]. There is a French military contingent of 11,000 and a small urban sector making reasonable incomes, although, the majority of the population is in extreme poverty. This poverty is reflected in the welfare indices of a life expectancy of 50 years and an illiteracy rate of 54% (World Bank, 1999, p. 232).

The Djibouti economy is characterized by a high-level of external dependence and reliance on earnings in the service sector. Djibouti has few natural resources, with average annual rainfall of less than 150 mm and no permanent rivers. Hence, agriculture consists of a few irrigated regions and a nomadic livestock production. The secondary sector, the industrial and manufacturing sector, is poorly developed because of a small domestic market, lack of locally available raw materials, and an unskilled labor force. The national economy is dominated by a tertiary sector where services account for over three-fourths of the GDP. The main economic activities are the port, services to the military (30% of GDP in 1991), and other urban service activities including the bureaucracy.

Because of the world recession in the '80s, the flood of 1989-90, and the civil war between the two main ethnic groups (Afars and Issas) from 1991-94, per-capita income fell by 43% from 1978 to $854 in the early '90s (1993 US$, World Bank, 1998). There has been a modest recovery[2] with the port booming due to the Ethiopian/Eritrean war (1998-2000). A negative, factor was the retrenchment of the French military (1998-2000).

A principal long-run problem for the government is the extreme poverty levels in both urban and rural areas. The government's 1996 profile indicates that approximately 45% of Djiboutians were living in households with expenditures below the level necessary to provide basic needs. Ten percent live in extreme poverty, i.e., they could not afford to buy the food necessary to maintain a minimum level of caloric consumption. If the survey had included information on the three most impoverished groups, e.g., the homeless, nomads, and those living in temporary structures, poverty estimates would have been even higher (World Bank, 1997).

The incidence of extreme poverty is more than seven times higher in rural areas than in Djibouti-ville, due in large part to the greater number of safety nets derived from the city's market and service activities (World Bank, 1997). Unemployment is extremely high (45%) with the most disadvantaged groups at more than 60%. Income groups differ dramatically in terms of social indicators, such as the percentage of children enrolled in school. Child malnutrition is widespread (World Bank, 1997). Among children under 5 years of age, 26% are chronically malnourished (stunted) and 13% suffer from acute malnutrition (wasted).

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[1] In the Comesa web page (http://www.comesa.int), the July 1997 population is 434,116 and the 1995 estimated GDP $500 million with a life expectancy of 48 years. The difference is principally the refugee population of approximately 120,000 (for estimate of the refugees, see Omolo, 1999).

[2] GDP growth rates of 0.5% in 1997 and 0.8% in 1998 as compared with - 2.9% in 1994 (Economic Intelligence Unit, 1999, p.2).

[3] At the primary level in 1996, the net enrollment rate among the poorest quintile was 53%, 25 percentage points below the rate in the top quintile (World Bank, 1997).

The high levels of unemployment have not caused a reduction in wages because the high public-sector wages, together with other labor-market restrictions, limit downward adjustment in private-sector formal wages, giving rise to a dual labor market and high unemployment rates (World Bank, 1997). The same dual economic structure constitutes a major obstacle to the competitiveness of Djibouti's small secondary sector (industrial and manufacturing) in relation to potential markets, such as Ethiopia.

## The Agricultural Sector

The climatic conditions are characterized by rainfall from 30 mm to 300 mm with a mean of 150 mm per year. Eighty-three percent of total rainfall evaporates and therefore cannot be used by plants or for recharge of water tables. The rain comes in heavy storms three to four times a year. Much of the water is lost to the sea. In view of the heavy rainfall and physical conditions of the basin, infiltration of water which goes into the soil to recharge water in the wadi beds during the flood period is low. The effective rate of infiltration is estimated to be only 5% of the total rainfall.

The temperatures are high, over 30°C with a high humidity of 90% during summer and 50% in the winter. The high evapotranspiration ranging between 2,500 to 3,000 mm per year is over 10 times the potential rainfall. Without irrigation of some type, there are no crop activities, hence the concentration on nomadic livestock production. The main crop activity is to use subsurface or retained water in intensive crop activities on small areas. There is concentration on fruits and vegetables. Ten percent of the total area, or 6,000 ha, has the potential for irrigation.

Surface water does not exist and with rains falling three to four times a year, the surface water from the rain storms is lost in plains or mostly in the sea. Underground water is in the form of alluvial water table of wadis 1 to 2 m deep. These tables often are the only sources of water and can be reached by scooping out the sand. Goebel (1983) described six important wadis in the country. Some of these are flowing in closed basins (endoreic system) while others run to the sea (open system) .

Five major zones of agropastoralism exist alongside watering points or intermittent water courses close to urban areas in the gardenbelt around Djibouti town and in rural horticulture in the oases. Most of the horticultural production is practiced in small gardens of less than 0.5 ha of various fruit and vegetable crops, among which are tomatoes, onion, chilies, guava, citrus, mango, papaya, and date palms. Gross returns from vegetable production are very high since several crops per year can be produced and urban prices in Djibouti are high. It is estimated that farmers at the Wadis make $4,400 to $6,900/ha/year (Djibouti Franc at 172.93/US$. World Watch, Sept. 21, 2000) and $13,300/ha/year in the city for an annual value of $5 million from irrigated crop production (Emerton, 1998; Habib, 1998). Though farming provides an important source of household income, the bulk of fruits and vegetables consumed in urban Djibouti are still imported from outside Djibouti. It is estimated that domestic agricultural production supplies 10% of Djibouti (the capital) demand (CNE, 1991).

Fruits and vegetables produce very high gross revenues. They require large labor and purchased inputs. Expanding these activities requires, first, the optimal use of the available water, then large amounts of purchased inputs, and, finally, improved cultivars regionally adapted.

Only 65% of the available irrigated land is farmed each year (FAO,1995). Table 1 shows the results of producer cooperatives identifying their problems in this survey.

**Table 1. Priority problems reported in interviews by cooperatives in southern Djibouti, Feb. 2000**

| Problems | Cooperatives | | | | | |
|---|---|---|---|---|---|---|
| | Ali-Sabien | As Eyla | Wea Arta | Tad-joura | Obock | Amboula Wadi |
| Getting water from existing wells due to competition or drought | X | X | X | | | |
| Transportation/marketing | X | | X | | | |
| Poor extension service | X | | | | | |
| Limited access to improved inputs, seeds, fertilizer | X | | | | | X |
| War contributed to breakdown in irrigation technology/wells | | X | | | X | |
| Inadequate technical support for repair/maintenance | | X | X | | | X |
| Salinity | | | X | X | X | X |

Source: IGAD/INTSORMIL interviews in Guelleh, 2000.

On the input side, little inorganic fertilizer is available. With the existing system of rural co-operatives for fruit and vegetable production of rural crops, bulk buying could be undertaken. Most seeds are imported from France.

A primary technical problem in these sandy soils with high evapotranspiration is salinity. There is variation between crops and within crop species in tolerance to salinity. However, much higher returns are expected from use of available water and increasing soil fertility than from varietal selection for salinity tolerance.

## The Research System

The Djibouti Institute for Higher Scientific and Technical Research (ISERST) is the only research establishment in the country. Its mission is to conduct research to promote the socioeconomic welfare of the country. Of 40 employees, there is a 10-person "life sciences" department focused on agriculture. It includes one Ph.D. in plant biology and physiology, one Master's in soil science, one agronomist, four technicians, and three laborers. About 11% of the 40 employees in the entire Institute have higher degrees; only three are women. Salaries are currently approximately four months late and staff morale is low. The Institute has often been encouraged to generate its own funds from services rendered at cost to the private sector.

There are poor linkages between research and extension. A demonstration center has been proposed which could be used by the Ministry of Agriculture, ISERST, and NGOs for demonstration of technologies before release for adoption. This center would serve later as an agricultural or farmers' training center.

## The Extension Service, NGOs, and Co-operatives

Public extension is a small unit (6 college graduates with 2 M.S. degrees, 5 technicians, and 45 staff). It is located in the Department of Agriculture and Forestry. The Demonstration Center is a very promising development for extension and for building research/extension links.

Two hundred NGOs are officially registered by the government, but only three to five are considered active. There is high involvement by NGOs in refugee activities. Within agriculture, they tend to focus on tools and seeds. There is also some involvement with gardening, the principal crop production activity in Djibouti.

Co-operatives are generally involved in the main crop activity of fruits and vegetables. But the number of active co-operatives have been reduced by the civil war (1991-1994).

Womens' status in Djibouti is subordinate to that of males due to the dominant patriarchal model. The behavior of females is controlled by societal rules and traditional customs; traditionally women have been left out of the main sphere of decision-making in politics, economics, and society.

Nevertheless, the constitution recognizes the equality of sexes and women's rights. Djibouti has taken the initiative to create various institutions to benefit women. Since independence in 1977, there has been progress in the education of girls, care given to mother and child, and women's integration in employment, especially into government service.

The situation of Djiboutian women is gradually being improved, and their role in the economy is becoming more important. Although women represent 75% of the employed in the informal sector, they are still not well represented in the formal sector. The new generation of women participants in the education system is progressing steadily. Female enrollment rates in primary schools increased from 40% in 1943 to 74% in 1996-97 (Republic of Djibouti, 1999). The previous generation of women has not benefitted from this educational opportunity, hence the present illiteracy rate for females is still 73%.

The government launched a health education program dealing with nutrition, hygiene, and literacy. About 4,000 women have participated but only 700 have finished the program.

## Lessons Learned

Agricultural research under ISERST is directly under the Office of the President. Since budgets are first among the ministries first only the residual is available in the Office of the President. This budget is then divided among the units under his control. Agricultural research has to share its allocation with all the national research sections in different Ministries. The Director of ISERST is not a cabinet minister, nor is he an elected member of parliament. He is a civil servant. The Office of the President is very much preoccupied with want and hunger crises. The ties from the President's Office of researchers to their clientele especially to extension, NGOs, the private sector, and farmers are more difficult from this level of government. Putting ISERST personnel back under the traditional Ministry(ies) would improve their interaction and accountability with their client groups.

## Conclusions

A long-term strategy for crop production in Djibouti should emphasize:

1. Irrigation and salinity management;
2. Soil fertility improvement especially improving the availability of inorganic fertilizers;
3. Use of drought- and saline-tolerant plants

Currently, the lack of water and high soil salinity are the most serious factors limiting crop productivity. Specifically, value of production per cubic meter of water is a more important criterion than land productivity. However, the water-management problem is far more inclusive. Water-management capability must include such sophisticated elements as monitoring the recharge of underground reservoirs and the establishment and enforcement of both rates of extraction and rights to water. Other elements are keeping pumps in operation as well as efficient procurement of supplies and equipment, which currently are very costly. More outside technical input, as from Israel or of the United States, to improve irrigation systems and using water more efficiently needs to be a principal priority for crop production.

Once irrigation systems are improved the principal agents of input markets will need to be supported, especially the importers and distributors of improved seed and inorganic fertilizers. Along with inorganic fertilizers, methods to manage irrigation in soils with high infiltration rates and low cation exchange capacity will be necessary so that water and mineral nutrients are more efficiently utilized by the crops.

A principal recommendation for the research system is to utilize a team of horticulturalists with irrigation experience to define research priorities. The team will need to address marketing and processing issues of fruit and vegetable production to avoid the price collapse of easily saturated markets.

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# Interviews

**Farmers' Organizations**

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Mohamed Abdallah Youssouf, Chief, Obock Sector
Mohamed Miyir, High Commissioner, Ali-Sabieh District
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Ismahaan Mohamed Hadi, Assistant Treasurer
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# Eritrea

## War and Agricultural Success in Semiarid Agriculture

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# Figure

## Box



## Tables

# Acronyms

| | |
|---|---|
| ACORD | Agency For Co-operation and Research in Development |
| ASARECA | Association for Strengthening Agricultural Research in Eastern and Central Africa |
| CED | Chronic Energy Deficiency |
| CIMMYT | International Maize and Wheat Improvement Center |
| DANIDA | Danish Foreign Aid Agency |
| DAP | Diammonium Phosphate |
| DARHRD | Dept. of Agricultural Research and Human Resources Development, MoA |
| DHS | Demographic and Health Survey |
| ECARSAM | East and Central Africa Sorghum and Millet Network |
| ECDF | Eritrean Community Development Fund |
| EEC | European Economic Community |
| EPLF | Eritrean Peoples Liberation Front |
| FAO | Food and Agricultural Organization of the United Nations |
| GTZ | German Development Agency |
| IARC | International Agricultural Research Center |
| ICARDA | International Center for the Development of Arid Lands |
| ICRAF | International Center for Research on Agro-Forestry |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| IDA | International Development Association (Development Division of World Bank) |
| IFAD | International Fund for Agricultural Development |
| IFDC | International Fertilizer Development Center |
| IFS | Integrated Farming Systems |
| IGAD | Intergovernmental Authority on Development |
| ILRI | International Livestock Research Institute |
| INTSORMIL | International Sorghum and Millet Collaborative Research Support Program |
| MoA | Ministry of Agriculture |
| NCA | Norwegian Church Aid |
| NGO | Non-Governmental Organization |
| NORAD | Norwegian Development Agency |
| NSDP | National Seed Development Program |
| NEW | National Union of Eritrean Women |
| PREFER | RÂPE/UNDP donor coordination structure (PROFERI) |
| RRPE | Recovery and Rehabilitation Program for Eritrea (RÂPE) |
| SG2000 | Sasakawa Global 2000 |
| SPFS | Special Program for Food Security |
| SWOT | Strengths, Weaknesses, Opportunities, Threats |
| SZRS/ACORD | Southern Zone Savings and Credit Scheme (ACORD) |
| TSP | Triple Super Phosphate |
| UNDP | United Nations Development Program |
| UNICEF | United Nations International Children's Emergency Fund |
| US$ | United States Dollars |

# Economic Conditions

In 1997, Eritrea had a population of 3.28 million, a per-capita income of $210 (1997 US$) not adjusted for the Purchasing Power Parity, and a life expectancy of 55 years (World Bank, 1999, p. 232).

Favorably situated with easy access to both European and Middle Eastern markets, Eritrea had already developed a strong base of export-oriented, irrigated, and rainfed agriculture by the early 1920s. Although production and exports decreased during the Second World War, they resurged quickly by the early 1950s.

Unfortunately, Eritrea's early prominence in irrigated and non-irrigated agriculture and in commercial livestock production and trade was destroyed by the country's 30 years of war[1]. The same war disrupted a large number of the internal coping mechanisms and production patterns that had helped Eritrea to survive on its large semiarid land and arid land base. A recent FAO document describes how (1994a, p. 5):

> "What had been until the Ethiopian takeover [in 1962], and even through the mid-seventies, one of the more developed territories in north-eastern Africa, with a nucleus of productive and competitive commercial agriculture (fruit and vegetables, meat and dairy processing, cotton) and light industry (textiles, leather goods) as well as a well educated population (which formed a prominent part of the civil services as well as of trade and industry and the liberal professions in Ethiopia), [was] reduced to a near-subsistence economy heavily dependent on food aid for its survival." (FAO 1994a, p. 5).

By 1994, Eritrea was satisfying only 25% of its food supply needs and faced problems with food access. According to the results of the Demographic and Health Survey (DHS) done in 1995, 38% of children 6 to 36 months were stunted and 16% were wasted. In Gash Barka, Southern Red Sea and Northern Red Sea, a prevalence of wasting of around 23% has been reported. Stunting and wasting show a clear age-specific pattern with the proportion of children stunted rising gradually from 4 to 21 months of age, at which time it peaks at about 61%, then drops between 22 and 27 months of age before rising to 80% by the end of the third year. UNICEF's cumulative figures (1987-1997) showed Eritrea to have some of the highest rates of malnutrition in the region (Table 1). According to the results of the 1995 DHS, malnutrition is also high among adults. Forty-one percent of the population were found to be suffering from Chronic Energy deficiency (BMI <18.5) while the prevalence was 45.3% for women; 7.5% of men and 8.6% of women in the survey had a BMI <16 which is associated with severe malnutrition.

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[1] Ethiopia in 1962 unilaterally abrogated the federation status which the United Nations had conferred upon Eritrea in 1951. The 30 years of war gained intensity in 1974 when Ethiopian Emperor Haile Selassie was ousted by a coup. The Mengistu government of Ethiopia waged a fierce war against Eritrea for the next 17 years. As a result, much of Eritrean infrastructure and productive capacity were damaged or destroyed, trade and industry declined, tens of thousands of Eritreans died in combat or as a consequence of the bombardment of cities, and at least half a million Eritreans fled the country (FAO 1994a, p. 1).

The most recent regional data on malnutrition suggests a certain amount of regional variation between zones in terms of the types and levels of malnutrition (National Statistics Office 1995). Although precise figures are lacking, it appears that malnutrition is greatest in the highland areas where populations have less access to livestock products (meat and milk) (FAO 1994b, p. 3).[2, 3]

**Table 1. Underweight children in six IGAD countries.**

| Country | % under Age 5 |
|---|---|
| Eritrea | 44 |
| Ethiopia | 48 |
| Kenya | 23 |
| Somalia | N/A |
| Sudan | 34 |
| Uganda | 25 |

N/A: Not available.
Source: UNICEF 1996.

The new national government that took power in 1993 made agricultural development in general, and the development of intensive, semiarid agriculture in particular, top priority based upon the country's precarious food situation and the high dependence of the population on agricultural employment (86%) (FAO 1994a,b,c). Since 1994, the Ministry of Agriculture has carried out a focused program aimed at providing smallholders with the inputs and credit needed to adopt more intensive rainfed agriculture. This strategy was facilitated by the government's decision to provide government subsidies for key inputs such as fertilizer, seeds, and tractor rental services. Some of the other innovative features of Eritrean development during this time period included the decision to eliminate all non-emergency food aid. The country has also been extremely selective in determining what types of foreign donor and NGO assistance it would accept[4]. Eritrea's heavily subsidized agricultural extension programs have helped the country to substantially increase area and production (Table 2). Even with these higher rates of production, however, Eritrea was able to supply only 75% of its total food needs in 1999.

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[2] Lowland pastoralist and agro-pastoralist households consume the most milk, up to a litre per person per day, largely from goats. In the form of boiled or smoked milk, or as cheese, milk is their main source of animal protein and fats, in diets whose other main item is grain (FAO 1994c: 3). Fresh milk in highland farming households is prized and drunk boiled, when they can get it. But milk is not always ready available to rural highlands, since their main interest in large livestock is in draught oxen.

[3] For this reason, the 1994 Agricultural Sector Review recommended that the MoA agricultural research and extension give more prominence to pulses and oils seeds, which were already second in importance after grains, in order to ensure a better supply of added protein, fats and oils for lower income rural and urban households (FAO 1994c: 3-13). The same joint FAO and MoA sector review emphasized the critical importance of short and medium term Eritrean policy focusing on food security as opposed to food self sufficiency (*ibid*).

[4] Especially important was the decision to require all NGOs to work in close collaboration with the MoA in implementing various components of the MoA strategy. This unique mode of operation is reflected in the fact that the Ministry lists all NGO aid to the sector in the same tables that it lists other types of foreign assistance that supports jointly executed programs (Table 14).

**Table 2. Area and production estimates for cereal, pulse and oilseed production, 1992-1999.**

| Year | Area (ha) | Production (kg) |
|---|---|---|
| 1992 | 327,200 | 262,400,000 |
| 1993 | 395,600 | 98,050,000 |
| 1994 | 362,960 | 266,570,000 |
| 1995 | 349,440 | 140,275,000 |
| 1996 | 371,000 | 96,900,000 |
| 1997 | 393,403 | 67,760,800 |
| 1998 | 499,951 | 471,842,100 |
| 1999 | 472,427 | 356,339,800 |

Source: MoA, 2000, p.1.

Although the government plans to increase the amount of irrigated land over the next decade, rainfed production in the semiarid zones will continue to be the major source of future food production and nutritional gains.

## Major Agroecological Zones

A small portion of Eritrea (0.8% of the total land area) that is wedged between the semiarid Central Highland Zone and the arid, semi-desert Coastal Plain Zone is characterized by higher rainfall (700-1100 mm) (Table 3, Fig. 1). Despite the higher rainfall, the area's extremely mountainous terrain has restricted the development of intensive settled agriculture to a small area of highly intensive terraced farming that supports only 2 to 3% of the country's population which, like the population of the western escarpment, is highly mobile. Each year the area receives an influx of transhumant pastoralists from the Central Highland Zone, primarily, and secondarily from the nearby Coastal Plain Zone during the dry season (April/March-September). Agricultural development policy for this zone focused on intensive, terraced, mixed agriculture, especially the production of coffee, barley, wheat and maize (in that order of importance). The traditional subsistence farming systems are characterized as mixed cereal/pulse systems. Due to the mountainous terrain, there is not much potential for further agricultural expansion.

The rest of Eritrea (99.2%) is classified as arid or semiarid. Sixty percent of the rural population live in the provinces of the Central Highlands Zone (FAO 1994a, p. 47) (Table 3). One consequence of the protracted war for independence that focused on the central highlands, was to disrupt the traditional patterns of land use and forestry that had enabled the highland areas to support their high-population densities.

The high-population densities of the central highlands contrast with the lower population densities of the southwest lowland zone (which comprises approximately 21.6% of the population) despite the relatively high quality of the lowland area's soils. The southwest lowlands have traditionally

been an area where agro-pastoralism was combined with mixed, crop agriculture. The lower population densities of the southwest lowland zone, despite high population pressure and degradation in the central highlands, is attributed to the historic productivity of the central highland systems. Since independence, the national agricultural policy has attempted to address the specific constraints and opportunities of these two distinct agro-ecological zones that are home to about 82% of the total population and approximately 24% of the total land area[5] (Table 3).

A third semiarid agricultural zone with relatively distinct agroecological features and production possibilities is the western escarpment which constitutes approximately 2.5% of the total land area and probably less than 2% of the population, much of which is transhumant. Agriculture in this area tends to be dominated by agro-pastoralism and pure pastoralism. Government policy in this area has tended to focus on the extension of improved veterinary and animal health services. More recently, the government has supported a number of pilot projects to promote irrigation in the eastern escarpment and in the Coastal Plain Zone. This is an area that is considered to have very high potential for commercial, irrigated production.

## Technology Introduction in the '90s

With input subsidies on tractors, fertilizer and credit, Eritrea has been pushing hard since the mid-'90s to increase production of the basic food staples. Since most of Eritrea is either semiarid or arid, the focus has been on sorghum and millet with lesser emphasis on wheat and barley. With the continuing warfare, the introduction of labor-saving technology has been very important, and tractor-rental schemes have been promoted. The government has also attempted to imitate the Ethiopian successes in raising input levels and introducing new cultivars but with more emphasis on the drought-resistant cereals sorghum and millet. The interviews suggest wide variation between the official crop production zones in terms of the use of tractors, inorganic fertilizers and improved agronomic techniques (Table 4).

Water-retention techniques are practiced in various regions of the country including oxen cultivation, bunds of dirt and stones, use of runoff, and supplementary irrigation. The government has also attempted to extend the use of these techniques through its mainline extension programs. There is the beginning of research activity on more sophisticated water-retention techniques such as tied ridges. Improved implements for oxen cultivation are also being evaluated. Both tied ridges and improved cultivation implements can have substantial effects on water retention, making it more profitable and less risky to adopt inorganic fertilizers.

As in Ethiopia, the principal mechanism for raising input levels and extending new cultivars has been subsidies on extension, credit, and fertilizer, plus making available seed of new cultivars or cleansed traditional cultivars. The combination of these policies has resulted in a rapid increase in input use, production, and yields. A key difference that distinguishes the Eritrean experience from similar success stories in the higher rainfall areas of Kenya and Ethiopia is the fact that this success has been almost entirely focused on the semiarid zone.

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[5] Population figures for the agroecological zones are gross estimates based on the Socioeconomic Survey for Rural Water Supply Program Planning in Eritrea, UNICEF, March 1997. These estimates were based on an attempt to correlate regional boundaries with agro-ecological boundaries.

## Table 3. The major agroecological zones in Eritrea

| Agro-ecological zone | Agroec. zone (Min. ag.)** | Rainfall (mm)* | Alt. (m)* | Evap. range and (R/Eo)*** | Growing days**** | Pop % | Land area* % | Major soils | Major land-use activities | Major crops |
|---|---|---|---|---|---|---|---|---|---|---|
| Transition (Subhumid) | Greenbelt (GBZ) | 700-1100 | 600-2625 | 1600-2000 (43-55 R/Eo) | 90-240 | 2% | 0.8% | Cambisols Lithosols Fluvisols | Terrace agriculture and transhumant agriculture | Maize Sorghum Coffee Barley |
| Semiarid (Moist Highland) | Central Highland Zone (CHZ) | 500-700 | 1600-3018 | 1600-1800 (31-39 R/Eo) | 90-120 | 60% | 7.4% | Cambisols Luvisols Lithosol Regosols | Mixed agriculture | Barley Wheat Teff Maize Sorghum Finger Millet Pulses |
| Semiarid (Moist Lowland) | Southwest Lowland (SWLZ) | 500-700 | 500-1600 | 1800-2000 (28-35 R/Eo) | 90-120 | 22% | 16.2% | Cambisols Vertisols Fluvisols Regosols Lithosols | Agro-pastoralism to mixed agriculture | Sorghum Pearl Millet Sesame Cotton |
| Arid (Arid Highlands) | Western Escarpment (WEZ) | 200-500 | 1600-2820 | 1600-1800 (13-28 R/Eo) | 90-120 | 2% | 2.5% | Lithosols Cambisols Regosols | Agro-pastoralism | Sorghum Pearl Millet Barley |
| Arid (Arid Lowland) | NW Low-land Zone (NWLZ) | 200-500 | 400-1600 | 1800-2000 (11-25 R/Eo) | 30-60 | --- | 32.3% | Erosols Cambisols Flavisols Lathosols | Pastoral to agro-pastoral | Sorghum Pearl Millet |
| Arid (Semi-Desert) | Coastal Plain Zone (CPZ) | 100-200 | 100-1355 | 1800-2100 (6-10 R/Eo) | 0 | --- | 38.8% | Kerosols Salonchak Lithosols Cambisols Fluvisols | Pastoralism and limited spate irrigation | Maize Sorghum Pearl Millet |

*() indicates the classification of this zone using the most recent analysis by the Ministry of Land, Water and Environment, June 1997 which was conducted in collaboration with FAO under CP\ERI\4554.

**indicates the classification of agroecological zones most commonly used in the Ministry of Agriculture today. This system is based on the FAO Sector Review.

***r/Eo=Rainfall/evapotranspiration.

****Source: Eritrea Department of Environment (DOE), Ministry of Land, Water, and Environment (MLWE), 1999, in Adhanom, 2000.

Source: Ekube, 2000 and Teferi, 2000, based on the Ministry of Agriculture and Ministry of Lands, Water, and Environment classification system.

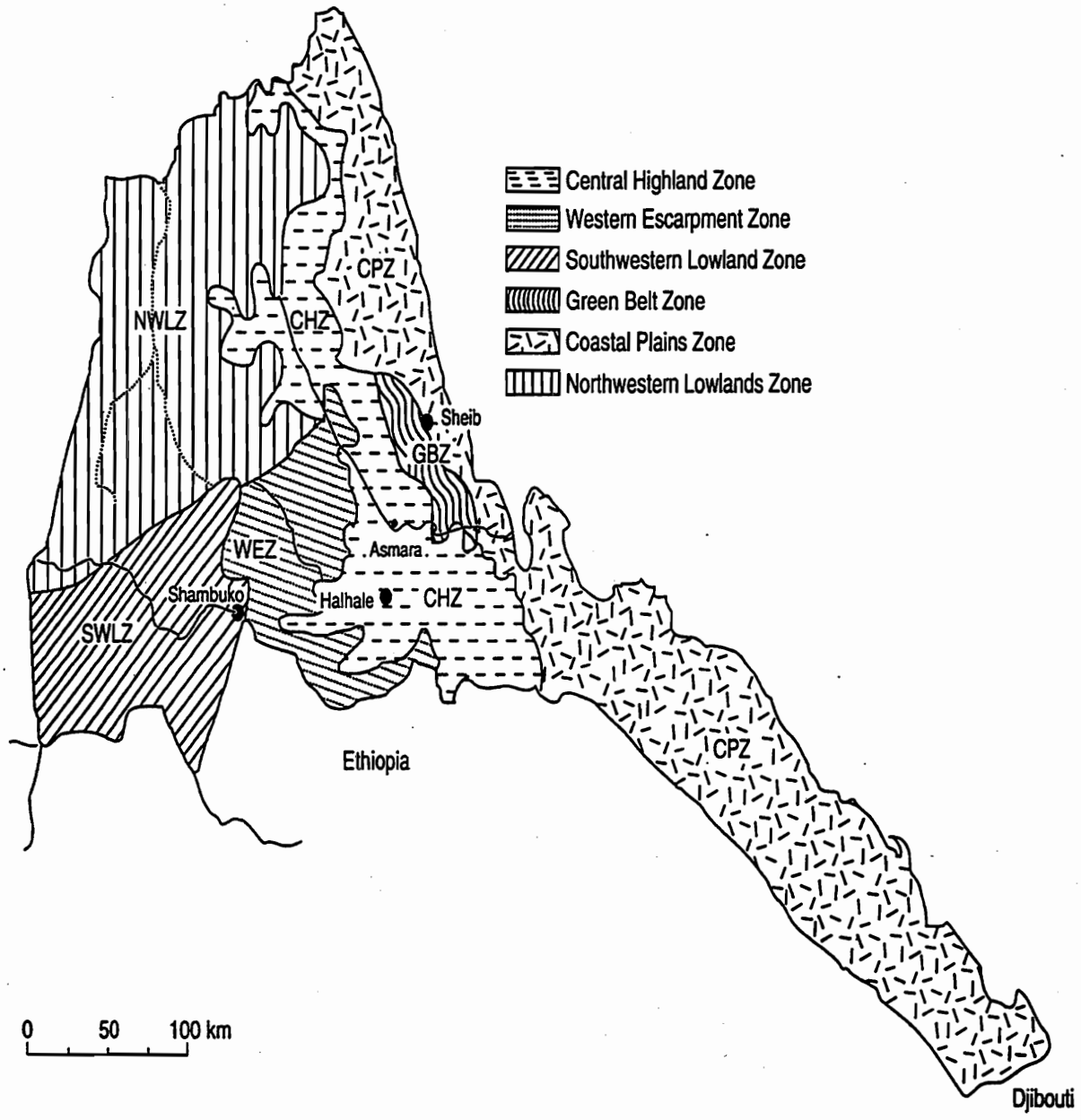


**Fig. 1. Agroecological zones of Eritrea.**

**Table 4. Diffusion of improved practices in the three major crop-producing zones in Eritrea.**

| Crop/cultivar | Semiarid | | Arid | Priority research areas |
|---|---|---|---|---|
| | Central Highland Zone (CHZ) (Moist Highland) | Southwestern Lowland Zone (SLZ) (Moist Lowland) | Eastern Lowlands Coastal Zone Plain (CZP) | |
| Row Cropping | ++++ (Mechanized Agriculture) | ++++ (Mechanized Agriculture) | ++ | -- |
| Tied ridging | 0 | 0 | ++ | New research area |
| Implements: | | | | |
| Tractors | ++++ | ++++ | ++ | New research area |
| Ox-drawn | 0 | 0 | 0 | New research area |
| Intercropping/ crop rotation | 0 | 0 | 0 | New research area |
| Fertilizer recommenda-tions | ++++ | ++++ | Irrigation | Move away from blanket fertilizer recommendation |
| Improved weeding | ++++ | 0 | 0 | -- |
| Plant populations | ++++ | 0 | 0 | -- |
| Timing of planting | ++++ | 0 | 0 | -- |

Key: ++++ = Over 20% diffusion estimated as % of area planted to crop in region
+++ = 10-20% diffusion
++ = 5-10% diffusion
+ = Less than 5% diffusion 0=No diffusion
On the alluvial soils there has not been a response to fertilization

Source: IGAD/INTSORMIL interviews, MoA. March, 2000

There has been a standard fertilizer recommendation of 50 kg/ha of urea and 100 kg/ha of DAP. On-farm trials demonstrated that these blanket recommendations resulted in yield increases of barley, wheat, and sorghum from 1997-1999 (Table 5). The soils unit staff claim on-farm yield increases of up to 100% with the basic fertilizer recommendation for sorghum, teff, wheat, barley and maize. The soils unit staff claim farm-yield increases of up to 100% with the basic fertilizer recommendation for sorghum, teff, wheat, barley and maize.

These is still a very low level of the basic nutrients of N and P, which have been generally found to be deficient in the country. Moreover, there is substantial variability in soils. The soils unit of the DARHRD is now conducting a series of soil surveys in the country in order to characterize the soils in terms of both fertility levels and texture. These surveys are designed to assist the unit in developing appropriate soil-management practices including fertilizer recommendations for

specific locations and crops. The unit is also carrying out on-farm trials in various locations of the country varying the levels of N and P.

**Table 5. Yield responses from the blanket fertilizer recommendation for barley, wheat, and sorghum across five sites over three years, 1997-1999**

| Crop | Yield (kg/ha) | |
|---|---|---|
| | Control Plot | Fertilizer Plot |
| Barley | 650 | 900-1480 |
| Wheat | 980 | 1320-2100 |
| Sorghum | 1850 | 2030-2990 |

Note: 100 kg = 1 quintal conversion made from original table in quintals.
Blanket fertilizer recommendation: 50 kg/ha of urea and 100 kg/ha of DAP.
Source: Soils Unit, DARHRD, 1999b.

There have been more agronomic improvements in the Central Highlands than anywhere else with row planting, fertilizer, tractor use, and other improved practices being concentrated there. Although the research division is beginning to conduct on-farm tests of animal and mechanical traction equipment, and on control of insects, diseases and, weeds, the highest priority for new research has been on new cultivar development. This strategy has enabled the Eritrean researchers to engage in research with the international agricultural research centers and to concentrate on screening. To date, the major focus on new cultivars has been on sorghum, millet, and barley with shorter growing seasons. (See Table 6 for diffusion of these new cultivars.)

## Sorghum

Sorghum is one of the principal food crops in Eritrea, planted in 46% of the land area (172,500 ha) of all the cropped land in the country (DARHRD, 1999a,b) and concentrated in the lowlands. The variety Dinkmesh was introduced from Ethiopia; the variety Wade Akar was selected from the local land races. These varieties have been produced by the farmers in the eastern and western lowlands, respectively, since the 1980s. Unfortunately, the yields of these varieties have stagnated around 1 to 1.8 mt/ha and the highest yields have been obtained using fertilizer. The DARHRD has, since 1995, established collaborative linkages with ICRISAT that have enabled them to screen a large number of ICRISAT-bred sorghums.

**Table 6. Diffusion estimates for new cereal cultivars in the three major crop zones in Eritrea, March 2000.**

| Crop Cultivars | Semiarid | | Arid |
|---|---|---|---|
| | Central Highland Zone (CHZ) (Moist Highland) | Southwestern Lowland Zone (SLZ) (Moist Lowland) | Eastern Lowlands (Coastal Zone Plain) (CZP) |
| **Barley** Atza Local | + | 0 | 0 |
| | | | |
| **Wheat** | | | |
| Boohay | + | 0 | 0 |
| H105 | + | 0 | 0 |
| Australia | + | 0 | 0 |
| HAR 1685 | + | 0 | 0 |
| | | | |
| **Sorghum** | | | |
| Dinknesh | 0 | 0 | + |
| Wade Akar | 0 | + | 0 |
| 89MW5056 | 0 | 0 | + |
| 89MW5003 | 0 | 0 | + |
| 1529415 | + | 0 | 0 |
| 1529376 | + | 0 | 0 |
| PP290 | 0 | + | 0 |
| IC54210 | 0 | + | 0 |
| | | | |
| **Pearl Millet** ICMV 221 | 0 | + | 0 |

Key: ++++ = Over 20% diffusion estimated as % of area planted to crop in region.
+++ = 10-20% diffusion
++ = 5-10% diffusion
+ = Less than 5% diffusion
0 = No diffusion

Source: IGAD/INTSORMIL interviews, MoA. March 2000

**Table 7. Average performance of on-farm tested sorghum varieties in western lowlands, 1998.**

| Serial No. | Variety Name/ Code | No. Days to 50%Flowering | Yield / ha |
|---|---|---|---|
| 1. | IC54 210 | 66 | 2970 |
| 2. | SDSL 89420 | 68 | 2680 |
| 3. | Dinkmesh | 68 | 2380 |
| 4. | SC 701-14E | 56 | 2380 |
| 5. | Marimariti | 66 | 2500 |
| 6. | CR:35:5 | 73 | 2580 |
| 7. | PP 290 | 65 | 2220 |
| 8. | Bazanai | 61 | 1870 |

Note: 100kg=1 Quintal conversion made from original table in quintals. High levels of fertilization

Source: Highlights of Agronomy Research Unit, 1999. MoA/DARHRD.

**Table 8. Average performance of on-farm tested sorghum varieties in eastern lowlands, 1998.**

| Serial No. | VarietyName/ Code | No. Days to 50% Flowering | Yield (kg/ha ) |
|---|---|---|---|
| 1. | IES492020DL | 69 | 3300 |
| 2. | ICSV 1179 BF | 64 | 3300 |
| 3. | 89MW5056 | 60 | 3600 |
| 4. | 89MW5053 | 66 | 3400 |
| 5. | 1587854E35/1 | 64 | 5200* |
| 6. | ICS49303365H | 68 | 4200* |
| 7. | Higery | 70 | 2050 |

* Is not average yield but calculated from single year single plot.

Note: 100 kg=1 Quintal conversion made from original table in quintals. High levels of fertilization.

Source: Highlights of Agronomy Research Unit, 1999, MoA/DARHRD.

These included 83 entries for the highlands (Halhale) and 249 entries for the lowlands (Shambuko and Sheib). Good progress was made in adaptive testing, selection, releases, and initial seed multiplication of a few new cultivars (Obilana 2000, NSDP 2000). Cultivars IS 29415 and IS 20376 have been released for production of commercial seed for the highland zones (in the year 2000). Varieties PP290 and ICSV 210 for the western lowlands and varieties 89MW5053 and 89MW5056 for the eastern lowlands were released in 1999 and will be multiplied in 2000 by the National Seed Development Program (Tables 7 and 8). These varieties out yield the local varieties

in their regions. In addition, they mature earlier than the local varieties (60-70 days to 50% flowering compared to the locals in the highlands that take up to 100 days for 50% flowering).

**Pearl Millet**

In Eritrea, pearl millet is second to sorghum as an important food crop being produced in 16 percent of the total cropped area principally on the sandy soils of the western lowland zone. Pearl millet is more suited than sorghum for production in the dryer, shallower and poorer soil environments. The local pearl millet cultivars have generally had low yields (0.8-10 mt/ha). As with sorghum, collaboration with ICRISAT was initiated in 1996 involving screening of 101 ICRISAT-bred cultivars at both Shambuko and Sheib research stations. This collaboration has led to the identification and release of variety ICMV 221 (Obilana 2000; DARHRD 1991). ICMV 221 was selected jointly with the farmers based on a number of its attributes. These include: high yield (2.0-2.8 mt/ha on station), resistance to downy mildew disease, drought tolerance, early maturity (75-85 days), medium height (160-200 cm), bold attractive panicles, large round grains, and excellent injera quality. The National Seed Development Program (NSDP) is multiplying ICMV221 for distribution to farmers. In 1999, the NSDP distributed 8 tons of seed of that variety (DARHRD 1999a).

**Barley**

Barley is next to sorghum and pearl millet in importance as a food crop in Eritrea and is principally utilized as a beverage for humans and as an animal feed. It is mainly grown in the highlands. Research on barley has concentrated in the exploration of the local land races and screening of cultivars imported from ICARDA and neighboring Ethiopia. The local land race Atza has been found to be the most superior to all others in terms of yield, adaptation, straw quality, grain color, and brewing qualities (DARHRD 1999a,b) and is being promoted for production. However, ten other entries from the ICARDA introductions have also been found to be good and are undergoing further evaluations.

**Wheat**

Wheat, like barley, is an important crop grown in the highlands of Eritrea. There are a number of local cultivars growing very well which are capable of producing good yields with good attributes. Several introductions from ICARDA and Ethiopia are out-performing local cultivars and are being produced in larger quantities. One variety, Australia, was introduced by NGOs as food aid from Australia during the war in 1986. Farmers planted some of this seed and found it adapted with good yields and good utilization attributes. It has since been produced in Eritrea. Newer introductions include Boohay, Povan 76, and HAR –1685, all from Ethiopia. Variety HAR-16845 has excelled in yield followed by Povan76. They have been earmarked for release (Table 9) .

**Table 9. Season length and yields of new wheat cultivars in on-farm yield trials, 1999.**

| Variety | Days to Maturity | Mean Yield kg/ha |
|---|---|---|
| HAR-416 | 99 | 1688 |
| K6290 | 99 | 1600 |
| Enkoy-Holleta | 97 | 1512 |
| Australia | 106 | 1810 |
| Boohy | 106 | 1827 |
| HAR=1685 | 99 | 2078 |
| Pavan 76 | 99 | 1925 |
| Ald's/Hawes | 103 | 1684 |
| Mene-white (check) | 101 | 1555 |
| Mean | 101 | 1742 |
| CV% | 5.95 | 9.95 |

Note: 100 kg=1 Quintal conversion made from original table in quintals.

Source: MoA/DARHRD 1999.

## Legumes and Oilseeds

Legumes (pigeon peas, cowpeas, chickpeas, and lentils) and oilseeds (groundnuts, sesame, and cotton) are important potential sources of plant protein to supplement the lack of animal protein in the diet. The Department of Crop Research has therefore initiated research into the introduction and development of legume and oilseed production in the country. Prior to this research, there had been very limited production of chickpeas, faba beans, and lentils.

Collaborative linkages have been established with ICRISAT to do research on chickpea and groundnuts, and with ICARDA to do research on chickpea, lentils and faba beans. Legumes and oilseeds are particularly targeted to play a useful role in inter-cropping and crop rotation practices. These crops also have high potential in the export market and the private sector producing them will greatly benefit. For example, one investor, Investment Consulting Group, is importing five tons of groundnut seed for production targeting the Saudi Arabian market. Pigeon peas have an expanding market particularly among the Indian communities where it is consumed as a sauce (popularly called dahl). Sesame and groundnuts have a large Arabian and European market for confectionaries.

The government of Eritrea needs to be encouraged and assisted to emphasize the production of legumes and oilseeds in the country. These crops will help provide a balanced diet to the population. They will also provide benefits such as reducing susceptibility to damage by insects and pathogens and the legumes will increase soil nitrogen content when used in rotation or intercropped with cereals such as sorghum or millet. The legumes and oilseeds also have a potentially large export base.

# Input Markets

The Eritrean government's chief priority in the '90s has been to intensify production (increase yields) in the semiarid regions through higher input use as Ethiopia has done in the adequate rainfall zones. Since there is little private sector activity in the input markets, the success of these intensification programs has resulted in a parallel expansion of the role of the Ministry of Agriculture in the production, procurement and distribution of inputs and in the provision of short-term agricultural credit. The Ministry has market centers located throughout the country, from which inputs are distributed to farmers on a cash or credit basis. A number of bilateral and multilateral agencies and NGOs have donated inputs or assisted financially with their procurement. The major inputs sold are seeds, fertilizers, pesticides, tractors, farm implements, irrigation equipment, livestock, veterinary drugs, and vaccines. The responsibility of input supply can be expensive to government in terms of administrative costs, transportation, and storage. In addition, the extension workers are spending most of their time in the distribution of inputs. This reduces the amount of time they can spend in performing actual extension services such as conducting on-farm trials and demonstrations, and advising farmers on best practices.

## Fertilizer Market

The government is the sole dealer responsible for the procurement and distribution of fertilizer to farmers throughout the country. Whereas seed has, for a long time, been distributed free of charge, the Eritrean government has traditionally charged a fee for fertilizers. In 1993, the government subsidy for fertilizer amounted to 50% of the import price (FAO 1994b). Today, this subsidy has been reduced to 41% for DAP and 23% for urea (Table 10). Fertilizer inputs have increased from 2,688 tons in 1994 to 34,500 tons in 1999 (Table 11). The rapid increase in fertilizer inputs is due mainly to increased use in irrigated farming and to its promotion in the SG2000 and Integrated Farming System Projects (IFS). The most commonly used fertilizers are Urea and DAP, responding to the two most pressing nutrient deficiencies (N and P). Government policy subsidizing inputs has been aimed at obtaining rapid production increases with the long-run objective of phasing out the subsidies once the demonstration effects have been observed and farmers have seen the benefits of fertilizer use.

Farmers are still receiving the blanket recommendation for fertilizer (50 kg/ha urea and 100 kg/ha DAP), which was developed by researchers in Ethiopia in the late 1960s. This blanket recommendation overlooks the wide variation among soils between regions. On alluvial soils, farmers lower rates of fertilizer may be sufficient and on degraded soils, substantially more fertilizer would still be expected for maximum yield. Researchers have started to analyze the country's soils with a view to making more appropriate fertilizer recommendations. This process should receive more support in order to hasten the production of useful research results. Research should also be undertaken on the requirements for the other major nutrients such as potassium and minor nutrients such as iron, manganese, sulfur, and calcium, the deficiencies of which can also lead to low yields.

Application of fertilizers is only beneficial when sufficient water is available to the plant at the critical periods of plant development. In some cases, when fertilizers are applied, and no moisture is available, the effects can be negative as the fertilizer may draw away water from the crop. The wide variation observed in fertilizer response suggests that this soil moisture issue is affecting the

impact of fertilizer use in the semiarid zones. To date, however, the government has had neither the technical personnel nor adequate financial resources to conduct research and extension on the yield effects and profitability of the combination of water retention techniques and fertilization. As indicated in the Kenya and Ethiopia reports in this series, a large number of water retention techniques exist that can be adapted to an area depending upon soil type, available labor, and traction source.

Except for farmers participating in the SG2000 and IFS programs, the rest of the small-scale farmers are not knowledgeable about the benefits, nor are they trained to apply fertilizer. They need to be given hands-on experience in the safe handling of fertilizer, and in the timing rates, and methods of fertilizer application.

**Table 10. Import and selling prices of fertilizer and government subsidy rates, 1999.**

| Type of Fertilizer | Purchasing price (US$/quintal) | Selling Price (US$/quintal) | Subsidy % |
|---|---|---|---|
| DAP | 29 | 17 | 41% |
| Urea | 17 | 13 | 23% |

Note: The Nafka was $7.41 in May 1998 and $10.00 in June 2000. At 8.5 Nafka/US$, the Eritrean prices were converted to US dollars.

Source: Unpublished data from files of Procurement and Supply Management Unit, MOA, March 2000.

**Table 11. Fertilizer imports into Eritrea, 1994-1999.**

| | Type of fertilizer (ton) | | | |
|---|---|---|---|---|
| Year | DAP | TSP | Urea | Total |
| 1994 | 698 | 600 | 1,400 | 2,698 |
| 1995 | 500 | -- | 1,200 | 1,700 |
| 1996 | 2,675 | -- | 1,810 | 4,485 |
| 1997 | --- | -- | --- | --- |
| 1998 | 1,555 | -- | 518 | 2,073 |
| 1999 | 18,900 | -- | 15,600 | 34,500 |

Source: Unpublished data from files of Procurement and Supply Management Unit, MoA, March 2000.

As more and more farmers realize the benefits of using fertilizers, the Eritrean government will be hard pressed to cope with projected escalation of demand. The private sector, therefore, needs to be encouraged to get into the business of supplying fertilizers. For this to occur, however, the government needs to re-address its present policy of providing subsidies for fertilizers. Although the presence of a subsidy is probably a necessity for a high percentage of the rural population at the present time, it is a disincentive to the private sector. One alternative would be for the government to stimulate the private sector by subsidizing the sector rather than the farmer. In theory this would reduce the cost to government and release the extension staff to perform their mainstream extension duties.

It would be an error, however, to assume that this transition to private sector fertilizer supply could happen overnight. For one, the private sector is simply a very small sector of the Eritrean economy. Two, for the fertilizer to be profitable, it needs to be combined with better water-retention techniques. This increased return to fertilizer investments may be one of the main advantages of the tractor soil preparation techniques mentioned above. Third, many of the farmers have very low incomes making it more difficult to invest in inputs.

**Seed Markets**

A national seed program has been an important activity of the government since 1996, again following Ethiopia with DANIDA support. A seed laboratory has been built and the government is producing and distributing clean seed. The quantity of seed being produced is still below the national requirements. Except for some horticultural seeds, the MoA is the major supplier of seed to farmers. The government of Eritrea has indicated that the private sector should play a leading role in the production, processing, and distribution of seed.

**Credit Markets**

Credit was a popular option for development assistance in the immediate post-war reconstruction and rehabilitation period (FAO 1994a,b,c). Each of the two major rehabilitation and reconstruction projects (FAO 1994a,b,c,) extended credit in connection with their programs to help restock animals. There were also a number of NGO and donor-assisted veteran resettlement programs that extended credit to their beneficiaries.

While this proliferation of war-time and post-war credit programs may have eased the constraints associated with specific programs, it was in no way sufficient to support the needs of a national agricultural program. For this reason, agricultural credit was identified as a major concern by the national government in 1994 (FAO 1994a,b,c).

Since 1994, the MoA has been the major source of agricultural credit for inputs associated with its programs. In each of the three major agricultural extension programs (the Special Program for Food Security, SG2000, IFS) the credit was provided as seed, fertilizer, and pesticides, and reimbursed "in kind" or in cash at harvest. A similar structure was used to organize farmers into the tractor user groups that shared tractor services that were reimbursed to the MoA at the end of the agricultural seasons. In each case, the extension agent was responsible for both identifying who was eligible for a credit as well distributing the inputs.

These in-kind credit programs played a major role in encouraging farmer participation in the extension programs that doubled the total area planted and total food production during the last five years. The same government subsidized inputs (and in kind credits) were awarded in ways that permitted even households with few resources and female households to participate. The lower rates of participation by poor households, especially households headed by females, appears to be because of their lack of understanding of the generous subsidized terms of this program.

The chief weakness of the three major government extension programs was that the very success of the programs in encouraging the use of more advanced technologies quickly outstripped the

ability of the staff of the Ministry to keep up with the rapidly growing demand for feed and fertilizer. Another weakness was the fact that the MoA credit programs only supported input credit, i.e., a partial package. Given the critical importance of land preparation, tilling, and water harvesting techniques to achieving the fullest economic impact of fertilizer, the MoA recognizes the need for complementary credit sources.

This year, as part of the planning process associated with the preparation of a new phase of donor support for extension, the Ministry is considering various ways to reduce its direct role in input supply and credit by devolving some of the responsibility for these activities to the farmer groups and tractor user associations. They are also considering various new models for encouraging commercial banks and group credit (rural banks) institutions to become more active as sources of funds for inputs and agricultural credit for smallholder agriculture, as well as the export-oriented, commercial rainfed and irrigated agricultural sectors.

**Summary**

In 1993, the Government of Eritrea embarked on an ambitious program to increase the area planted and the productivity of the country's rainfed agricultural systems in the semiarid areas by encouraging the use of inorganic fertilizer and improved cultivars through distribution of the inputs through the extension service and input subsidies. By 1998, an estimated 9% of the total area under cultivation in pulses and cereals was associated with the new technology extension programs; by 1999, the figure had increased to 21%. These high rates of acceptance of improved technologies were associated with substantial increases in the total area planted (31-34% increase over 1992) and total production (26.4-44%). The official government figures for the use of fertilizer shows a twelve-fold increase between 1998 and 1999.

Average yields on the fields associated with the SG2000 and Integrated Farming Systems extension packages are 1.5 to 2.5 times higher than for farmers using the traditional technologies. The yields are, however, substantially lower than those of other regional experiments and are less than yields researchers have achieved at agricultural stations. The principal reason for these differences appears to be the lack of adequate research and extension on fertilizer use. Especially important has been the extension service's use of a blanket fertilizer recommendation with little recognition of the need to supplement fertilizer with water harvesting technologies.

The MoA's willingness to extend subsidized inputs and credit to farmers was a major factor in the rapid and widespread adoption of these new technologies during the last five years. One consequence of the very rapid uptake of the new technologies associated with these extension programs has been to outstrip the capacity of the newly created Ministry of Agriculture (MoA) to supply the critical agricultural inputs (seed, fertilizer, pesticides, tractor rental services) needed to sustain them. The responsibility of production, procurement and distribution of inputs should therefore be gradually shifted to the private sector.

Experience in other countries has shown that private-sector provision of inputs and services is more efficient than that done by the public sector. The government realizes this, and plans are being made to encourage the private sector to engage in input procurement and distribution for profit. The MoA is now attempting to stimulate local farmer groups, banks, and companies to take

a more active role in input supply and credit and to increase the diversification of the semiarid cropping systems by encouraging small livestock and irrigated horticultural production.

## Output Markets

With its stress on achieving food self-sufficiency, Eritrea has maintained a large role in food marketing. The Eritrean Grain Board, a unit of the Ministry of Trade and Industry, is the state agency charged with purchasing and marketing agricultural products—especially cereals, pulses, and oil seeds. The Eritrean Grain Board was established in 1993 to execute the government's policy in grain marketing, procurement, and distribution and to maintain a national grain reserve. The Grain Board's operation has been largely directed toward supplying the urban demand, especially in Asmara (Ekube 2000).

Eritrea monitors its cereal supply very closely through the National Food Information System and the Eritrean Grain Board. The chief reason for this is the extreme vulnerability of the food supply to climatic fluctuations. Eritrea is often described as being "structurally food deficient." The Government's concern with food insecurity in early 2000 was increased by the addition, due to the recent war with Ethiopia, of more than 70,000 refugees and another 350,000 displaced people who depended almost entirely on government food aid. As the government moves to phase down the subsidies and encourage the private sector to supply inputs to the agricultural sector the government of Eritrea will also need to encourage competition and withdraw from marketing food. Once this process is begun, growth prospects in the different commodity areas will become a much more important policy concern.

### Demand Prospects for the Semiarid Crops

Since 1998, imports of teff from Ethiopia have been restricted, increasing the demand for sorghum, the principal substitute for teff which is the principal ingredient of injera. With rising incomes since 1993, the demand for poultry will increase, raising the demand for sorghum and millet as feed grains.

The domestic market for small ruminants is also increasing. The government of Eritrea intends, over the next ten years, to begin expanding its export of small ruminants to Saudi Arabia—a country that was a major outlet for Eritrean livestock exports in the 1960s and 1970s. Looking to the future, the MoA has collaborated with FAO in conducting a survey of the Jeddah Market as a basis for orienting the development of livestock research and extension activities.

Chickpea provides the sauce used on the injera, and is a basic staple of the Eritrean diet. It is also roasted so there is clearly potential for domestic demand with rising incomes. Both groundnuts and pigeon peas have potential for increased export expansion to other countries in the Horn of Africa. Eritrea has excellent access to the Middle East and European markets.

Sesame has been an important export of Eritrea and both sesame and sunflower grow well in semiarid conditions but Eritrea presently imports all its cooking oil. Further identification of the factors constraining increased domestic consumption of local oilseeds would be expected to have a high payoff.

**Demand for Horticultural Crops**

Historically, fruits and vegetables were important exports from Eritrea in the 1960s and 1970s. Since this time, however, the basic infrastructure for the management of these exports has broken down, and the market requirements have changed. Under its new water control and diversification initiative, the Ministry of Agriculture is seeking to (MoA/SPFS 1998):

1. identify suitable small areas, about 50 hectares each, for horticultural production, especially vegetables which can be irrigated through existing or proposed dams (Tagges, et al. 1999);

2. conduct market research in the Middle Eastern and domestic markets to provide information that the MoA can use to orient its crop research and infrastructure development projects;

3. facilitate planning by the MoA and other units of the Eritrean government for future donor investment in the infrastructure needed to facilitate export production in the medium (five years) and long (10-15 years) term;[6]and

4. identify private sector entities interested in investing in horticultural development in Eritrea and determine what legal and policy constraints inhibit this investment, and determine what, if any, processing constraints might exist for the proposed horticultural crops (for example tomato processing technology for fresh tomatoes).

The initial outlet for horticultural produce in Eritrea is the internal market that is dominated by Asmara where population of 500,000 consumes around 47,000 tons of fruits and vegetables annually (ICG 1999: 6). The market for high-quality produce such as grapes, strawberries, avocados, cherries, tomatoes, and lettuce, etc. is smaller and more volatile, but at this time highly profitable (ICG 1999). The Saudi market, which currently imports the large majority of high-value produce from Holland and California, is considered to offer greater long-term opportunities. The fast (30 minutes), cheap (US$ 0.60 per kg.) and regular (almost daily flights) freight supply from Asmara to Jeddah and Riyadh presents a competitive gateway to the Saudi market for commercial growers willing to focus on high-quality produce, packaging, marketing, and supply regularity (MoA/FAO 1999; ICG 1999: 7). Although horticultural exports have potential, and may become attractive options in the future, the MoA support for these areas should not be at the cost of additional investment in rainfed cereal production on which most of the Eritrean population depends for its source of calories.

The MoA is to be commended for its extensive investment in market research in connection with its current initiatives to promote agricultural diversification and water resource development. To date, however, this research has focused entirely on the European and Saudi Arabian markets.

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[6] Broad categories of infrastructure that need to be developed include: (1) normal grading and packing collection centers on a community basis and (2) ordinary dry storage and cold storage for vegetables.

More emphasis needs to be given to regional markets such as Djibouti, Sudan, Libya, Kenya, Ethiopia, and Uganda.

## The Research System

With independence and peace in the mid-90s, Eritrea could begin building its research capacity. There is a strong commitment from the Government and donors to support research staff and training. The share of the agricultural sector budget allocated to research increased from 0.3 to 2.3% from 1995-1997. The total research staff of the Department of Agricultural Research and Human Resource Development (DARHRD) has increased from one professional staff member in 1992, to 11 in 1995 and 68 in March 2000. The research division has five units: field crops and agronomy (plant protection, genetic resources, and soils); horticulture; forestry; livestock; and agricultural engineering.

There are three main agricultural research stations to cover the major agroecological zones. There are also a number of substations and testing sites that will gradually be undertaking research:

1. the Halhale research station, with substations at Merano, Mandefera, and Senafe which is representative of highland areas with a mandate for cattle, small ruminants, barley, wheat, teff, sorghum, horticultural crops and legumes;

2. the Shambuko research station, with a substation at Akaordat, representing the western lowlands whose mandate is for cattle, sorghum, pearl millet, sesame, groundnuts, maize, horticulture, and forestry. A second substation is planned for Galuj, in the southwestern lowlands where there is good rainfall and black cotton soils are widespread; and

3. the Sheib research station, with a substation at Gahtelay, represents the eastern lowlands which are the main area for irrigation. The station's mandate is for pearl millet, sorghum, maize and groundnuts.

Of the 65 researchers attached to the DARHRD there were one Ph.D., 12 M.Sc., 2 DVM, 24 B.Sc., 17 diplomas, and 9 certificate holders. Of these, 57 are male and only 8 are female. These staff were distributed among various disciplines with the highest number being in agronomy followed by soil science; food production and animal science had the lowest number (Table 12). There is a higher concentration of staff in the Halhale Research Station that is located in the high potential highland area adjacent to Asmara. All eight female staff are in this station whose main activities focus on wheat and barley. The other stations where research is focused on sorghum and pearl millet, have fewer staff.

**Table 12. Number of MoA employees in research by station and by area of expertise, March 27, 2000.**

| | Education Levels | | | | | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Regional location** | **Grade 0-11** | **Grade 12** | **Grade 12+Certificates** | **Grade 12+2 Dip** | **BSc/BA/** | **MSC/MA/MBA** | **DVM** | **Ph.D.** | **Total** | **Total %** |
| **1999-2000** | | | | | | | | | | |
| Headquarters Makaal/Asmara | -- | | | | -- | 2 | 1 | | 3 | 4.6% |
| Halhale | — | — | 7 | 16 | 19 | 9 | 1 | 1 | 53 | 81.5 % |
| Shambuko | — | — | 2 | -- | 3 | 1 | -- | -- | 6 | 9..2% |
| Sheib | — | — | -- | 1 | 2 | -- | -- | -- | 3 | 4.6% |
| Total | — | — | 9 | 17 | 24 | 12 | 2 | 1 | 65 | 100% |
| Total% | — | — | 13.8% | 26.2% | 36.9% | 18.4% | 3.0% | 1.5% | 100% | — |
| **1999-2000** | | | | | | | | | | |
| Agronomy | — | — | 3 | 4 | 7 | 3 | -- | -- | 17 | 27.4 % |
| Soil Science | — | — | 2 | 1 | 4 | 2 | -- | -- | 9 | 14.5 % |
| Gene Bank | — | — | — | 2 | 4 | 1 | -- | -- | 7 | 11.3 % |
| Horticulture | — | — | 1 | 3 | 3 | -- | -- | -- | 7 | 11.3 % |
| Plant Protection | — | — | 1 | 1 | -- | 1 | -- | 1 | 4 | 4.5% |
| Soil and Water Conservation | -- | — | 2 | 1 | 2 | -- | -- | -- | 5 | 8.0% |
| Farm Implements | — | — | — | 3 | -- | -- | -- | -- | 3 | 4.8% |
| Food Processing | — | — | — | — | 1 | -- | -- | -- | 1 | 1.6% |
| Animal Production | — | — | — | — | 1 | -- | -- | -- | 1 | 1.6% |
| Veterinary Science | — | — | — | — | -- | -- | 2 | -- | 2 | 3.2% |
| Forestry | — | — | — | 1 | 3 | 1 | -- | -- | 5 | 8.0% |
| Planning | — | — | — | — | -- | 1 | -- | -- | 1 | 1.6% |
| Total | — | — | 9 | 16 | 25 | 9 | 2 | 1 | 62 | 100% |
| % Total of all staff | — | — | 14.5% | 25.8% | 40.3% | 14.5% | 3.2% | 1.6% | 100% | — |
| **1995** | | | | | | | | | | |
| All fields | — | — | 6 | 0 | 1 | 3 | 1 | 0 | 11 | — |

Source: MoA Human Resources Division, March 2000 from MoA computer records.

Thirty-eight members of the DARHRD staff have attended short-term training programs at various CGIAR centers and other advanced research institutes. These include ICRISAT, CIMMYT, ICARDA, ILRI, ICRAF, IFDC, and the universities of Texas A&M, Auburn, Wales, South Africa (McMillan and Esele. 2000, Annex 1, Table 2). These short-term training programs range from two to six months. In general, this type of training has contributed significantly to improving the technical skills of the staff in implementing various research programs. Several in-country training programs were also organized for the administrative and extension staff in experimental designs, statistical analysis, scientific writing, on-farm research methods, research and extension linkages, data-based management, and monitoring and evaluation[7].

To date, the research focus of this new institution has been to acquire new materials, cultivars and concepts from other regions and test them for adaptation to the Eritrean environment. The DARHRD has established collaborative linkages with regional networks, international agricultural research centers, and other national agricultural research systems such as:

1. ASARECA networks including the potato network, the African highlands initiative, the soils network;

2. ECARSAM sorghum and millet network;

3. ICRISAT for sorghum and pearl millet;

4. ICARDA for wheat, barley, chickpea, lentils, and faba beans;

5. CIMMYT for wheat and maize;

6. ICRAF for agroforestry; and

7. INTSORMIL for *Striga* in sorghum.

The collaboration with ICRISAT, for example, has enabled identification and release of two sorghum varieties, PP290 and ICSV210 for the western lowlands, two for the eastern lowlands, 89MW5003 and 89MW5056, and one pearl millet variety, ICMV 221, for the western lowlands (Obilana, 2000).

To date, the DARHRD research department has concentrated almost entirely on adaptive research to screen, evaluate on-farm, and diffuse new technology borrowed from the International Agricultural Research Centers. The Department's emphasis on screening is entirely justified given that it is only beginning research with inexperienced research staff. In the near future, however, it would be advisable to consider developing a breeding program with crossing blocks where the introduced materials are cross-bred with the local land races. The local land races have adapted to the local environments over a long time and therefore have useful attributes. The introduced materials, on the other hand, also have useful attributes especially higher yield potential and resistance to pests and diseases. Crossing of the locals and exotic materials enables selection for adaptation but with better attributes not presently found in the local cultivars. Donors, especially

[7] The workshops were conducted with technical assistance and funding from ICRISAT, ICARDA, and CIMMYT.

the Italian government and DANIDA (emphasis on seeds development by Denmark), have been supporting the development of research capacity. The University of Asmara is planning to launch its first postgraduate programs in agriculture in about five years. It will need to be better integrated with the Eritrean research system if it is to utilize scarce personnel more effectively than is usually the case in African countries.

## The Extension System

Since the mid '90s, the Eritrean government has created a series of programs whose principal goals are to expand agricultural output by promoting higher input use and new cultivars. The extension service has been central to the implementation of this program, including delivering the subsidized inputs, principally fertilizer and seeds. In contrast to the Ethiopian program that emphasized wheat and maize which are better adapted to the higher rainfall zones, the Eritrean programs concentrated on sorghum, barley, teff, and millet. Approximately, 50% of the area in cereals and pulses is in sorghum, a crop well adapted to the semiarid areas. In 1999, farmers in one-fourth of the sorghum area who participated in one of the intensification programs of the Eritrean government out yielded non-participating farmers by 70 to 80%. Similar gains were claimed for barley, teff, and pearl millet, until an outbreak of downy mildew infected the millet.

### Early Evolution of the State Extension System

After 1971, the Eritrean Peoples Liberation Front (EPLF) included an agricultural commission whose goal was to promote technology dissemination in the interest of the people involved in the liberation struggle. These activities were undertaken in the EPLF controlled areas. During this time, the EPLF agricultural commission sought improved seeds from the major regional international agricultural research centers (IARCs) active in the region (e.g., ICARDA, ICRISAT) and NGOs.

The base mobilization/extension unit for the wartime crop extension and production programs was the elected village councils. This strong organizational base among the population, with highly developed communication upwards and downwards through councils at the district, provincial, and national levels, was one of the secrets to their successful record in technology diffusion. In the immediate post-war period, this grassroots network was transformed into a local government structure extending over 41 sub-provinces, 251 districts, and 2,535 villages, the latter organized in some 1,600 village councils (*baito*).

At independence (1991), the Eritrean government merged the people who had formerly worked for the Ethiopian national extension service based in Eritrea with the EPLF agricultural commission. In 1992, the EPLF Agricultural Commission was transformed into the Department of Agriculture. The Department of Agriculture then became the Ministry of Agriculture in 1993.

Between 1991 and 1994, the main objectives of the Ministry of Agriculture were to jump-start the rural economy and arrest environmental degradation. (Table 13). To achieve these objectives, the newly created MoA embraced a wide range of activities including planning, input supply, planting material production, soil and water conservation (small dam construction, terracing, tree planting, soil testing), feeder-road construction and rehabilitation, installing irrigation facilities, tractor hire,

pest control, prevention and treatment of livestock diseases, artificial insemination, training, technology testing and transfer, rehabilitation and management of state farms and agroindustrial enterprises.

The pace of reconstruction and development increased after 1993 with the advent of the multi-sectoral and multi-donor financed Recovery and Rehabilitation Program for Eritrea (RRPE) (1993-1994). Out of $16.6 million committed for agriculture, 93% was for the procurement of seasonal inputs, livestock, and farm equipment, and $1.2 million was for institutional strengthening (TA, vehicles, office supplies and equipment) (FAO 1994b, Annex 3:, p. 12). Other aids to agriculture during this transition time period came from the EEC (for integrated rural development), technical assistance; and from the Italian Cooperation for input procurement (seed, fertilizer, pesticides, work oxen, farm tools, and equipment). Most aid was funneled through the RRPE or UNDP donor coordination structure (PREFER). The chief exception was German aid, through GTZ, which included a number of discrete community self-help projects (ibid.).

From 1991, the NGOs continued to support government implementation with more than 20 international NGOs directly involved in agricultural development (ibid.). In 1993 and 1994, their contribution to the MoA was estimated at around $20 million annually, a figure equivalent to the annual contribution (combined) of the multi-donor RRPE and Italian Cooperation (ibid, pp. 10-13). It was anticipated in 1994 that future NGO activities would likely focus on the more marginal areas and the provision of socioeconomic safety nets (ibid.).

It was against this background of rapid post-war reconstruction that the country embarked on its first comprehensive Agricultural Sector Review. The process was highly participatory and included a number of background papers, Ministry and non-Ministry Eritrean experts (FAO 1994a, p. 3)[8]. The resulting document included a list of identified needs for coordinated donor support to develop agricultural research and extension. Eritrea's record for sound management of the preceding generation of transition development funds combined with the review's emphasis on infrastructure development, capacity-building, and input supply attracted donors that supported different components of the program (Table 14). Although the limited development of the private sector in Eritrea in the early 1990s forced the government to play a direct role in input supply, the Agricultural Sector Review emphasized the government's commitment to facilitating evolution of the private sector.

[8] The Sector Review was carried out under the responsibility of the Policy Analysis Division of FAO's Economic and Social Policy Department.

## Table 13. Number of MoA employees in extension-related positions, 1994 and 1999-2000*/**

| Regional location | Education Levels | | | | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| | Grade 0-11 | Grade 12 | Grade 12+ | Grade 12+2 Diploma | B.Sc./ BA | MSc/ MA/ MBA | DVM | Total | Total % |
| **1999-2000*** | | | | | | | | | |
| Headquarters (Makaal)/Asmara | 6 | 8 | 28 | 31 | 28 | 21 | 2 | 124 | 20% |
| Anseba | 3 | 2 | 22 | 22 | 26 | 1 | 3 | 79 | |
| Debub | 21 | 20 | 50 | 36 | 24 | 1 | 2 | 154 | |
| Gash Barka | 15 | 13 | 50 | 31 | 28 | 0 | 3 | 140 | |
| N.Red Sea | 12 | 11 | 16 | 20 | 25 | 0 | 1 | 85 | |
| S.Red Sea | 0 | 4 | 7 | 8 | 6 | 2 | 1 | 28 | |
| Total | 57 | 58 | 173 | 148 | 137 | 25 | 12 | 610 | 100% |
| Total % | 9.4% | 9.5% | 28.4% | 24.2% | 22.5% | 4% | .2% | --- | 100% |
| Total % | 47.3% (less than diploma) | | | 24.2% | 26.7% (B.Sc. and above) | | | | |
| **1994**/***** | | | | | | | | | |
| Headquarters — Civilian | 122** | | — | 11 | 2 (B.Sc. and above) | | | 135 | 12.8% |
| Regional Offices — Civilian staff (land resources [soil and water conservation, forestry]), animal resources, rural agricultural development | 686*** | | — | 176 | 56 (B.Sc. and above) | | | 918 | |
| Subtotal | 808*** | | | 187 | 58 (B.Sc. and above) | | | 1053 | 100% |
| Subtotal % | 76.7% (less than diploma) | | | 17.76% | 5.5% (B.Sc. and above) | | | — | 100% |
| Headquarters — Ex-Fighters (same depts. as above) | 9*** | | — | 0 | 4 (B.Sc. and above) | | | 13 | |
| Regional offices — Ex-Fighters (same depts. as above) | 699*** | | — | 4 | 8 (B.Sc. and above) | | | 711 | |
| Subtotal | 708*** | | | 4 | 12 (B.Sc. and above) | | | 724 | |
| Subtotal | 97.8% (less than diploma) | | | 55 | 1.65% | | | 100% | |

*Source and methodology: Based on the MoA calculations conducted by the Danish Embassy/FAO review mission, "Redefining of Strategies for Farmer's Advisory Services," March 2000. This analysis reviewed all job titles for staff at different grade levels and eliminated job titles (accounting assistant, administrator, chemist, design engineer, electrician, Halhale horticulture research technician, etc.) that were not considered to be extension posts.

**Source and methodology: Based on the MoA calculations of staff by level of education and department which were included in the 1994 Sector Review (FAO 1994b, Annex 3, Tables 1c and 1e).

***1994 Sector Review figures were disaggregated for literates, grades 1-8 and 9-12. For the purpose of this analysis, these figures are merged and compared with the current figure of Grades 0-11.

**Table 14. Bilateral, multilateral, and NGO collaborative programs with the MoA Land Resources and Crop Production Dept., 1994-1999**

| Project/programs (donor support) | Local | External | Infrastructure | Staff Training | Overseas Training | Input Supply | Farmer Training |
|---|---|---|---|---|---|---|---|
| Assistance for National Food Information System (FAO/Gov Italy) | 483.640 Nak | 316,400 US$ | X | X | -- | -- | -- |
| Bada irrigated agriculture (AFRICARE) | – | 609,200 US$ | X | -- | -- | -- | -- |
| Capacity building (NORAD) | -- | 550,200 US$ | -- | X | X | | |
| Central Highlands Horticultural Development (African Development Bank) | | 2,041,550 US$ | 316,400 US$ | X | --- | X | -- |
| Special Program for Food Security (FAO/Gov Italy) | ----- | 540,000 US$ | X | -- | -- | X | X |
| Eastern Lowlands Wadi Development Project (IFAD) | 263,597 Nak | 3,289,800 US$ | X | X | -- | X | -- |
| Greening Eritrea (DANIDA) | 2,075,667 Nak | 10,000,000 US$ | X | -- | -- | -- | X |
| Integrated Watershed Development (Saudi government) | --- | 2,516,000 DK | X | X | | | |
| Mendefera Integrated Rural Development (Self-Help International) | -- | 1,055,500 US$ | -- | -- | -- | X | X |
| National Seed Development (DANIDA) | 386,911 Nak | 6,526,100 DK | -- | X | -- | -- | X |
| National Tree Seed Development (DANIDA) | 254,980 Nak | 2,141,695 DK | -- | -- | -- | X | -- |
| Riverine Forest (SOS Sahel) | ---- | 395,400 ECU | -- | X | -- | - | -- |
| Sasakawa Global 2000 Agricultural Project in Eritrea (SG2000) | --- | 277,700 US$ | -- | -- | -- | X | X |
| Strengthening Agricultural Research and Extension (FAO/Gov Italy) | 25,000 Nak | 1,078,600 US$ | -- | -- | X | -- | -- |
| Zula Integrated Development (NCA) | --- | 556,100 US$ | -- | -- | -- | X | X |

Source: MOA, Project Profiles and Budget Information, Asmara, Eritrea, pp. 1-222, and updates with Ministry staff, in Ekube, 2000.

X indicates that the project funded activities in this area.

The creation of the Ministry of Agriculture coincided with the recruitment of 1,000 secondary school graduates (ex-fighters) as field level staff on two-year trial contracts. This new recruitment pushed the number of female staff to 40% and increased extension coverage (one extension agent for every 300 to 350 rural households, i.e., two to three villages) (FAO 1994, Annex 3, p. 6). The same hiring, however, created a huge need to train extension workers since 98% of the ex-fighters who joined the DARHRD had less than a high school education. (Table 13). To cope with the sudden influx, the Ministry geared up a hasty crash course to train new extension workers that was taught by the existing extension staff in a temporary building. In 1996, the Ministry was restructured again with staff retrenchment to retain only the best extension workers.

Strong, informed leadership will be necessary for these new research and extension models to take root. This is a problem in Eritrea where there is a dearth of agricultural scientists trained at the B.Sc., M.Sc. and Ph.D. levels and a lack of training programs. The need is especially great for female research and extension staff who had many fewer opportunities to travel abroad for undergraduate and graduate study courses.[9]

The University of Asmara is contemplating a new model for collaboration with MoA in upgrading certificate and diploma level extension and research workers.[10] This collaborative program offers an unprecedented opportunity to develop the firm base of male and female leadership that the MoA needs to lead its programs in the coming decades. This program is especially important for female research and extension staff for whom the social costs of overseas education are especially high. Consideration should also be given to developing collaborative M.Sc. and Ph.D. training programs in key fields, such as food technology, forestry, soil science, agronomy, agricultural economics, rural sociology, and extension that combine a mixture of in-class training with correspondence courses. The same upgrade programs offer an unprecedented opportunity to increase the quality and relevance of the College of Agriculture's training and research programs by strengthening the University's linkages to MoA research and extension programs. This approach of building up staff development from below may also help Eritrea avoid some of major problems that its neighbors face in which the extension and research programs are dominated by staff with little field experience.

**Introduction of the New Intensification Programs (1994-present)**

A new model for decentralized government was announced in 1994 that included the creation of an independent Ministry of Agriculture. Under this new model, the administration of extension was separated from research and placed under the Department of Rural Agricultural Development. Soil-and-water conservation activities were placed under the Land Resources Department. The two departments combined included 1,777 employees (1,053 civilian and 724 ex-fighters) (Table 13). Since 1994, Eritrea's agricultural extension programs have focused on three national-level pilot programs that were designed to intensify production in smallholder agriculture. The first was the

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[9] At the time of this study, only one of the 42 home economics staff has a B.Sc.. degree. The official records of the ministry show that out of 166 female extension staff, 47 have B.Sc. and none have a M.Sc. (MOA, HRD in McMillan and Esele. 2000: Annex 2, Table 1 and pg. 37).

[10] The precedent for this program is two innovative training programs that the University introduced in 1998 to upgrade certificate-level training to the level of a diploma for legal assistants and social workers with assistance from UNICEF.

Special Programme for Food Security (SPFS) which employed participatory on-farm demonstrations to show simple crop husbandry practices imported from other countries (primarily Ethiopia). When the program began in 1995 on a pilot basis in three villages representing three different agroecological zones having different socioeconomic and ecological variations, it included 243 demonstration farmers. Since this time, the total number of voluntary participants has increased tenfold (Table 15).

The following year, the government embarked on a second pilot program to promote subsistence agriculture in collaboration with SG2000 in the central highlands. This program focused on introducing inorganic fertilizers and new cultivars (or cleaned seed of present cultivars where no new cultivars were available). The major difference between the SG2000 program and the Special Program for Food Security is the SG2000 program's formal commitment to providing feedback to researchers on the technologies being demonstrated and tested, especially with regard to fertilizer applications. Both programs experienced a rapid growth in farmer adoption after the initial demonstration phase. Both provided the government with a new vision for technology diffusion for smallholder agriculture.

In 1998, the labor scarcities resulting from the war with Ethiopia encouraged the government to introduce a third program involving rapid labor substitution — the Integrated Farming System (IFS). The IFS package provided credit to qualified farmers to purchase tractor services, seeds, and fertilizer. To qualify, farmers had to link with neighbors to consolidate their land and to form a service cooperative for coordinating input supply and the cost of a shared tractor. Widespread publicity and support of the Eritrean government for the program resulted in a spectacular takeoff with 44,924 ha being planted under the new IFS in just the first year. This number doubled to 98,057 ha in the second year (Table 15). In 1999, approximately one-fourth of the total land area of the country was associated with one of the three programs (MoA, informal estimates). Yield data are hard to measure and notoriously inaccurate from government ministries. Nevertheless, the reported gains for this program are impressive (Table 16).

The MoA is in the process of redefining its entire extension and research strategy that continues to be heavily focused on increasing food security by: (a) promoting more sustainable rainfed yields and (b) increasing the diversity of local and national level revenues through the development of small- and large-scale irrigation. As part of this process, the MoA is attempting to define a new strategy for extension and research that is designed to be more participatory and demand driven[11].

[11] The key to this new strategy is to strengthen the ability of farmer organizations to work with the MoA as active partners in the distribution of inputs (seeds, fertilizer) and in the development and testing of new varieties, agronomic practices, water-harvesting technologies (both rainfed and irrigated). This initial inclusion of farmer organizations in development is expected to pay off by reducing the long-term recurrent costs to the government for input supply and extension. In connection with the new model for farmer advisory services, the government is contemplating the development of a series of new initiatives to strengthen research and extension-worker capabilities (or knowledge and skills) by formal training and technical assistance (MoA/FAO 2000). It is expected that under the new system, technical information and inputs will be more available to women farmers.

Parallel to the new model for advisory services, the MoA is in the process of finalizing the terms of its collaboration with the Ministry of Health in executing the nutrition component of a new IDA-supported Eritrea Integrated ECD Project.[12]

**Table 15. Major pilot projects for extension in Eritrea, 1995-1999.**

| Arid/ semiarid | Agroecological zone | Special program for food security | | SG2000/ Gov. Eritrea | | Integrated farming systems project | |
|---|---|---|---|---|---|---|---|
| Transition | Greenbelt* | No | | No* | | No | |
| Semiarid | Central Highland Zone | Yes | | Yes | | Yes | |
| | Southwest Lowland | Yes | | No | | Yes | |
| | Western Escarpment | No | | No | | Yes | |
| Arid | NW Lowland Zone | No | | No | | No | |
| | Coastal Plain Zone | Yes — spate irrigation | | No | | Yes — irrigation | |
| Participation | | No of Farmers | Area (ha) | No. of Farmers | Area (ha) | No. of Farmers | Area (ha) |
| 1995 | | 243 | | ------- | | — | — |
| 1996 | | 246 | | 296---- | | — | — |
| 1997 | | 379 | | 2031-- | | — | |
| 1998 | | 2725 | | 3103 | | | 44294 |
| 1999 | | 4717 | | 3651 | | | 98057 |

**Despite this area having the highest rainfall, it is not considered to have as much agricultural potential for the future as the central highland, southwest lowland, and western escarpment regions. This is due to several factors including the topography that is very steep, the limited land area and the high population densities that already exist in this area. Population densities are very high in the Greenbelt.

[12] The goal of the project is to reduce the high rates of malnutrition observed in infants and toddlers in the first two years of life by strengthening village-level nutrition and health education programs, reducing women's labor, and improving food quality and quantity for all women particularly those who are pregnant and lactating (World Bank. n.d.: 4-5). Given the strong record of the MoA home extension agents in working with rural women in the past, it was decided to make them the major communication channel through which these messages will be routed (ibid.). In connection with this project, the number of home extension agents will be increased from 40 to 60 and the home extension agents will receive three months special training to strengthen their skills.

**Table 16. Comparison of crop yields obtained under different MoA extension programs, 1997-1999 kg/ha*.**

| Year | Crop type | Tradi-tional | Special program for food security | SG2000 | Integrated farming systems |
|---|---|---|---|---|---|
| 1997 | Sorghum | 1000 | 700 | 2000 | -- |
| | P. Millet | -- | -- | -- | -- |
| | Barley | 800 | -- | 1500 | -- |
| | Wheat | 850 | 1100 | 1850 | -- |
| | Maize | 1000 | -- | 2900 | -- |
| | Teff | 650 | -- | 1450 | -- |
| | | | | | |
| 1998 | Sorghum | 700 | 1700 | 1400 | 1800 |
| | P. Millet | 600 | -- | 600 | -- |
| | Barley | 800 | 1500 | 1800 | 1500 |
| | Wheat | 700 | 1570 | 1500 | 1500 |
| | Maize | 600 | -- | 2000 | 1500 |
| | Teff | 600 | -- | 1600 | 1000 |
| | | | | | |
| 1999 | Sorghum | 800 | 1800 | 2000 | 1300 |
| | P.Millet | 400 | -- | 600 | 1200 |
| | Barley | 600 | 1500 | 1500 | 1500 |
| | Wheat | 700 | 1500 | 1500 | 1800 |
| | Maize | 600 | -- | 1800 | 1500 |
| | Teff | 300 | -- | 800 | 1000 |

*Conversion from quintals; 1 quintal = 100 kg.

Sources: MoA Land Resources and Crop Production Dept., Crop Production Division, annual reports in Ekube, 2000.

## Equity and Gender[13]

The first phase of the agricultural programs begun in 1994 focused on increasing production. The country is now reflecting on how to strengthen drought resistance and environmental sustainability which were objectives of these first-generation crop extension programs. At the same time the extensionists are starting to pay more attention to some of the socioeconomic issues that affect farmers' willingness and ability to benefit from these programs. Especially important has been the Ministry's growing interest in improved targeting of the country's poorest farm families, a high percentage of which are female-headed (estimated to be around 35% nationally with wide variation among regions).

Rural Eritrean society has traditionally been characterized by a relatively strict patriarchal order in which a female's status depended on her father or her husband (UNICEF 1996, p. 25). A girl was expected to marry at a young age and education was not given a priority. Although women do

[13] Special thanks to the MoA Research Staff who contributed actively to the identification and analysis of some of the key issues in this chapter, including Gimja Amare Masho, Nezehty Abbay, Gidey Gebreslassie, Alganesh Tesfamariam, Eden Maekele, Rozina Berketeab, Teblez Zeccarias, Elsa Abraham, and Elsa Ghebregziabher.

not often own land, they have always played an important role in the crop production systems of the region.

One consequence of the long liberation struggle was an increase in women's access to a wider range of educational and employment opportunities. Indeed, the Ethiopian Peoples Liberation Front (EPLF) training programs discriminated in their favor (UNICEF 1996, p. 24; NEW 1993). In 1990, 30% of EPLF combatants were women. Women commanded EPLF battalions, drove tanks, and undertook guerilla activities. In EPLF-held areas, they worked as doctors, teachers, mechanics, administrators, and factory workers.

The speed of change in gender roles was accelerated under the leadership of the National Union of Eritrean Women (NEW) which became the principal apparatus to mobilize female support for the war and the major mechanism to orchestrate two-way communication between the people and the government regarding legal and social reforms and programs to benefit women.

At the same time, while the war catalyzed a number of positive shifts in gender ideologies and organizational capabilities which favored women, it created a host of new impediments to improving women's living standards. Especially important were a substantial increase in the number of *de facto* and *de jure* female headed households and the breakdown of a great deal of the country's basic infrastructure.

The combination of these factors with the highly unstable food production during the long war for liberation exerted a toll on women's and children's health (UNICEF 1996, p. 32).

**Box 1. Women's Roles in Agriculture and Land Resources Conservation**

In rural Eritrea, women play very important roles in practically all life-sustaining activities including farming, which ostensibly appears to be a male activity. However, due to religious, ethnic and regional variations, women's roles differ widely. For example, the women who live in the highlands and within the mid-altitude areas of Eritrea are mostly Christians, and they actively participate in the social life of the community more or less equally to their male counterparts. In the agricultural sector, women take part in many activities including weeding, cleaning the crop fields, harvesting, and transporting the harvest home. However, women do not plow. Women who are widowed, divorced, or not married depend on male relatives for plowing or they make some other arrangements with other men to plow their crop fields.

In the lowlands, the majority are Muslim. Muslim women usually remain at home; their engagement in the crop fields follows religious prescriptions of gender roles. They, however, perform a number of tasks at home including the usual household chores. They take care of the family, go to market, sell what they produce, and buy what the family needs. The exception to the western lowlands is the Kunama woman who takes part in all farming activities as do the highland women. (Source: Rehabilitation of Degraded Lands, University of Asmara and MoA, 1998, Asmara, Eritrea.)

**Participation in Rainfed Agricultural Extension Programs**

All three major extension programs since the mid '90s have been open to women[14]. There was, however, no special effort to go to women's groups to encourage their participation. Given the persistent conservative bias in gender relations in most rural areas and the low levels of literacy of many women, it is not surprising that they tended to participate in these programs at lower rates than men. Ekube (1999, p. 9) found that 409 (15%) of the 2,725 participants in the Special Program for Food Production in 1998-99 were female-headed households.

In analyzing some of the factors that discouraged women's willingness and ability to benefit from these subsidized agricultural services, one has to consider the high labor demands associated with routine housekeeping and child care. The burden of the womens' double roles was increased by the lack of improved water points and fuel wood supplies in the vast majority of villages. These labor burdens fell especially hard on the 35% of rural households that are estimated to be female-headed. All of these constraints were exacerbated by the remobilization of the army and the population displacements associated with the renewed hostilities with Ethiopia in 1998 (Gruper von Kerenshazy and Tschainesh 2000).

Another factor that affected women's participation in the MoA agricultural programs was the their lack of understanding of the terms under which these services could be acquired (Gruper von Kerenshazy and Tsanisch 2000). Specifically, while men in the villages understood that the small, heavily subsidized fees for tractor services could be paid at the end of the agricultural seasons, many women did not. The women's lack of understanding was the direct result of their marginalization from the mainstream communication channels within the village. Although government policies encourage and indeed mandate that 30% of the leadership positions in the village councils (*baitos*) be held by women, the majority of councils continue to be dominated by men. This lack of informed participation by women in leadership positions affects their ability to get accurate information on extension programs.

**Participation in MoA Home Economics Programs**

Parallel to the activities of the MoA Agricultural Extension Workers, the MoA has organized a separate subset of programs focused specifically on women and improving the living conditions of the farmer households. These activities are coordinated by the Home Economics Unit that is under the Department of Land Resources and Crop Production which falls within the MoA Crop Production and Protection Division. (Gimja, 1999a,b).

The Unit undertakes various activities including: (1) publication of training materials, such as leaflets, posters, pamphlets and manuals, which are distributed to women farmers through the MOA home economics agents; (2) preparation of public information training by means of mass media sources, such as radio, television, and newspapers; and (3) the organization of theoretical and practical training programs on food and nutrition, clothing and textiles, mother and child care,

[14] (1) The Special Program for Food Security (SPFS), (2) the Sasakawa Global 2000 Program, and (3) the Integrated Farming Systems Program.

home improvement and management, health and environmental concerns, and income-generating activities. The Unit is also responsible for the collection of data pertaining to women farmers and farming households as well as investigating gender issues that arise in connection with specific programs (Gimja, 1999a,b). Over the last two years, the Unit has benefitted from various supplementary grants from UNICEF and DANIDA which have helped fund staff training and implementation of these programs.

Since 1995, UNICEF has provided support to the Home Economics Unit to strengthen its nutritional education. Based on our interviews with UNICEF and MoA staff, both partners consider this program to have substantially increased the level of local knowledge about infant nutrition and childcare. The UNICEF director stated that he expected to see this increase in local knowledge reflected in a substantial increase in nutritional standards in the next national health and demographic survey.

More recently the Home Economics Unit (with support from FAO and UNICEF) conducted a series of preliminary and more specialized training programs for women that involved 411,710 and 10,051 respectively in just one year (World Bank, 2000).[15]

Although the Home Economics Unit emphasizes the importance of introducing labor- saving, household technologies for women, the linkages between extension and research on this topic are very weak. This weak linkage is exacerbated by the fact that there is no recognized food technology unit with the research division. The few food technologies in the country are scattered among the Ministry of Health, the Veterinary Livestock Services, the Ministry of Crop Industries, and the Grain Board, as well as the MoA Home Economics Unit and Research Divisions.

**Participation in MoA Research**

As discussed above, the majority of the demonstration farmers in the extension program associated with the village groups are men, in large part because these are the people the village leaders (who are male) tend to choose. The research by the soils division is more participatory since the researchers were forced to go out and talk to people about their land-degradation problems before developing corrective measures. A female member of the soils research staff emphasized, however, that the decisions of whom to interview were not their own but dictated by the local government leaders. The only other programs where we found a female scientist or technician to be in direct contact with women farmers were in the forestry research projects. Of the eight women technicians and researchers interviewed, only two had ever talked with women farmers off-station. This lack of contact with female farmers reflects a more general trend in research since 1994 which has been

[15] Once a regional location has been identified for an activity, the home economist conducts a survey to identify the problems and needs of the community. Based on this survey, the home economist prepares a plan for preliminary training. This training is conducted in groups in the communities. The training covers food and nutrition messages and home improvements. After this initial round, a group of women are selected for special training. These special training programs usually last for 15 days and focus on special topics that include home improvements and income generating activities (horticulture and animal husbandry for poultry and bees) Each woman selects the specific activity she wants to undertake and gets additional training for that selected income generating activity. The women are then given credit in kind (chicken, goat/sheep, beehives and accessories, agricultural tools) with which to undertake the chosen activity. During 1999, 411,710 women were given this preliminary training; another 10,051 that were selected from this larger group were selected for inclusion in the special training workshops. This activity was supported by UNICEF and FAO. Another 2000 women are slated for training by the home economists during 2000 (World Bank 2000).

top down and focused on increasing delivery of inputs to farmers in a speedy and efficient manner needed to increase food production quickly. Strengthening linkages between research and extension was broached in the preliminary discussions for the proposed MoA/FAO/DANIDA initiative, "Redefining Strategies for Farmers' Advisory Services" (from the extension side) (2000-2005) and for the second phase of the MoA/Republic of Italy/FAO project, "Strengthening of Agricultural Research in Eritrea" (2000-2003).

Every one of the women professionals interviewed both within and outside the Ministry of Agriculture emphasized the critical importance of staff at all levels being made more conscious of gender issues. To date, neither MoA research nor extension staff have benefitted from any sort of organized training in gender sensitivity or gender analysis. Given the enthusiastic response of MoA extension and researchers who attended the March 21, 2000 workshop at which the draft technical paper on "Gender Relations in Eritrea" (Gruper von Kerenshazy and Tsehainesh 2000) was presented, there seems to be a tremendous demand and receptivity for this type of training and analysis.

These activities are likely to be hampered by the lack of a recognized, interdisciplinary working group or program that crosscuts the different research and extension programs. A task force/working group would provide a focal point for communication with other individuals in some of the most active donor agencies (DANIDA, FAO, World Bank) and NGOs (e.g., AFRICARE, ACORD, etc.), as well as gender units/experts within the regional IARCs (ICRISAT, CIMMYT, ICARDA). An additional difficulty is the lack of basic socioeconomic studies and gender disaggregated monitoring information.

## Conclusions

This substantial increase in technology uptake and food production in Eritrea's semiarid zone constitutes a major regional success. Technology transfer to date has focused on the screening and diffusion of a limited number of new varieties introduced from outside Eritrea. This success is even more remarkable given the fact that Eritrea started off with only 11 technicians and researchers in the entire research division in 1995 and almost no infrastructure base for either research or extension. Although the number of staff has increased to 64 in 2000, the staff still has very limited technical training.

Despite the low level of training in the extension service, extensionists have been very successful in increasing output. The two most important factors accounting for this rapid technology transfer were: (1) the government's willingness to heavily subsidize inputs, namely seed and fertilizer, on credit; and (2) the strong local support for government extension throughout the semiarid areas. The combination of these two factors seems to have facilitated the rapid technology transfer despite a high household/extensionist ratio (one agent to 1,750 households in March 2000).

The same rapid increase in the transfer and utilization of technology has quickly outstripped the ability of the government to satisfy the rapidly growing demand for improved inputs. Although the government has created two new seed-processing companies and is working with communities to improve seed production and distribution, it cannot keep up with demand. The demand for fertilizer has increased to the point that extension agents spend most of their time handling farmer input orders and credit reimbursements to the MoA.

The Ministry of Agriculture is now considering various ways to divest itself of the responsibility for input distribution and transfer these activities to farmer groups and the private companies. At the same time, it is contemplating a new pilot program with the NGO ACORD to extend the highly successful ECDF and SZRS/ACORD group credit programs to support input and technology credits to village extension groups.

There is room for the expansion of rainfed cereal and pulse production in the coming years. Even in an average rainfall year (1999), Eritrea managed to produce only 70% of its national cereal requirements. There is also evidence of increasing demand for livestock production in national markets and room to expand exports of livestock products to the Middle East. Current plans for the MoA emphasize further strengthening of the country's production program for dryland cereals as well as increased diversification by development of small- and medium-scale livestock production and increasing the area planted in small and medium-scale irrigation.

The same revised strategy which is being developed will include new ways to improve the participation of poorer farmers, a high percentage of whom are women. The government is also developing a new multi-sector initiative involving the Ministry of Health and the Home Economics Unit of the MoA to address some of the non-production issues, such as labor-saving household technologies and nutritional education.

## Looking to the Future

The ability of the Eritreans to create strong links among farmers, extensionists and agricultural researchers and to rapidly intensify agricultural production is impressive. The agricultural research system will need to develop new cultivars by crossing local varieties with exotic germplasm which can confer improved characteristics. Fertilizer research and extension recommendations will need to move beyond blanket recommendations by focusing on improved evaluation of soil characteristics, testing of soils, plants and water, and mapping of differing soil characteristics throughout the country.

Much more emphasis in both research and extension needs to be put on the combination of water-retention and fertilization strategies. The extension service needs to facilitate the evolution of the private sector, so that the government of Eritrea can withdraw from the agricultural input supply business.

The engagement of the private sector in the seed and fertilizer distribution businesses has its own problems, as was demonstrated in the other national reports. At present, with the accelerating diffusion of improved agricultural techniques, the public sector cannot respond rapidly enough to the increasing demand for inputs (seeds, inorganic fertilizers). In the long run, privatization is more efficient and will provide higher quality services. The private sector will be needed to identify and expand new products and processing services.

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# Sudan

## Three Farming Sectors and a Continuing War

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## Acronyms

| | |
|---|---|
| APC | Agricultural Production Corporation |
| ARC | Agricultural Research Corporation |
| ASSCO | Arab Sudanese Seed Company |
| CNS | Comprehensive National Strategy for 1992-2002 (for Sudan) |
| DAS | Dept. of Agricultural Statistics, Ministry of Agriculture and Forestry, Khartoum |
| ENCCP | Ennuhod Co-operative Credit Project |
| FAO | Food and Agriculture Organization of the United States |
| GNP | Gross National Product |
| GOS | Government of the Sudan |
| IIED | International Institute for Environment and Development |
| MFC | Mechanized Farming Corporation, parastatal supporting the mechanized rainfed projects. |
| N | Nitrogen |
| OFRP | On-Farm Research Project in Traditional Rainfed Areas, Sudan |
| P | Phosphorus |
| SOM | Soil Organic Matter |
| SWKADP | South and West Kordofan Agricultural Development Project |
| TSP | Triple Super Phosphate |
| UNDP | United Nations Development Program |
| UNFPA | United Nations Population Fund |
| WSARP | Western Sudan Agricultural Research Project |

## Economic Background

In mid 1999, the Sudanese population was 30.2 million with 5 million in the south directly affected by the continuing war. FAO estimated that in 1999 there were 2 million nutritionally at risk in spite of a good agricultural year for the country (FAO/WFP, Dec. 1998, pp.11,16). The population is growing at the annual rate of 2.7%. Agriculture employs 75% of the population and produces 48% of the GNP (Abuelgasim, 2000, p.1). The people living in dryland regions in the Sudan were estimated at 10.6 million in 1999, 35% of the population. In 1997, national per capita income was $280 and life expectancy 54 years (World Bank, 1999, p. 232).The continuing civil war over most of the last thirty years has kept incomes and welfare low in spite of progress in the agricultural sector.

Beginning from the public investments in the '20s Sudan has been very successful in the development of irrigated systems on the vertisols. Then, after the Second World War there were substantial investments made to install mechanized farming systems on the dryland vertisols. The mechanized rainfed systems were expanded very rapidly in the last thirty years and now two thirds of the country's principal staple, sorghum, comes from there. Sorghum accounts for 75% of cereal production in Sudan and is eaten as a bread, porridge, beverage and beer(Sanders et al, 1996, p.114).

The neglected farming system has been the traditional small holders concentrated on the sandy and clay soils primarily in Western Sudan. In the '80s USAID and the World Bank attempted to build up the research system in the West but events of the early 90s in the continuing civil war led to the donors largely ceasing their activities in Sudan. To date there has been little improvement in agricultural productivity in Western Sudan. Moreover, in the '90s there has been a period of stagnation on both the irrigated and the mechanized dryland systems resulting from the lack of public resources.

This country report has the following format: a) background on the three principal farming systems; b) review of successes and potential successes in new technology introduction; c) the national research system;, d) extension activities of the public service and NGOs, and finally e) conclusions.

## Agricultural Systems in the Sudan

The drylands are approximately between 10 and 14 degrees north of the equator (Fig. 1). There are 684,000 sq km in this region (including some irrigated areas of wheat and barley above 14 degrees). This is 27% of the crop area (Ministry of Agriculture and Forestry, 1996). Below Kadugli, the rainfall is greater than 800 mm (Fig. 2); however, on the Goz sands with substantial infiltration and high evapotranspiration this still leaves very little water available to plants, so semiarid production conditions extend into these higher rainfall areas.

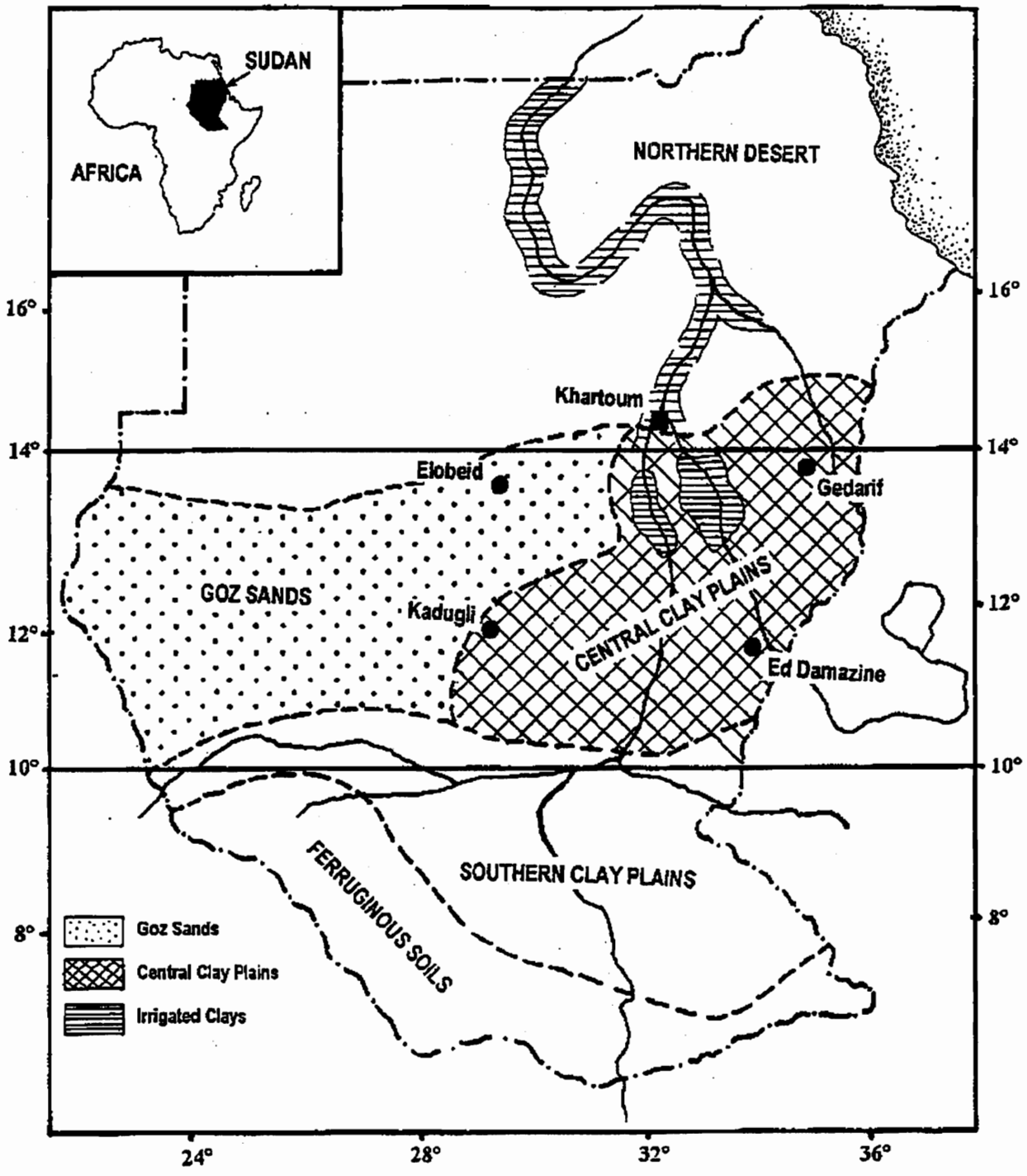


**Figure 1. Soil types and irrigated zones in the dryland farming belt in the Sudan.**

Source: Files of ARC

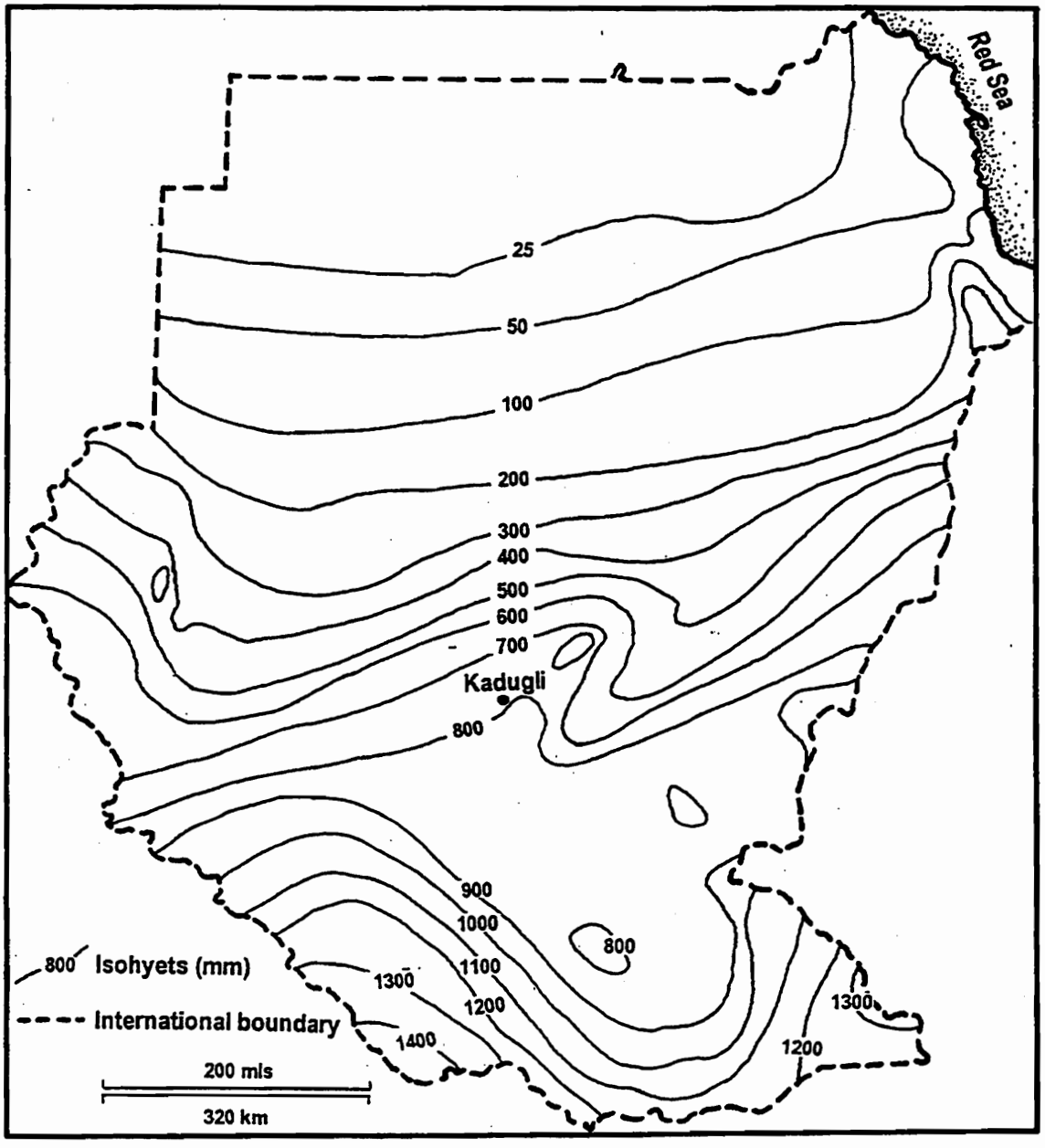


**Figure 2. Mean annual rainfall in the Sudan. (in mm).**

Source: files of ARC

In this semiarid region there are three predominant production systems, the irrigated sector, the mechanized rainfed zones, and the traditional smallholder. The first two systems are concentrated on the vertisols, the heavy clays of much of the Central Clay Plains ( Figure 1).[1] Sudan has one of the highest concentrations of vertisols in the world with 40 to 50 million hectares (Sanders, et al., 1996, p. 118).

The combination of physical properties and soil fertility of vertisols are excellent for agriculture if land preparation can be mechanized with animals or tractors. The irrigated areas in the dryland zone have been predominantly located on the vertisols. The Gezira project alone, (approximately 46% of the Sudanese irrigated area), covers 875,000 ha with total irrigation in Sudan at 1.9 million ha (D'Silva, 1986, p. 92). The irrigated area ranged from 6 to 14% of the sorghum area in the '90s (Figure 3) but substantially understated the importance of the irrigated sector as a safety valve for adequate cereal production. In 1991 when sorghum production was being abandoned in much of the principal two dryland zones due to the drought, 44% of sorghum production came from this irrigated area, even though it was only 14% of the crop area that year.

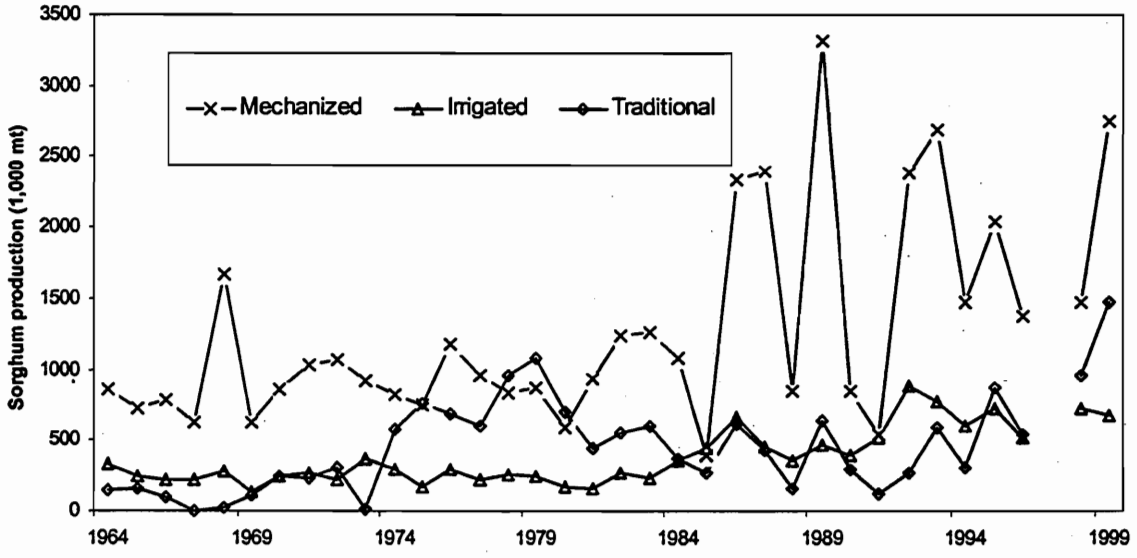


**Figure 3. Sorghum production in the three production systems of the Sudan.**

Source: updated from Sanders et al, 1996, p.115 with unpublished data from the Agricultural Research Corporation and for the last two years with FAO/WFP, 1998, p.6. Note that the 1999 data are their projections.

[1] Note that there are also Gardud clays especially in central Sudan. These Gardud soils will become important in the discussion of the traditional smallholder and are different from the vertisols. Unfortunately, the above map does not distinguish between the types of clay soil.

In the Gezira project, farms ranged in size from 6 to 17 ha with 106,000 farms providing full time employment for 350,000 workers and seasonal employment for another 450,000 (estimate for the end of the '80s; Holdcroft, 1989, p. 6). Traditionally, the irrigated scheme has been run by government dictate with an emphasis on foreign exchange earnings. Principal crops of the Gezira have been cotton for exports and wheat to reduce imports. In the '80s the Gezira produced 75% of the long staple cotton, 40% of the peanuts, and 85% of the wheat (Sanders, Shapiro and Ramaswamy, 1996, p.120). More recently in the area in which farmers were allowed to choose their own crops, sorghum became a preferred choice. Over the 1982-1993 period sorghum ranged from 26 to 48% of the crop area in the Gezira scheme

The irrigated sector surpassed the traditional sector in sorghum production during the '90s and then stagnated in '98 and '99 while the traditional sector recovered. In the late '90s there has been less public support for the irrigation projects. Infrastructure has declined and the traditional sector surpassed the irrigated sector in sorghum production (Figure 3). Substantial public investment is now necessary to revitalize the irrigated sector both for foreign exchange and for food security objectives.

In the East, outside of the irrigated regions there was little settlement before the mechanized project was begun (Figure 1). The vertisols are too heavy for manual land preparation. Moreover, there was generally a lack of drinking water impeding smallholder settlement. The mechanized, rainfed program was begun immediately after World War II and has been an amazing success in the expansion of cultivated area. Cultivation in the mechanized production area has increased from 5,000 ha in 1945 to over 5 million cultivated ha in both 1993 and 1995 before falling to 3.8 million in 1999.

Government policy in the last three decades has been to encourage the importation of sufficient tractors and more recently combine harvesters[2] to enable rapid settlement here. This importation has been facilitated by the Mechanized Farming Corporation (a parastatal responsible for the mechanized, rainfed sector). Credit has been provided at low interest rates for purchasing the machinery and for operating expenses. Land rental rates from the government are minimal.

Sixty-five percent of the area is operated by individuals in parcels ranging from 420 to 630 ha (Kidane, 2000, p. 8). The rest is held by corporations in larger areas. At the end of the '80s approximately 5,000 large farms employed 100,000 wage earning employees and up to one million seasonal workers from Western Sudan and Ethiopia (Holdcroft, 1989). By the end of the '90s there were approximately 9,000 farms in the mechanized drylands (Kidane, 2000).

In spite of the low and erratic rainfall, little use of purchased inputs, and poor access to markets during the crop season the mechanized, rainfed sector has been producing 46 to 67% of sorghum production during the '90s (Fig. 3). On these heavy, crusting soils techniques for both water retention and for drainage, when there is too much rainfall, are necessary to significantly increase yields and to reduce the riskiness of inorganic fertilizers. The levels of nitrogen and organic matter are very low on these soils so nitrogen application has been repeatedly shown to have a substantial effect on yields (Sanders et al, 1996, p. 130; M. Ahmed, 1994).

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[2] Seasonal labor has been sufficiently cheap that harvesting is by hand and the combines generally are used as stationary threshers.

One principal problem for sorghum production in the Sudan is the dependence on the mechanized rainfed zone with its large variability in both area and production (Fig. 4). The area planted varies in response to prices the previous year. The government frequently has prohibited exports to assure domestic supplies and consequently has driven down prices. Yields then vary substantially with the timing and quantity of rainfall and the other stochastic factors of insect and disease. All of these factors contribute to large scale production variability of Sudan's sorghum production.

The most important agricultural system ranked by the number of households is the traditional smallholder sector. At the end of the '90s there were an estimated 1.6 million households in this sector. This can be compared with approximately 200,000 households in the irrigated sector and 9,000 in the mechanized rainfed zone.[3]

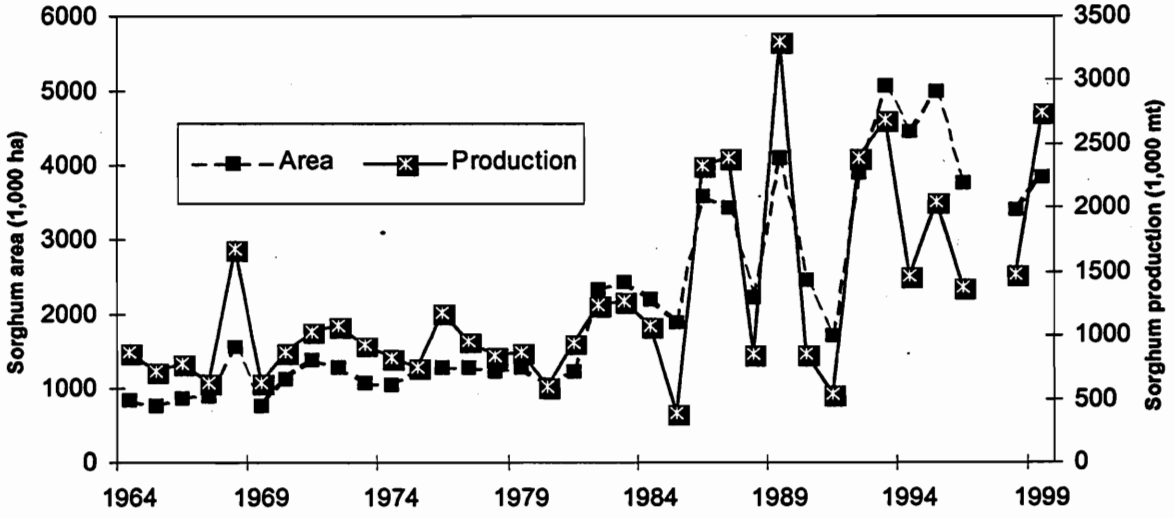


**Figure 4. Sorghum area and production in the mechanized sector of Sudan, 1964 - 1999. Source: Updated from Ahmed and Sanders, 1998, p. 256.**

The traditional sector produces all the gum arabic (in the West 50%), 90% of the millet, half of the groundnuts and sesame and 20% of the sorghum (over the '90s 13 to 30% of production (Figure 3; Kidane, 2000. p. 10). This traditional smallholder system is concentrated in Western Sudan, where there are 30% of the population and 45% of the cattle (Figure 1;World Bank, Performance Audit Report, 1993, p. v)

The traditional smallholders are located in west, central Sudan. Approximately 70% of the traditional smallholder area is in the sandy dune soils("Goz"). There are also some areas with

[3] The Gezira is approximately half the irrigated area in the country and the estimate of the number of households was 106, 000 for the end of the '80s in the Gezira. For the same period there were 5,000 households in the mechanized rainfed zone so there was an approximate doubling of the households in the mechanized rainfed zone in the last decade. So there has been no growth in the number of households in the irrigated sector with an almost doubling of the number of households in the mechanized rainfed sector.

heavier clay soils and some alluvial soils on the plains. With limited animal traction and lack of implements besides the simple hoe there has been a preference among smallholders for the more easily prepared sandy soils.

On these sandy dune soils, millet, peanuts, cowpea and sesame are the principal crops. Yields are very low, few inputs are used, and little is marketed. There is no systematic crop rotation system; shifting cultivation is practiced in response to soil fertility decline and there is heavy *Striga* infestation. Field crops are grown continuously for only 4 to 5 years and then returned to fallow.

Although monocropping of pure stands of cultivated field crops is the dominant cropping system, traditional smallholder farmers also practice inter-cropping or mixed cropping (Elhag Hassan Abuelgasim, 1999). These intercropping systems include watermelon with sesame or sorghum, groundnut with sorghum and sesame, and cowpea with sesame or sorghum. Home gardens ("Gabareek") are a survival strategy practiced mainly by women to bridge the hunger period before harvesting the main production fields. A mixture of early maturing varieties of sorghum, millets, maize, cowpea, groundnut, okra and other vegetables are planted in a single "Gabareek" near the homestead for ease of accessibility and to make use of manure and household garbage disposal.

The continuous monocropping of cereals (particularly the pearl millet monocropping system) have resulted in soil fertility depletion. Low organic matter content of the soils where cereals are monocropped also contributes to the low biomass production. Then fertility is further depleted by a high rate of decomposition of organic matter associated with high temperatures.

In the Goz soils, infiltration is high hence nutrient content and water holding capacity are low. These soils are structurally weak and prone to both water and wind erosion. Their excessively high percolation rates and leaching hamper efficient use of fertilizer, particularly N. Soil organic matter levels tend to be less than one percent. The P stocks are low in the sandy soils, but with the low clay content there is no problem of P fixation. Therefore, the P requirement for substantial yield increase is generally low. Inorganic fertilizer use is almost non-existent but needs to be combined with organic fertilizers to raise crop yields.

On approximately 30% of the soils in the West there are clay (Gardud)[4] soils, with 4 million ha in Kordofan state alone. These soils have more agricultural potential than the sandy (Goz) soils as they have higher fertility and water holding capacity. Unfortunately, they are highly compacted and have poor infiltration rates (Omer and Elamin, 1997, p. 230). This means that the initial land preparation needs to be with animal traction or mechanical power. Otherwise small farmers will continue to avoid them. Moreover, water erosion and degradation of these clay soils land can be substantial so effective soil conservation is required.

Where the Gardud soils are cultivated sorghum based cropping systems predominate accounting for approximately 50% of the area. Sesame is the main cash crop grown with short staple cotton second The other minor crops include pearl millet, cowpeas, maize, okra, and a few vegetables, mainly in home gardens.

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[4] Sandy clay, relatively fertile soils with poor physical properties of compacted layers and surface crusting leading to runoff problems (Georgis, 2000, p. 26). Water retention techniques are important on these soils.

Since the clay soils are difficult to cultivate using hand tools, traditional farmers have begun hiring tractors for land preparation and sowing. This practice is common now in the Blue Nile areas and near villages[5]. Other constraints include declining soil fertility and high pest infestation particularly the parasitic weed *Striga*.[6]

On traditional small farms on both soil types there are large storage losses. Moreover, transportation to markets is generally expensive and difficult with poor infrastructure. Historically, public policy has been one of neglect for this traditional smallholder sector. Given the large population in this sector more systematic attention to the development of technology and policy seems to be appropriate on both welfare and efficiency grounds.

## Success and Potential Successes in Technology Introduction

### The Irrigated Zones

The introduction of Hageen Dura I, a sorghum hybrid, has been an impressive accomplishment in the Gezira. The Gezira scheme expanded hybrid seed production after the private seed producers left the industry in 1986. This was a disastrous year for sorghum profitability as a large area had been planted in response to the high prices from the drought year of 1984-85; then the weather was excellent so there was a large output increase. Sorghum prices collapsed. This inability to depend upon private sector seed producers in the early stages of the growth of demand for a new cultivar is an important lesson for those promoting privatization in the seed sector.

During the first years of introduction of Hageen Dura I, farmers and family members claimed that the taste of this sorghum was inferior to traditional cultivars. After a few years as farmers realized the new technology combination could double or triple their yields, this complaint disappeared. Ninety percent of the farmers interviewed in 1992 reported that Hageen Dura I was as good as or better than traditional sorghums in taste (Sanders et al, 1996, p. 124). Apparently within some range, taste preferences can change depending upon the economics of the situation. Farmers evidently can learn to eat some high yielding cultivars even though they often complain about them at the beginning of the introduction process.

The major diffusion problem in the '90s became the inability to supply farmers with improved seed and fertilizers when the demand for these inputs accelerated. The Gezira Authority has been an efficient parastatal but this type of rapid response to demand increase is difficult in the public sector. Besides the acceleration in the use of improved seeds there was a rapid increase in the demand for inorganic fertilizers as well as a rapid growth in the marketed surplus of sorghum. More systematic support for private sector evolution of the input and product markets becomes critical as the new technologies are introduced (for further details and documentation for the seed and fertilizer markets for Hageen Dura I see Nichol and Sanders, 1996; also Nichol and Sanders, 1997).

Irrigation projects need to be intensively managed. Infrastructure needs to be maintained. Water needs to be appropriately priced and allocated. These are highly productive systems, so input and

[5] Note that the Blue Nile is in the eastern Sudan so not all the traditional smallholders are located in the west.
[6] *Striga* is associated with soil fertility depletion and continuous cereal production.

product markets need to be functioning well, especially for seed, fertilizer and credit. Historically there has been substantial governmental support in the marketing both for the export crop, cotton, and the import substitute wheat. Public resources to support irrigation projects have become scarcer with the civil war and Sudan's isolation in the international area. Irrigation channels have become clogged and production stagnating in the sector. This is the key area for Sudan to achieve high output levels so this is a very serious omission to neglect the steady evolution of productivity in the irrigated sector. Moreover, the development of the input and product markets for the irrigated sector has potential spillover effects for both the mechanized rainfed and the traditional smallholder sectors Both will need to have access to improved seed, inorganic fertilizers, and new markets.

### In the Rainfed Mechanized Zone

Since World War II, there has been substantial governmental support for the mechanized rainfed, sector. The increase in area and production in the rainfed, mechanized sector was an impressive accomplishment (Figures 3 and 4). In the '90s the mechanized rainfed sector produced 46 to 67% of Sudan's basic food crop. The mechanized area expansion was exponential facilitated by governmental subsidies of mechanization, credit, and land. This system remains very extensive and now as the frontier is disappearing, soil fertility depletion is increasingly common as is *Striga*, a parasitic weed associated with low soil fertility. The use of water retention and drainage to minimize water logging with heavy rainfall will need to be combined with increasing use of inorganic fertilizers especially nitrogen in these vertisols. While the irrigated sector uses high levels of inorganic fertilizers, the input marketing system has not been extended to the mechanized, rainfed zone. Water management on these heavy clay soils is more complex than on the Gardud clays but the potential profitability of the vertisols is higher.

## Traditional Smallholder Production

### Potential Technologies on the Sandy Soils of the Traditional Smallholder

Traditional practices to maintain soil fertility without inorganic fertilizers are technically sound but quantitatively deficient in improving soil fertility. In most semi-arid regions intensive and continuous cultivation has depleted soil nutrients to the extent that further cultivation will require inorganic fertilizer for supplying the mineral nutrients. Otherwise yields stay stagnant at very low levels and ultimately even decline further. Sustainable crop production will only be possible with inputs external to the farm or country, namely inorganic fertilizers.

This means that the traditional practices to maintain soil fertility, such as cereal-legume inter-cropping, rotation, and the expected locally available manure, cannot replace the depleted soil nutrients unless combined with inorganic fertilizer application especially N and P fertilizer (McCown et. al., 1992). In the long term, there needs to be concern with increasing soil organic matter (Box 1) and with regular soil analysis as there are many other soil nutrients that can become yield constraints.

There are various cultural practices and organic fertilizers to supplement the effects of inorganic fertilizers. For example, food crops such as sorghum have been successfully cropped without

## Box 1
## Improving Soil Organic Matter

Sandy soils have low organic C and total N content, because of low biomass production and high decomposition rates (due to high temperatures and intensive cultivation). Thus, sandy soils present problems for efficient use of both water and fertilizer. Nutrient depletion rates also vary with soil properties. The proportion of nutrients lost is greater in sandy soils, but the total loss may be greater in clay soils. This is because sandy soils have lower cation exchange capacity than do clay soils and because soil organic matter particles are less protected from microbial decomposition in sandier soils than in loamy or clay soils.

The maintenance and improvement of soil organic matter (SOM) is very important for soil water and fertility management because some soil microbes can fix atmospheric nitrogen and release mineral nutrients essential for plant growth. The decomposition and fluctuations in SOM pool sizes are, therefore, of major significance to nutrient storage and cycling.

SOM also plays an important role in sandy soils through increasing cation exchange capacity (the sum total of exchangeable cations on the surface of soil particles), which is one of the factors in soil nutrient cycling. SOM in sandy soils also assists in storing nutrients in organic form in semiarid areas. Thus, SOM plays a very important role in the storage and cycling of nutrients in the plant and is especially important in sandy soils.

SOM affects soil physical properties mainly through its influence on soil structure especially in the formation of water stable aggregates, which can increase water infiltration rates within the soil and reduce runoff. The improvement in soil structure in both fine textured and coarse textured soils also improves plant emergence and root penetration.

Therefore, maintenance of soil organic matter is a prime concern in soils because of its beneficial effects on desirable physical, chemical and biological properties of soil. Building up SOM and maintaining soil fertility in the soils of semiarid areas is essential to crop production on a sustainable basis.

A rapid increase in the SOM and N provided by green manure is particularly beneficial in improving the highly degraded sandy soils in the semi-arid areas of the Sudan. The use of shrubs that retain foliage during the dry season may also offer potential. Recent research in alley cropping, for simultaneous production of green manure and crop, has shown positive results on yields and soils but needs to be analyzed for its profitability (Georgis and Roger, 1989).

There are also some grain legumes of longer duration such as pigeon pea and varieties of cow pea, which lose a substantial amount of biomass in the form of roots and leaves that fall before harvest when grown alone or in an inter cropping system (Giller & Cadisch, 1995). A sole pigeon pea crop drops up to 40 kg of N $ha^{-1}$ in fallen leaves during its growth (Kumar Rao et al., 1983). The small harvest index of pigeon pea also means that a relatively large proportion of the fixed N remains in the field, which can give a substantial benefit to subsequent crops if P fertilizer is also applied.

reduction in yield with the leguminous perennial crops such as pigeon pea as long as there were reasonable rates of P application.

Thus there are a number of options to combine with inorganic fertilizer to reduce the quantities required, increase organic matter levels, and improve water use efficiency. Surprisingly, there has been very little emphasis on this primary soil fertility constraint by either researchers, public extension or NGO extension.

**Potential Technologies on the Clay (Gardud) Soils in Western Sudan**

Clay soils have much higher agricultural potential than the Goz sands if water is properly managed. Field research has now demonstrated different water retention alternatives. With ridging alone[7] without tying them or fertilization sorghum yields were increased 57% from 878 kg/ha on the flat areas to 1373 kg/ha. Dikes in areas with the fertilization effect of Acacia increased millet yields fourfold from very low levels, i.e., from 200 to 800 kg/ha. There were also favorable responses to inorganic fertilizer under experimental conditions on both millet and sorghum (Urea and TSP).[8] Finally, the combination of water harvesting plus N and P raised sorghum (Hageen Dura I) yields 166% from 890 to 2,370 (Abuelgasim, 2000, pp. 32-34).[9]

A comprehensive five year experiment compared tillage methods on the Gardud soils. First contour dikes at ten meter intervals were constructed to slow runoff. Then within these intervals, four tillage treatments were evaluated. Ridges without tying increased sorghum yields over no till 134% from 299 to 701 kg/ha. Broad bed furrows (elevated production on 80 cm beds with 70 cm furrows) resulted in a yield increase over no till of 182%to 842 kg/ha. Chisel plowing resulted in an improvement over no till of 384% to 1, 448 kg/ha. 1,448 kg/ha (Table 1).

**Table 1. Effects of different tillage methods on yields and other plant characteristics of sorghum in Elobeid area, Kordofan State.**

| Tillage Systems | Plant stand (000) | % of plants with heads | Grain yield (kg/ha) | Straw mt/ha |
|---|---|---|---|---|
| Chisel | 100 (95%) | 83 | 1448 (389%) | 4.0 (167%) |
| Broad-bed Furrow | 72 (68%) | 70 | 842 (107%) | 2.3 (74%) |
| Ridge Furrow | 54 (480%) | 54 | 701 (72%) | 2.5 (60%) |
| No-till (control) | 44 (42%) | 47 | 299 | 1.5 |

Note: The above data are averages of three years of data. The experiment was carried out over five years but two years of data were lost due to rats and grasshoppers.
(The numbers in parentheses above are the percentage increases over the control.)

Source: Omer and Elamin, 1997, p. 239

These are impressive and even dramatic results clearly demonstrating the advantages of various water retention techniques on Gardud soils. These results need to be aggressively demonstrated to farmers. Over time it will be necessary to combine the water retention treatments with inorganic fertilizers as the initial fertility advantage of opening up new soils is lost and the nutrients depleted.

[7]In the U.S. this would be referred to as furrowing or furrow ridges.
[8]These responses to inorganic fertilizers occurred on both sandy and clay soils.
[9] This was on the clay (vertisols) of the East under dryland conditions.

These results illustrate the importance of first retaining the water by preparing the soil with any method that is going to slow down runoff. The chisel plowing facilitates infiltration of rainwater further by extending the depth to which the soil profile is broken compared to tied ridging and broad bed furrows. Hence, this treatment has the largest effect in increasing yields.

All three improved tillage systems not only resulted in grain yield increases but also in more straw, which is important as animal feed. Smallholder farming systems include both livestock and crops. The combination of the contouring at 10 m and the chiseling was also shown to be highly profitable by a factor of 2.3 times the return of the no till (Omer and Elamin, 1997, p. 239).

These tillage technologies are currently being verified on farmer's field in several areas of Gardud in Kordofan State. Farmer's perceptions about the technologies are positive. Farmers appreciate the advantages of chisel plowing and use of ridging to increase soil water storage and yields in Gardud soils. The big transition in land preparation is the movement from the hand hoe to animal or mechanical traction. Where either animal or mechanical traction is available and economical, farmers would be expected to extend cultivation onto the Gardud.

## Evolution of the National Seed Market

Until 1996 a government agency, the National Seed Administration of the Ministry of Agriculture, was responsible for most of the seed propagation activities in the country. This Administration was charged with receiving the breeder seed of the officially released ARC crop varieties and producing the foundation and certified seed. The seeds produced were then sold to the large production schemes and individual growers. Several of the irrigation projects including the Gezira and Rahad Schemes also produced their own seeds.

In 1997 the government dissolved the National Seed Administration trading it to the Arab Sudanese Seed Company (ASSCO) as part of its privatization activities.. This company is then a joint venture between the Government of Sudan, the Arab Agricultural Investment Corporation and other investors. The government retains a 40% share in the new company based upon the government's contribution of facilities and land formerly of the National Seed Administration. The company has six stations country wide with three stations servicing the semi-arid region. The General Seed Administration under the Minister of Agriculture is now responsible for activating the seed law and seed quality standards. By early 2000, some 20 private seed growers had registered with the General Seed Administration but only two or three companies were actually producing seeds (Abuelgasim 2000, pg. 27).

The Gezira Authority continues to produce its own seed. The other Sudanian irrigation schemes have avoided a dependence upon the private sector by creating Agricultural Production Corporations (APC) which are small scale replicas of the Gezira Project Authority. As in the Gezira Project the tenants of the irrigation projects pay the APCs for services and inputs. There continue to be substantial complaints about input delivery, as in the case of the Gezira Project seed sales of Hageen Dura I. Clearly, the failure to privatize input delivery has become a principal barrier to more rapid productivity increase in the irrigated zones (for further details and documentation for the seed and fertilizer markets for Hageen Dura I see Nichol and Sanders, 1996: also Nichol and Sanders, 1997).

The Arab Sudanese Seed Company has been producing the new cultivars received from the ARC There have also been community seed production activities by development programs and NGOs (Abuelgasim, 2000, pp. 27-29; Elgalani 2000, pp 16-18) Neither the ASSCO nor the community based seed production is adequately serving the traditional smallholder demand for new cultivars of sorghum, groundnut, and sesame. The ARC still provides old cultivars to ASSCO. As in the other countries of the Horn Sudan has not been able to keep up with breeding advances in the rest of the world and utilize improvements in germplasm, which are available internationally. Sudan has been isolated by the continuing war. Moreover, the lack of operational funds makes it more difficult for its scientists to maintain contacts with scientific networks abroad and to do their continued testing and adaptation trials.

## The Research System

The Agricultural Research Corporation (ARC), the key research organization since its establishment in 1902 in Shambat near Khartoum, coordinates agricultural research nationally, formulates agricultural research guidelines, and conducts research in its research stations and sub-stations located in different agroecological zones throughout the country. ARC conducts about 90% of the applied agricultural research in the Sudan (Abuelgasim, 2000, p.7).

The ARC is an old distinguished agricultural research organization with substantial human capital investment in its personnel. In early 2000, the ARC had 223 active research scientists (99 Ph.Ds) and 95 assistant research scientists (B.Sc) (Abuelgasim 2000: 18).[10] There were an estimated 150 senior scientists with over 20 years of professional experience in agricultural research (Abuelgasim, 2000, p. 20).

Unfortunately, ARC has not been well financed by the central government for at least two decades so there has been a brain drain. During the last decade as the donors departed, financing of research and even scientists' salaries has been completely inadequate. So the ARC is a casualty of the draining of public finances by the continuing civil war.

There are 24 research programs headed by team leaders including 16 commodity based research programs and 8 supplementary programs. These research programs are conducted in 19 research stations distributed all over the Sudan (Table 2). Additionally, there are also 4 specialized research stations each with a special emphasis respectively on: soil and water management; plant protection; forestry; and food research respectively.

During the '90s there were less than 10 female scientists working within ARC stations. With the increase of the number of females joining the universities there were 52 female research scientists within ARC in the year 2000; eleven of them were Ph.Ds and 41 M.Sc. Thus, 22% of ARC active scientists in 2000 were women.

[10] Out of 251 research scientists, 21 scientists are presently seconded to other organizations and 7 are on leave with pay (Abuelgasim 2000: 18).

| Table 2. ARC research stations, location, starting date, research emphasis. | | | | |
|---|---|---|---|---|
| **No.** | **Research Station** | **Location town, State** | **Starting year** | **Main emphasis** |
| 1 | Gezira | Wad Medani Gezira | 1918 | Irrigated sectors serving Gezira Scheme, multi-disciplinary commodity oriented |
| 2 | Sennar | Sennar, Sennar | | Irrigated agriculture foundation seed production by ARC, horticultural research |
| 3 | Kenanna* | Abu Naama, Sennar | 1968 | Both rainfed and irrigated, was the first main rainfed station before West Sudan regional research program began in the '80s; activities dwindling recently due to lack of funding. |
| 4 | Damazeen | Damazeen, Blue Nile | 1990s | Mechanized rainfed |
| 5 | Shambat | Khartoum North, | 1904 | The first and oldest station. It was used mainly for cotton (breeding) research; presently multi-disciplinary irrigated cereals, grain legume horticultural crops. |
| 6 | Shendi | Shendi, Nile | | Irrigated, mainly horticulture and grain legumes. |
| 7 | Hudeiba | Ed Damer, Nile | 1960s | Irrigated, cereals and winter legumes, horticulture crops and forestry |
| 8 | Dongola | Dongola, Northern | 1990s | Irrigated horticulture, cereals and legume crops. |
| 9 | Kosti | Kosti, White Nile | 1990s | Irrigated, to serve White Nile Schemes |
| 10 | El Obeid* | El Obeid, North Kordofan | 1983 | The main traditional rainfed research station, holistic farming systems research approach (summer cereals, legume, oil crops, rosette, horticulture crops, gum arabic, agroforestry and tree seed, animal product and socio-economic studies |
| 11 | Kadugli* | Kadugli, South Kordofan | 1983 rehabilitated 1982 | Rainfed traditional crops, higher rainfall, cereals, systems approach, crop. Partially operating due to civil war |
| 12 | Nay | Nyalla, South Darfur | 1992 | Rainfed traditional cereals, legumes, crop protection, and range studies. |
| 13 | Gedaref | Gedaref, Gedaref | 1990s | Mechanized rainfed farming sorghum, sesame as main crops plus other miscellaneous crops State Government helping to establish this new station. |
| 14 | Rahad | El Faw, Gedaref | 1980s | Irrigated, to serve El Rahad Scheme; cotton, wheat. |
| 15 | New Halfa | New Halfa, Kassala | 1960s | Irrigated, to serve El Girba Scheme; cotton, wheat. |
| 16 | Kassala | Kassala, Kassala | 1970s | Irrigated Flood, horticultural crops, legumes. |

*= Dryland farming research station
Source: Elhag Hassan Abuelgasim, 2000, pp. 16,17.

## Dryland Agricultural Research

To date, the vast majority of agricultural research in Sudan has been focused on the irrigated regions (see the stations 1-3,5-9,14-16). From the total of 223 active senior research scientists within ARC, only 39 researchers (18%) are allocated to the rainfed agricultural research program (Table 3). Even the mechanized rainfed systems in spite of their large allocation of public resources to subsidize services have little research support compared with the irrigated sector. One of the first applied research programs for mechanized rainfed was started by the Canadians at Sim Sim in the 1980s. The Gedaref and Damazeen stations, which focus on mechanized rainfed systems, were only added in the 1990s.

**Table 3. Discipline and dryland focus of presently active ARC researchers.**

| Discipline | ARC staff | Dryland staff | % |
|---|---|---|---|
| Crop Protection | 48 | 6 | 13 |
| Agronomy | 19 | 7 | 37 |
| Breeding/genetics | 25 | 4 | 16 |
| Soil/water | 34 | 4 | 12 |
| Horticulture | 26 | 1 | 4 |
| Forestry | 21 | 8 | 38 |
| Range/Forage | 2 | 1 | 50 |
| Animal Science | 3 | 2 | 67 |
| Food science | 23 | 0 | 0 |
| Agric Engineering | 9 | 1 | 11 |
| Agric. Economics | 10 | 5 | 50 |
| Cotton fiber tech. | 3 | 0 | 0 |
| Total | 223 | 39 | 18 |

Source: Agricultural Research Corporation files cited in Abuelgasim, 2000, p. 24.

The first major programs to target the traditional, smallholder rainfed farming systems were started in Western Sudan in the late 1970s through a joint USAID/World Bank initiative that lasted through 1985. The project, the Western Sudan Agricultural Research Project (WSARP), was to build four new research facilities, staff them, and to undertake a body of research to lead to a research strategy definition for the region (World Bank, 1993). The program built four research stations, trained 6 Ph.Ds and 8 M.Scs, and produced 55 research publications.

Only two of the facilities were staffed, El Obeid and Kadugli. Two others remain unstaffed in remote Dafur. The staff had to be evacuated from Kadugli at the end of the project due to the civil strife in the nearby Nuba mountains. At project commencement the plan had been to put 36 scientists in El Obeid but, as of the early '90s, there were only 14 staff members there (World Bank 1993, pp.v, 3). There were two major problems reflected in this experience: first, the difficulty of attracting scientific staff to remote rural locations; and secondly the chronic problem of the sustainability of donor financing as USAID abruptly stopped financing the project in 1985.

In the '90s Nay was added to serve this smallholder traditional sector. Research at Kenana is also directed at traditional crops as well as some irrigation activities. Nevertheless, the continuing priority for the irrigated systems is clear from the distribution of stations and scientific personnel (Tables 2 and 3).

The extent of resources both financial and human, that have been put into dryland agricultural research have been inadequate compared to the size of the problem and the large proportion of the population that inhabit dryland areas in the country. The existing dryland research centers are few

in numbers, do not cover all dryland agroclimatic zones of the country, and are inadequately scientifically staffed.[11]

## Ties to Other Research Institutions

Since 1990 the number of universities and higher education institutions in Sudan has increased tremendously—from eight to 44 institutions with a parallel increase in the potential number of students that can be admitted (from 6,080 in 1990 to 45,905 in 2000) (Abuelgasim 2000, pg 33). Historically the academic staff of the faculties of agriculture in the different national universities, have conducted some basic agricultural research and supervised graduate students' participation in this research as part of their M.Sc. and Ph.D. degrees. The source of funding for this type of university based research, however, has disappeared as the donors withdrew. There has however been regular collaboration between the ARC scientists and the university-based researchers and students at the agricultural universities located near the ARC research stations, such as the Universities of Gezira in Wad Medani and the University of Kordofan in El Obeid Station (Abuelgasim, 2000, p. 7).

## Governmental and NGO Extension Activities

Since 1981, Sudan has followed a gradual process of decentralization of its national agricultural extension services. After the adoption of the federal government system (1990-1995) the state Ministries of Agriculture were given autonomy in sponsoring agricultural extension. A general administration for extension and training exists at the Federal Ministry of Agriculture to provide technical backstopping for these state agricultural extension systems (Elgailani 2000, pp 1-6).

All of the major state corporations for irrigation and mechanization continue to provide extension through parastatal authorities. It is only the traditional smallholder sector in the west (Central and Eastern, Kordofan, and Darfur states) that is entirely dependent upon the state extension service.

In 1994 the national extension/farmer ratio was estimated at one agent per 200,000 farmers. (ElGailani, 2000, p. 8). A more detailed analysis of the Kordofan States, as an example of the best served state in the semiarid region, showed a total of 123 extension personnel (4 M.Sc., 41 B.Sc., 31 Diploma , and 47 High school graduates) or one extension agent per 30,000 individuals. There were seven functional vehicles available to the extension service at the time of this report (summer 2000). Since North Kordofan state has more development programs than most other states, there are more resources in the state, so this is expected to be a high ratio of agents to farmers compared with the other states (ElGailani, 2000, pp. 8,9). With so little transportation and other logistic support, the extension service is expected to be almost entirely dependent upon outside resources to reach farmers.

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[11] This is a common problem throughout Africa, where there are large differences in the quality and quantity of educational facilities and other amenities between the major cities and the rural areas. So scientific staff concentrates around the major urban areas and resists being posted to rural areas. Salary incentives, better facilities and higher operating budgets in rural areas and other incentives should be a major component of decentralization programs and be supported by both the government and donors once the war stops.

Most extension activities revolve around two services, provision of new cultivars and demonstration and training in new production practices. A top down approach promoting these cultivars and practices is utilized. Campaigns are "initiated and supported" financially by external sources of funding such as development projects or NGOs (ElGailani, 2000, p. 15). Table 4 indicates the cultivars that are being recommended in the traditional smallholder sector and the estimates of potential yields obtained from the experiment station.

**Table 4. Recommended crop varieties for different rainfall levels, their maturity, actual and potential yields in the semiarid region of the Sudan.**

| Crop Variety | Rainfall mm | Days to maturity | Traditional yield t/ha | Potential yield t/ha |
|---|---|---|---|---|
| **Sorghum** | | | | |
| Yarwasha | 250-400 | 90< | 0.195 | 0.4-1.8 |
| Arooselrimal | 250-400 | 90< | 0.195 | 0.5-2.0 |
| Gadamelhamam | >600 | 105 | 0.195 | 1.7-3.8 |
| Feteirita Wad Ahmed | >600 | 106 | 0.195 | 2.5-4.5 |
| Dwarf white milo | 400-600 | 85 | 0.195 | 1.7-2.5 |
| Feterita um Benein | 400-600 | 95 | 0.195 | 0.85-1.7 |
| Feterita Maatug | 400-600 | 90 | 0.195 | 0.85-1.7 |
| **Millet** | | | | |
| Ugandi | 250-400 | 85 | 0.101 | 0.4-0.8 |
| **Groundnut** | | | | |
| Sodiri | 250-600 | 90< | 0.24 | 1.015 |
| Gubish | 250-400 | 90< | 0.24 | 1115 |
| **Sesame** | | | | |
| El Obeid-1 | 250-400 | 85 | 0.119 | 0.251 |
| Promo | 250-500 | 90 | 0.119 | 0.254 |
| Zirraa-7 | 500-800 | 110 | 0.119 | 0.256 |
| Zirraa-9 | 500-800 | 110 | 0.119 | 0.244 |
| Kenana-1 | 500-800 | 110 | 0.119 | 0.185 |
| **Cowpea** | | | | |
| Einelgazal | 250-400 | 60 | 0.077 | 0.386 |
| Dahabelgoz | 250-400 | 60 | 0.077 | 0.464 |

Source:Abuelgasim, 2000.

The new cultivars cited of sorghum and millet including Feterita Wad Ahmed and Ugandi were introduced two to three decades earlier. The new cultivars are not new and Sudan is not taking advantage of material being developed by the international plant breeding community.

There is a general recognition of the problem of links between research-extension and farmers since financing is scarce for both the public extension service and the ARC. There is a large turnover in both the research and the extension services due to the low wages (ElGailani, 2000, pp.28-30). Given these constraints, the most successful examples of state extension (in terms of diffusion and net income increases) tend to be those in which their activities were reinforced by some bilateral, multilateral, or NGO support (Elgailani 2000: 18-21) (Box 2).

**Box 2. The Ennuhud Co-Operative Credit Project (ENCCP) in Western Kordofan supported by IFAD.**

The Ennuhud Co-operative Credit Project (ENCCP) was initiated in 1987 in Western Kordofan with the objective of increasing the income of small, drought affected households by improving the efficiency of the credit delivery of the state agricultural bank, strengthening agricultural extension services, and promoting co-operative activities. The project established 854 demonstration plots of improved seeds and associated technologies. These interventions increased incomes in the targeted villages compared to the control villages for each of the four crops: 13% for millet; 11% for sorghum; 110% for groundnut; and 66% for sesame. The project also succeeded in decreasing the ratio of extension workers to farmers from 1:26 to 1:16. (Issa 1998 in Elgailani, 2000, p.18)

Excluding the war areas of southern Sudan there are not many NGOs involved with agriculture compared with the other countries in the Horn of Africa and those, who do work in the semi-arid regions, are tightly regulated by the government through bilateral agreements under the Ministry of Finance. Given the size and the funding available to the state extension service, it is surprising that the government does not more actively encourage the entrance of NGOs.

There are 5 UN agencies, 7 international NGOs, and 12 national NGOs involved in agriculturally related activities in the three western states (Central and Eastern, Kordofan, Darfur). These agencies working in western Sudan concentrate on the introduction of new cultivars, which are generally provided by the Agricultural Research Corporation. There has been a focus in the El Obeid center on the selection of sorghum and millet cultivars for earliness. Improved agronomic practices (optimum seed rates, seed dressing, optimum planting distances, intercropping) have also been promoted by various extension organizations.

The NGOs sponsor farm trials, credit, an animal mechanization project, and womens' gardens ("Gabareek") (El Gailani, 2000, pp. 18-21). Several programs have been relatively successful in disseminating the new peanut cultivar, Sodiri. Now the availability of sufficient seed is the principal factor impeding a more rapid diffusion of peanuts in the area.

On the clay soils, ridge furrows and chisel plowing are becoming more common practices without being actively promoted or demonstrated (ElGailani, 2000, pp. 22-24). The 30% of the West Sudan in the Gardud soils has more potential than the sandy dune region (Goz) as long as either animal or

mechanical traction is available for the land preparation activity. Also on these clay soils on-farm trails have shown a substantial response to N and P.

Several NGOs and development programs have also concentrated on the critical water retention and fertilization activities. CARE on both the sandy and clay soils of Western Sudan has been organizing farmers with food for work into programs to construct contour dikes and furrow ridges. Global 2000 has been introducing the combination of inorganic fertilizers and new cultivars (see Table 4) of millet and sorghum on both types of soils and reports tripling of yields. Providing mechanical traction, FAO has been introducing the combination of tied ridges and chisel plowing on the "Gardud" soils. Similarly, the EEC, GTZ, and two development projects have been introducing animal traction and new implements to improve water retention (Abuelgasim, 2000, pp. 35-37).

So there is substantial activity for increasing water availability. In the Gardud soils, contour dikes and various tillage methods have been demonstrated and, with new traction sources, could be rapidly introduced. As animal or mechanical traction is introduced, there needs to be attention to inorganic fertilizers especially nitrogen. Then these projects need to move from pilot projects to larger scale activities.

With the long distance to the major urban markets, the depleted soils, the number of inputs required to increase both water availability and soil fertility, and the lack of public policy attention it will be difficult to improve the input and product markets sufficiently to interest farmers in inorganic fertilizers. Inorganic fertilizers, however, will be critical to breaking out of the soil depletion-poverty cycle and introducing higher yielding, sustainable systems.

Only manure is used in the region and the government has even attempted to restrict extension of fertilizer technology here by only making fertilizer available[12] in the irrigated regions (ElGailani, 2000, pp. 24-26). However, once water retention devices are in place there is a large increase in the response to fertilization both in increasing the profitability and reducing risk.

[12] With the economy tightly controlled by the state most of the fertilizer available to farmers has been distributed through parastatal agencies such as the Gezira Irrigation Authority.

## Conclusions

Sudan has had a distinguished research center, ARC, which it has never adequately supported. The situation has become especially serious in the last decade during which the ARC has been increasingly cut off from donor funding. The performance of agriculture in both the irrigated zones and the mechanized rainfed zones has also been impressive historically. Both have stagnated in the '90s as the energies and financing of the state has become even more concentrated on the continuing civil war.

Sudan cannot afford to continue neglecting its agricultural sector. The necessary starting point will be to rebuild the ARC with substantial public sector inputs for both scientists' salaries and operating costs. More diversification of research activity to improve support of the mechanized rainfed and the traditional smallholder sectors seem appropriate from both an efficiency and welfare perspective.

Any long term strategy for agricultural development in Sudan will need three components: a) rehabilitating the irrigation system; b) shifting from extensive to intensive systems in the mechanized rainfed systems; and, c) initiating the introduction of technologies to intensify crop production in the traditional smallholder sector.

Sudan has acquired valuable experience, while substantially increasing productivity over time in the irrigated sector. In the last decade even this sector has been neglected and has experienced deterioration of its infrastructure and loss of experienced professional staff. The first priority for developing Sudanese agriculture has to be in recapturing the high productivity of the irrigation schemes and rebuilding their infrastructure.

With the depletion of soil fertility and the high cost of infrastructure to connect new areas to major markets, Sudan's ability to continue horizontal expansion of mechanized dryland farming into new frontiers is disappearing. Hence, farmers, outside the irrigated regions, will need to purchase inputs to increase productivity. What has been missing is the government commitment to improved functioning and privatization of the critical input markets (seeds and inorganic fertilizers) oriented to improve services to rainfed agriculture.

There is a base of dryland research on water retention[13] and fertilization from the experiment stations and to a lesser extent from applied trials of NGOs and development projects. Substantial yield effects from these investments have been shown. These include water harvesting on clay soils-both vertisols and Gardud - or slowing infiltration in sandy soils. The different water retention techniques need to be combined with higher levels of inorganic fertilizers.

Scientists at El Obeid research station are attempting to develop this institution into a strong research center for the traditional smallholder and there are now two stations supporting the mechanized rainfed agricultural sector. Unfortunately, the government has never put much resources or shown much policy concern for the traditional smallholder sector. Nor has the government or the MFC been concerned with increasing yields in the mechanized rainfed zone.

[13] We prefer the term retention to management to emphasize techniques besides irrigation.

In the mechanized rainfed zone the policy emphasis has been on subsidizing the inputs to overcome labor constraints on large farms.

A necessary component of agricultural development will be public policy oriented to increase the profitability of agricultural production. This will encourage farmers to purchase seeds of new cultivars and inorganic fertilizers. The government needs to avoid policies such as the ban on sorghum exports of 1996-99 driving down the sorghum price. This type of policy reduces the profitabilility of agriculture and discourages farmers from intensifying production.

NGOs can be encouraged to do some of activities to stimulate input markets, including demonstration trials in the drylands and increased accessibility and credit for these inputs. More flexible policy encouraging NGOs would undoubtedly result in an increase of the number of NGOs working in the country and facilitate the intensification process.

# Appendix

## More background data on the Sudan

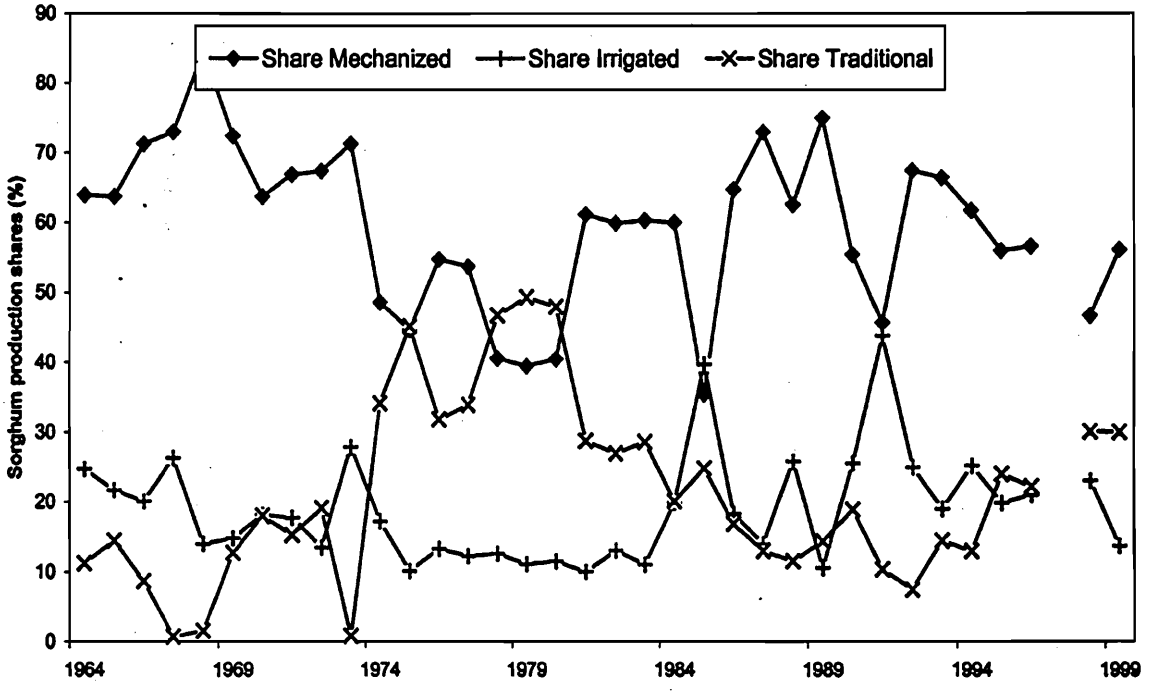


**Figure A-1. Production shares of the three sorghum sectors of the Sudan.**

**Table A-1. Sorghum area and production for the three sections in the Sudan.**

| Crop | Mechanized sector | | Irrigated sector | | Traditional sector | | Total Sudan | |
|---|---|---|---|---|---|---|---|---|
| Year | Area | Production | Area | Production | Area | Production | Area | Production |
| 1964 | 854 | 863 | 206 | 334 | 317 | 152 | 1377 | 1349 |
| 1965 | 779 | 725 | 195 | 247 | 353 | 165 | 1327 | 1137 |
| 1966 | 867 | 780 | 174 | 220 | 303 | 95 | 1344 | 1095 |
| 1967 | 900 | 621 | 189 | 224 | 248 | 6 | 1337 | 851 |
| 1968 | 1562 | 1672 | 206 | 278 | 207 | 30 | 1975 | 1980 |
| 1969 | 764 | 630 | 194 | 129 | 228 | 111 | 1186 | 870 |
| 1970 | 1124 | 862 | 249 | 246 | 405 | 244 | 1778 | 1352 |
| 1971 | 1385 | 1027 | 264 | 273 | 407 | 235 | 2056 | 1535 |
| 1972 | 1278 | 1072 | 215 | 215 | 421 | 304 | 1914 | 1591 |
| 1973 | 1081 | 927 | 213 | 363 | 427 | 11 | 1721 | 1301 |
| 1974 | 1041 | 822 | 229 | 292 | 1045 | 577 | 2315 | 1691 |
| 1975 | 1240 | 751 | 169 | 171 | 934 | 759 | 2343 | 1681 |
| 1976 | 1282 | 1183 | 258 | 289 | 1195 | 688 | 2735 | 2160 |
| 1977 | 1276 | 962 | 224 | 221 | 1316 | 607 | 2816 | 1790 |
| 1978 | 1236 | 837 | 219 | 261 | 1435 | 964 | 2890 | 2062 |
| 1979 | 1274 | 866 | 248 | 245 | 1379 | 1082 | 2901 | 2193 |
| 1980 | 1039 | 592 | 184 | 169 | 1134 | 701 | 2357 | 1462 |
| 1981 | 1224 | 936 | 210 | 154 | 808 | 440 | 2242 | 1530 |
| 1982 | 2342 | 1239 | 243 | 271 | 1522 | 558 | 4107 | 2068 |
| 1983 | 2443 | 1267 | 319 | 233 | 1515 | 601 | 4277 | 2101 |
| 1984 | 2198 | 1084 | 279 | 359 | 977 | 363 | 3454 | 1806 |
| 1985 | 1905 | 389 | 322 | 436 | 1129 | 272 | 3356 | 1097 |
| 1986 | 3587 | 2328 | 472 | 658 | 1468 | 609 | 5527 | 3595 |
| 1987 | 3440 | 2395 | 347 | 459 | 1173 | 428 | 4960 | 3282 |
| 1988 | 2232 | 853 | 299 | 352 | 858 | 158 | 3389 | 1363 |
| 1989 | 4094 | 3312 | 355 | 468 | 1128 | 638 | 5577 | 4418 |
| 1990 | 2449 | 850 | 317 | 392 | 1035 | 290 | 3801 | 1532 |
| 1991 | 1714 | 538 | 391 | 516 | 655 | 123 | 2760 | 1177 |
| 1992 | 3899 | 2386 | 579 | 884 | 672 | 265 | 5150 | 3535 |
| 1993 | 5065 | 2687 | 605 | 769 | 1890 | 586 | 7560 | 4042 |
| 1994 | 4465 | 1473 | 380 | 602 | 1449 | 311 | 6294 | 2386 |
| 1995 | 5007 | 2044 | 495 | 726 | 2250 | 878 | 7752 | 3648 |
| 1996 | 3779 | 1379 | 310 | 513 | 2040 | 542 | 6129 | 2434 |
| 1997 | | | | | | | | |
| 1998 | 3419 | 1477 | 351 | 730 | 1559 | 952 | 5329 | 3159 |
| 1999[a] | 3840 | 2746 | 394 | 674 | 2171 | 1471 | 6405 | 4891 |

Sources: 1964-1993 data from Sanders et al (1996, p. 115); 1994-1996 from Nichol and Sanders (1996, p.110); 1998-1999 data from FAO/WFP (1998, p. 6) a: projection from the field surveys of the FAO/WFP team.

**Table A-2. The different climatic regions, area coverage and potential crops in the Sudan.**

| Climatic Region | Area ('000 Km$^2$) | % | Potential field crops |
|---|---|---|---|
| Desert (lat. 16-22$^0$ N) | 726 | 29 | Sorghum, maize, millet, wheat barley and pulses, under irrigation |
| Semi-desert (lat. 16-22$^0$ N) | 490 | 20 | Sorghum, maize, millet, wheat barley and pulses, rice in areas under irrigation, |
| Low rainfall savanna (Lat. 10-14$^0$ N) | 685 | 27 | Millet, sorghum, maize, rice, oil crops, in all areas. Wheat and barley north of 14 N. under irrigation |
| High rainfall savanna (Lat. 4-10$^0$ N) | 349 | 14 | Sorghum, maize, millet |
| Swamps | 246 | 10 | Rice, sorghum, maize and millet after reclamation |
| Uplands | 8 | 0.3 | Mediterranean fruits and vegetables |
| Total | 2503 | 100 | |

Source: (Ministry of Agriculture and Forests 1996)

**Table A-3. Characteristics of agro-climatological zones by sub-district of the Kassala State, Eastern Sudan and Kordofan, Western Sudan.**

| Kassala State | | | |
|---|---|---|---|
| Sub-District | Agroclimatic zone | LGP* | Crop Pasture system zones |
| N. south | Warm, arid | 1-60 | Marginal pasture |
| N. west central | Warm, arid, I. | 1-60 | Marginal pasture |
| N. north | Warm, arid, I | 1-60 | Marginal pasture |
| NE Central | Warm, arid, I. | 1-60 | Marginal pasture |
| C. north | Warm, arid, I. | 1-60 | Marginal pasture |
| S. south | Warm, semi-arid, I. | 60-120 | Pasture |
| SW Central | Warm. Semi-arid, I. | 60-120 | Marginal pasture |
| SE central | Warm, semi-arid, I. | 60-120 | Marginal pasture |
| S. north | Warm, semi-arid | 60-120 | Pasture |
| Kordofan | | | |
| Kordofan State | Agroclimatic zone | LGP | Crop Pasture system zones |
| N. El-Obeid | Warm arid | 1-60 | Marginal pasture |
| S. El-Obeid | Warm, semi-arid | 60-120 | Pasture |
| N. West S | Warm, semi-arid | 60-120 | Sorghum/Bulrush millet/sesame |
| N.North S. | Warm, semi-arid, I | 60-120 | Sorghum/maize/sesame |
| SE west-s | Warm, moist semi-arid, U* | 120-180 | Sorghum/maize/cow pea |
| C-North-S | Warm, moist semi-arid, U | 120-180 | Sorghum/maize/cow pea |
| S. North S. | M. Warm, moist semi-arid, U | 120-180 | Sorghum/cow pea/ groundnut |
| W. East W | Warm, moist semiarid, U | 120-180 | Sorghum/ cow pea/ groundnut |
| NE South S | Warm, moist semiarid, U | 120-180 | Sorghum/ cow pea/ groundnut |
| SW South S. | Warm, moist semiarid, U | 120-180 | Sorghum/ maize/cow pea |
| C. East S. | Warm, moist semiarid, U | 120-180 | Sorghum/ maize/cow pea |
| E East S. | Warm, semiarid, I* | 60-120 | Sorghum/ maize/sesame |

*U = one reliable growth period, I = Major part irrigated, I = minor part irrigated, r = irrigated along rivers only, LGP Length of growing period

**Source:** (IGAD/FAO 1995)

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