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Agricultural Technology for the Semiarid African Horn

Country Study: Ethiopia

IGAD/INTSORMIL/USAID-REDSO

Revised January 2001

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IGAD (the Inter-Governmental Authority for Development)

IGAD (the Inter-Governmental Authority for Development) was created in 1986 in response to 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. In 1990 two regional strategy documents, one on environment and the other on food security, were developed. These regional strategies stressed development of the region's Arid and Semiarid Lands (ASAL) 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 creation of ASARECA (Association of Strengthening Agricultural Research in Eastern and Central Africa) in 1994 as a regional coordinating body for 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 were 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. They attempt 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; the second and third each include reports for three countries. [This report for Kenya was excerpted from Volume 2 and revised in January 2001.]

Contract Contacts:

IGAD

Benson Mochoge, Director
Agriculture and Environment Division
The Intergovernmental Authority on Development (IGAD)
P.O. Box 2653
Djibouti, Republic of Djibouti
Email: igadews.intnet.dj

USAID/REDSO/ ESA/AGR

Dennis M. McCarthy or
Department of State
Washington DC 20521-8900

Ksarani Rd.
P.O. Box 30261
Nairobi, Kenya
Ph: (254) 286-2400
Fax: (254) 286-0949
Email: dmccarthy@usaaid.gov

INTSORMIL

John M. Yohe, Program Director
INTSORMIL
University of Nebraska
P.O. Box 830748
Lincoln, NE 68583-0748

Ph: (1) 402-472-6032
Fax: (1) 402-472-7978
Email: jyohe1@unl.edu

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Ethiopia

Agricultural Success in the Higher-Rainfall Regions

Kidane Georgis
EARO

John H. Sanders
Purdue University

Della E. McMillan
University of Florida

Eliud O. Omolo
Egerton University

Thomas W. Crawford
INTSORMIL

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Acronyms

ANRS	Amhara National Regional State
Agri-Service	German NGO
ARTP	Agricultural Research and Training Project
CFWCP	Community Forest and Wildlife Conservation Project
CIDA	Canadian Agency for International Development
CIMMYT	International Maize and Wheat Improvement Center
CORDEP	Community-Oriented Development Project
CRDA	Christian Relief and Development Association
DAP	Diammonium Phosphate
EARO	Ethiopian Agricultural Research Organization
FAO/WFP	Food and Agricultural Organization/World Food Program
GDP	Gross Domestic Product
IAR	Institute of Agricultural Research (Predecessor to EARO)
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IGAD	Intergovernmental Authority on Development
INTSORMIL	International Sorghum and Millet Research Program
KIT	Dutch Agency for International Development
LGP	Length of growing period
MEDOC	Ministry of Development and Overseas Cooperation
MoA	Ministry of Agriculture
NARI	National Agricultural Research Institution
NGO	Non-Governmental Organization
NSIA	National Seed Industry
PRA	Participatory Rural Appraisal Methodologies
SAT	Semiarid Tropics
SG2000	Sasakawa Global 2000
SIDA	Swedish International Development Agency
SNNPRS	Southern Nations, Nationalities and Peoples Regional State
UNECA	United Nations Economic Commission for Africa

Economic Conditions

Ethiopia has a population of 61.7 million with a growth rate of 3.3%. Per-capita income in 1997 US$ was $110 (World Bank, 1998, p. 190).[1] Agriculture employs 85% of the population and accounts for 49% of the gross domestic product (GDP) and 90% of the national export earnings. In the '90s the growth rate of the economy increased to 5% from 1994-1998 as compared to 1.6% from 1981 to 1991. Major changes in economic policy since 1992 include: reducing the role of government; encouraging privatization; liberalizing markets, and rationalizing exchange rate policies (FAO/WFP, 2000, p. 5)

As agriculture goes, so goes the rest of the economy. The poor performance of the economy prior to the mid-90s resulted from inconsistent agricultural policies and the drain of a continuing civil war. In contrast in 1995-96 agriculture grew by 14.7% and the economy by 10.6%. With normal weather in 1996-97, agriculture grew by 3.4% and the economy by 5.2%. Then in 1997-98 because of bad weather, agriculture declined to 0.3% and the economy grew at 0.5%. There was a recovery in 1998-99, with agriculture growing at a 4.2% rate and the economy 6.3%. (MEDOC, revised National Accounts Series, 1999). Overall in the '90s, the growth of the agricultural sector has been moderate to good.

Of the total land area of 112.3 million hectares, 16.4 million are considered suitable for annual and perennial cropland; 6.80 million were cultivated in 1997-98 by approximately 7 million farmers. Cereals occupied 82% and pulses 12% of the cultivated area. Approximately one-fourth of cereal production was of teff, followed by maize and sorghum (National Bank of Ethiopia, 1999, pp 6, 7).[2]

Until the mid-'90s (from 1979-80 to 1993-94), food production (crop and animal origin) grew annually by only 0.5% (Zegeye and Habtewold, 1995). The chronic shortfalls in domestic supplies to meet minimum nutritional goals were often met through food aid and imports, but this situation perpetuates dependence on foreign aid and can strain the balance of payments.

Much of Ethiopia, especially the mountain valleys, have sufficient rainfall and good soils, including a widespread occurrence of vertisols and volcanic soils. Unfortunately, population densities are sufficiently high so that Ethiopia is under continual pressure to increase agricultural productivity. Since the mid-'90s Ethiopia, has been committed to a crash program of agricultural intensification. This intensification program has been very successful in the prime regions in increasing yields of the principal staples. It involved (1) the rapid introduction of improved cultivars, (2) increased use of inorganic fertilizers, (3) credit, and (4) demonstration trials. In 1998-99, the value of fertilizer imports almost quadrupled from the fairly constant levels of the 1995-98 period. The program has

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[1] Per-capita income estimated from National Bank of Ethiopia data in 1999 was 258 Birr. At 8 Birr/$, per capita income is $32.

[2] The teff area varies substantially with weather and economic factors.

benefited from several years of favorable weather. Unfortunately, it has not been as successful in the areas of lower rainfall, the focus of this study. Forty five percent of the arable land is classified as dryland and this only produces 10% of total crop production (Georgis and Tadele, 2000, p. 3)

In the rest of this report we will

1. Contrast the successes of the '90s with the continuing drought problems at the end of the '90s
2. Briefly discuss semiarid farming systems
3. Review technology performance and input markets in the semiarid regions
4. Briefly analyze performance of the national research, extension, and NGO activities
5. Review the gender issues
6. Focus on the lessons learned, a technology strategy, and concrete recommendations to accelerate the agricultural intensification process for the semiarid areas.

Success in the '90s in the Prime Areas

In 1993 Sasakawa Global 2000 began farm demonstrations, working within the national extension system. The initial approach of Sasakawa 2000 was to target the best agricultural areas, those with adequate rainfall. Improved cultivars of maize and wheat were identified as were improved agronomic practices, including inorganic fertilizers. Farmers were guaranteed to make at least their usual incomes on one-half hectare demonstration plots. From two regions, 167 farmers participated. With new cultivars and fertilization, maize yields averaged 5.1 mt/ha and wheat 2.8 mt/ha. In 1994, the crop coverage expanded to include sorghum and teff; 1,600 farmers participated. Maize yields averaged 5.4 mt/ha, wheat 2.8, sorghum 4.5, and teff 1.5 (Quiñones, personal communication, November 1999; for more details on the trials see Quiñones, Borlaug, and Doswell, 1997). The media became involved in reporting these results. With former USA President Jimmy Carter of Global 2000, the Prime Minister visited these demonstration plots.

The Prime Minister then called a meeting in several Ministries to take over the program and expand it. He told the extension service to make a budget. The program was expanded to 35,000 participating farmers in 1995 and then 350,000 in 1996. In 1996, the program included some drought-prone regions. Fortunately 1996-97 was an excellent rainfall year. Total food production

(cereals and pulses) increased to 10.4 million metric tons after having ranged from 5.4 to 7.4 million tons over the 1979 to 1994 period. The maize price collapsed from 90 to 100 Birr/quintal to 40 in one month (Quiñones, personal communication, Nov. 1999).[3] This price collapse in good rainfall years when new technology is being introduced is a serious common phenomenon. The maize price collapse indicates the importance of the simultaneous consideration of market expansion as the technology is being introduced (see the later discussion of output markets).

In 1997, the number of technology packages was increased, including: (1) livestock, milk, meat, eggs, and honey; (2) high-value crops: pulses, oil crops, and vegetables; and (3) storage technologies (Table 1). Participating farmers increased to 650,000. In 1998, national resource conservation and agroforestry were added. More than 2.9 million farmers participated. In 1999, almost 4 million farmers participated. Yields were increased by two to three times for most crops for successful participating farmers (Ibrahim Mohammed, Division Director, Federal Extension Service, personal communication, Nov. 1999).

Table 1. Technologies introduced by SG2000 in 1994 and thereafter extended by the Ethiopian Extension Service[a]

Year	Introduction of new packages
1994	Maize, wheat, teff, and sorghum package (adequate rainfall regions)
1995	No new introductions but continued 1994 package
1996	Maize, wheat, teff, and sorghum package (semiarid regions)
1997	High-value crop package (oilseeds, pulses, vegetables) Livestock package Post-harvest technology package
1998	Agroforestry package Beekeeping package Soil and moisture conservation package
1999	No new introductions
2000	Coffee production package Irrigation package Nutrition package

[a] The government took over and continued the SG2000 trials of 1994 and then added the new trials included in this table. The initial trials in the higher-rainfall areas have been the most successful in increasing yields, especially with maize and wheat.

Source: MoA, Extension Service, Interviews, April 2000.

[3] Obvious here was the importance of storage so that farmers were not obligated to sell at the post-harvest price collapse and the need to develop markets as part of the technology introduction process.

There was a substantial expansion of the extension service to support these new initiatives. Ethiopia created a revived extension service that increased in size from 4,000 extension workers in 1990 to 15,446 in April 2000 (Melaku and McMillan, 2000, p. 5).

An industry of inorganic fertilizer distributors with five active firms was present in 1998 and has more entrants now. Fertilizer sales to the small-farm sector increased to almost 300,000 mt (DAP and urea) in 1999 from 90,000 in 1993 and 141,000 in 1992.

The Ethiopian Seed Enterprise (a 100% government-owned firm) also evolved in its ability to provide quality seed. This company produced 14,000 mt of seed in 1994-95 and had a target of 22,000 for 1999-2000.

Since 1995 this Ethiopian experience has been an outstanding success story for rebuilding an agricultural system by

1. Developing a fertilizer-distribution industry
2. Improving the performance of its parastatal seed company
3. Changing the orientation and increasing the size of its extension service

The packages of new cultivars with improved agronomy, especially inorganic fertilizers, were developed by the research system. In 1996, researcher salaries in the national system were almost doubled.

Two criticisms of the mid-'90s success were that

1. There was little farmer feedback and little flexibility in packages

2. The packages were not always tested locally nor were they always successful, especially in the semiarid regions.

Dividing up the country into agroecological zones and obtaining more site-specific recommendations were two of the principal factors in the reorganization of the Institute of Agricultural Research (IAR) into the Ethiopian Agricultural Research Organization (EARO) in May 1997 (EARO/ARTP, 1999b). This is a natural evolution of research systems to refine the technological recommendations to be more site-specific after initial gains from improved seeds and fertilizers are attained in the best agricultural regions.

Postscript on the Success: Drought of 2000

In the spring of 2000, FAO and news reports indicated that 7 to 8 million people[4] were at risk of not having enough to eat until the next harvest. There were urgent appeals for food aid to the U.S. and Western Europe. If Ethiopia were so successful in developing its agriculture in the best areas, as we have reported above, what happened?

In 1998, the harvest in general was excellent and only slightly less than the record crop of 1996. Yet even with this abundant harvest, the World Food Program requested food aid for 2 million people. This was its estimate of the number at risk (FAO/WFP Crop and Food Supply Assessment Mission to Ethiopia, Dec. 21, 1998, pp. 1, 2).

In 1999, agricultural production declined slightly, 6% below that of 1998. However, the disparities between the adequate-rainfall regions and the semiarid regions increased substantially. In the surplus areas there were good crops and total production was off only 9% from the record year of 1996. Yet in the deficit regions, the declines were very serious, with a 35% decrease in Tigray, a 12% decrease in the southern region (SNNPRS – Southern Nations, Nationalities and Peoples Regional State) and a 5% decrease in the Amhara region — all compared with 1998.

On the national level there was a 26% decline in sorghum production and a 13% decline in maize production, although, wheat, teff, and pulse production were all higher than in 1998.

This juxtaposition of gross poverty and food deficiencies adjacent to abundance raises the chronic problem in agricultural development that increasing the food supply is not sufficient to benefit the poor. Ethiopia could invest in transportation and communication to move food between regions, but the problem still remains of increasing the purchasing power of poor people in the food-deficit regions to buy the food. Poor people have to find ways to pay for the food. If the income-earning potential of these people collapses, then even with falling food prices, they can go hungry.

The danger of relying only on food aid to resolve the problem is that by continually depressing food prices with imported food products, investments in increasing agricultural productivity are discouraged.

Another alternative for food-deficit areas is to increase their food-production productivity. This is the alternative that we consider in the next sections of this report. Fortunately, with some strategic

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[4] A United Nations World Food Program report estimated that food aid will be necessary "to support 7.8 million people affected by severe food shortages resulting from droughts, water logging and other weather related hazards" (FAO/WFP Crop and Food Supply Assessment Mission to Ethiopia, Jan. 26, 2000, pp. 1, 2).

investments, semiarid regions have some comparative advantages over adequate-rainfall regions. The food-deficit semiarid zones are not only a welfare problem but also a source of potential productivity and growth wherever more water can be made available and soil fertility improved (see Appendix).

Farming Systems in the Semiarid Regions

The semiarid areas of Ethiopia account for more than two-thirds of the total landmass of the country. According to the recent agroecological classification of the country (MoA 1998), the semiarid areas include arid (<45 days length of growing period (LGP), dry semiarid (46-60 days LGP), moist semiarid (60-120 days LGP), and sub-moist zone (120-180 LGP) (Fig. 1).

Population increases are higher in the rural areas, placing an extreme pressure on land in already established farm communities. The average population density is 35 people- km^{-2} and ranges from < 10-km^{-2} in Oromia zone in Bale to 250-km^{-2} in Kambata and the Wolayta area.

Despite substantial variation in cropping systems across three major semiarid zones, the cereal-based mono-cropping systems are predominant across regions. Major cereals in the lowlands are sorghum, maize, and millet. Teff joins these cereals in the mid-altitudes. In the higher altitudes, the major crops are wheat, barley, finger millet, and some teff. These are mixed farming systems, with small livestock being very important. Often different grain legumes are found here, again with variability by altitude and rainfall. These include common beans, peas, chickpeas, pigeon pea, and cowpeas.

The family size in the rural areas is large (with average household size of five per hectare of land) and the farms are small. The average landholding per household is generally less than a hectare in most parts of the semiarid areas.

In the semiarid regions, soils are often degraded in quality and marginal in fertility. But the principal constraint is the quantity and distribution over the crop season of water, adding to the riskiness of any practices to increase land productivity. Household food insecurity is further accentuated by poor rural infrastructure and marketing services.

Prices for products can vary substantially. A fundamental concern of technology development and policy support needs to be risk reduction. Hence, our emphasis is on the need to make more water available with water harvesting. This will increase the profitability and reduce the riskiness of investments to increase soil fertility.

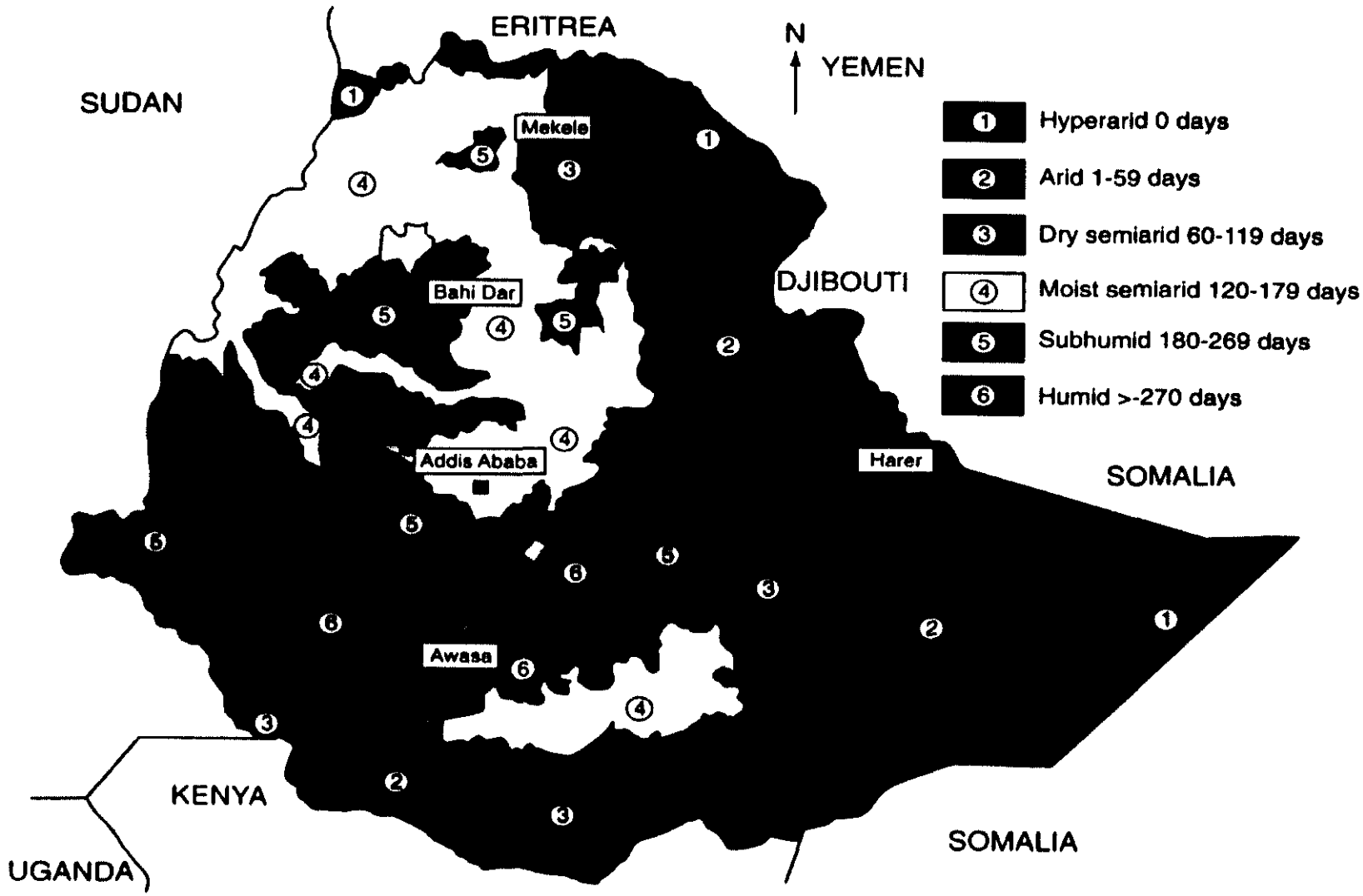

Figure 3. Growing days in Ethiopia's six zones..

New Cultivars With Biotic Resistances

In the last two decades there have been three areas of concentration in plant breeding in most semiarid regions of the world:

1 Selection and crossing for resistances to disease and to a lesser extent insects
2. Shorter-season cultivars for drought escape
3. Identification and selection for characteristics associated with higher yields

A summary of the new material released by EARO in the '90s is presented below. The most significant success has been in maize breeding. New maize cultivars for the drylands are AVC-3 and AVC-6. Under experimental conditions they yielded 3.5 mt/ha. They were released in the '90s and are being demonstrated now. Early (70 to 90 days to the maturity period) and extra early (40 to 60 days to maturity) maizes have been a principal focus, also incorporating disease resistances.

Maize is especially important as a short-season cultivar for the hungry period (Georgis and Takele, 2000, p. 21). Due to its greater susceptibility to soil fertility and water stress, maize needs to be incorporated on the small areas with higher fertility and more water, such as near the household where household garbage or tethered animals improve soil-fertility and water-retention capacity.

Similar advance in other crops and release in the late '90s were Meko 1 (sorghum); Cross 37 (teff); Awash 1, Roba 1, and GLPX92 (field beans). There is now a shift in EARO research policy to work more on a broader range of dryland legumes and to add dryland oilseeds (safflower and sesame). Movement into these new crops not only allows diversification[5] but also enables the search for new domestic and international markets for these regions.

Pigeon pea has not only substantial market potential but also excellent drought resistances and many new cultivars are available in the East Africa region (see the Kenya report for IGAD). Early cultivars of both mung beans and cowpeas with biotic resistances were released. In the oilseed, safflower and sesame, new cultivars with drought tolerance and good potential markets are available. They also grow well in association[6] (Georgis and Takele, 2000, pp. 26,27). Safflower tolerates well the heavy soils and sesame the lighter, marginal fertility soils. Safflower produces a high-quality vegetable oil much appreciated in developed countries. In Ethiopia it is frequently intercropped with teff.

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[5] Intercropping or alley cropping a cereal and a legume are excellent systems when substantial labor is available. Experimental results have often shown little cereal yield decline from a pure stand (Kidane, personal communication, Nov. 2000).

[6] Even the combination of cereals with a legume will still require fertilization with phosphorus for the grain legumes and both N and P for the cereal and oilseeds

New Sorghum Cultivars and Tied Ridges

Sorghum was included in the packages promoted by the government and Global 2000. In contrast to maize, there were few improved sorghum cultivars. Exceptions were three sorghum cultivars, with Striga resistance introduced initially in Tigray in 1996 (SRN-39, P-94-01, and P-94-04).[7] These early cultivars did very well in the drought year of 1997-98 and an estimated 2,000 farmers are now growing them in Tigray in the Sheraro, Adi Awala, Adi Hagerou, and Abelgela zones (Mezgabe Tsegaye, Director of Extension, Tigray, personal communication, Nov. 1999).

Without fertilizer and more water, the improved shorter-season cultivars do not outyield the locals in adequate-rainfall years. In three of the last four years, rainfall was abnormally low in the Tigrean sorghum areas. The new sorghum cultivars were shorter-season and outyielded the locals only during adverse weather years (field interviews in Tigray, Dec. 2000). Credit was provided and the new cultivars were introduced with inorganic fertilizers.

Figure 2 Tied ridges with water between them.
Source: Farming Systems Project in Burkina Faso

In 1996, the package extended to the semiarid regions also included tied ridges (Fig. 2). Without the tied ridges (or other water-retention technique) fertilization is more risky and often unprofitable. The advantages of tied ridges to increase semiarid yields in heavier soils have been well documented (Appendix).

Unfortunately, the adoption rate is low because making the ridges by hand is extremely labor-intensive. An animal traction implement is necessary. Fortunately, animal traction is pervasive in Ethiopia.

An animal traction, tied ridger had been developed in the Nazret experiment station (IAR) in the '90s (Fig. 3). This modified version of animal-drawn tied ridgers developed in the '80s in Burkina Faso in West Africa was first introduced into the Ethiopian extension program in 1996 (see Table 1) as

[7] These cultivars were only officially released in 1999 but had already been widely disseminated by farmers taking regional trial seed and distributing it to their neighbors (Gebisa Ejeta, personal communication, March 1999).

part of the new technology introduction program aimed at the semiarid regions. Farmers complained that implement was too heavy and awkward.[8] Melesse Temesgen, an agricultural engineer at Nazret, went back to work on his implement to respond to the farmer complaints.

In 1999, a much lighter implement was developed and rights were bought by a local private company to start distribution.

Since the local company also acquired distribution rights to several other machines, it is probably necessary for EARO to continue to promote the rapid distribution of the machine and/or to make it available to other companies.

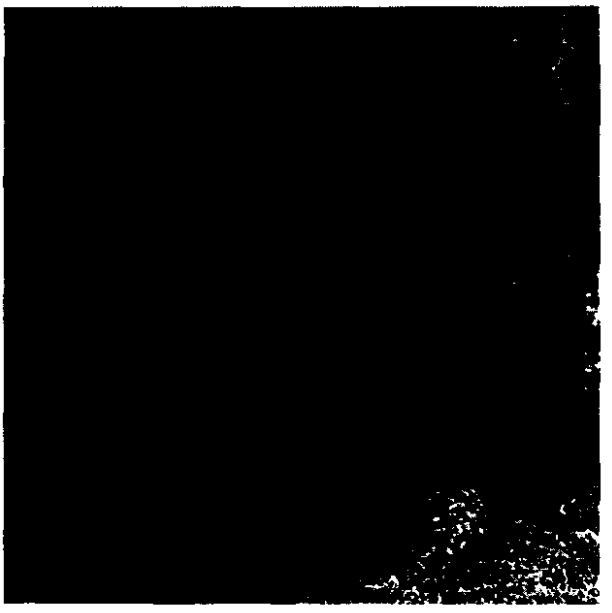

Figure 3. Tied ridger attached to traditional oxen-drawn plow.
Source: EARO files

Soil Management in the Amhara Region

Soil erosion and the lack of soil fertility are two major constraints to achieving food security in the Amhara National Regional State (ANRS). Many areas in the Amhara region have been cultivated for 3,000 years. The loss of topsoil by erosion from the Blue Nile watershed in the Amhara region is Sudan's and Egypt's gain. But for Ethiopia, it magnifies deficiencies of nitrogen (N) and phosphorus (P), the major causes of low soil fertility in the ANRS. Heavy grazing pressure on plant parts not harvested results in diminished organic matter, contributing to erosion and diminished capacity for biological nitrogen fixation.

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[8] The advantages of tied ridges are well appreciated by farmers, although the adoption rate is very slow because it is tedious and time-consuming to make them by hand. Farmers' attitudes toward the implement introduced in 1996 were assessed. Almost all farmers responded that the implement was too heavy for oxen to pull, especially when they were weak after dry-season feed shortage, which coincides with the time of land preparation. Farmers also indicated that the implement is made of metal, making it heavy and expensive. Also, working with the tied ridger requires additional manpower to guide the oxen to go straight and keep the specified row spacing (Georgis, 1999, pp. 23-25). The new implement in Figure 3 is an extension of the traditional plow with a small piece of metal that can be raised to leave the furrows closed.

With one of the most serious erosion problems in the world, Ethiopia loses approximately 12 tons/ha/yr., with losses exceeding 300 tons/ha/yr., or 250 mm/yr. on steep slopes such as are common in the Amhara region (see Table 2). Clearly, continuing investments in soil and water conservation measures are urgently needed in Amhara region as well as elsewhere in Ethiopia.

Table 2. Erosion problems in the Amhara region

Projects	Completed between 1997 and 1990	Surviving by 1990
Soil and stone bunds	71,000 ha	Soil bunds, 30% Stone bunds, 25%
Hillside terraces for afforestation	233,000 ha	60%
Checkdams in gullied lands	12,000 km	NA
Closed areas for natural vegetation	390,000 ha	7%
Land planted with different tree species	448,000 ha	22%
Bench terrace interventions	526,425 ha	NA

Source: USAID, 2000, pp. 7, 8.

For the really degraded marginal regions it is necessary to keep non-farm alternatives open. USAID (2000, P. 6) stated:

> Food security cannot be achieved by focusing only on chronically food insecure zones. The production of agricultural surpluses from high potential zones can provide low cost food to deficit areas. Success in high potential areas can reduce degradation in marginal areas by reducing production pressures on degraded and marginal land. Further, high potential areas have greater capacity to generate off-farm income for household members from low potential areas by employing labor in upstream (input provision) and downstream (agriculture product transformation) agricultural sector activities and other small businesses. On the other hand, the technology packages used in high potential zones are generally not appropriate and need to be adapted for more marginal, drought-prone areas.[9]

[9] This observation on policy neglects the problem of how poor people will pay for increased production in the better regions, the central dilemma of the present strategy of concentrating attention in the higher rainfall regions.

Input Markets

Seed Sector

Ethiopian Seed Enterprise, was instructed to become more profitable. It shifted its activities from a wide range of semiarid crops to a concentration on hybrid maize and wheat following the example of the main private seed company in Ethiopia, Pioneer. Seed production of teff was reduced from 24,000 quintals in 1994 to 2,400 in 1999. Teff is the principal staple of Ethiopia, widely preferred to injera.[10] Seed production of the primary activities of the semiarid regions — including grain legumes, sorghum, millet, and most grain legumes — were largely phased out.

One consequence of Ethiopia Seed Company's phasing down of seed production for the semiarid region has been an increase in the number of community-based seed production projects. The problem with this type of local-level project is quality control, especially for isolation and roguing. This type of decentralized private sector and community seed production can work with adequate technical help from EARO and the regional research technicians, who have often been hired as consultants or employees to begin the project. Over time, however, the EARO and regional research employees will need to return to their jobs, even though in the initial enthusiasm period they may have provided substantial technical input.

NGOs often attempt to provide the technical inputs here but this requires highly trained staff and is not usually cost effective in moving beyond a pilot project. Neither NGO community seed projects nor EARO private-sector spinoffs represent a long-term solution, especially when seed demand is expanding rapidly.

What can be done to encourage the development of a private sector to service the semiarid sector? Breeders and other agricultural scientists are well-trained and often innovative and have a wide range of contacts. Incentive systems need to be set up to encourage them to be involved in the diffusion process of new seeds and other technologies. For example, breeders could receive payments when their material is successfully diffused to farmers. This would be a strong incentive to get them to search for companies or help start small national companies. Similar operations could increase the availability of teff, sorghum cultivars, or other grain legumes. Besides unleashing their entrepreneurial ability, this financial incentive would also encourage agricultural scientists to put more effort into community-based seed programs until the demand for seed is increased sufficiently to interest the private sector.

[10] In recent years teff area has ranged from 1.4 to 2.2 million ha. In poorer rainfall years, there is increased planting of the shorter-season teff, so farmers have another method of responding to the expected failure of the longer-season maize or sorghum (Georgis and Takele, 2000, p. 17).

The seed sector has made substantial progress in the higher-rainfall regions but has not serviced semiarid regions as well. Both sorghum and teff need the resumption of professional seed production. Communal seed production will not maintain quality, and continued agricultural development requires increased availability of higher quality seed of new cultivars. The grain legumes and oilseeds need to benefit not only from the evolution of the seed sector but also the growth of new markets. The real test of privatization is now to move the system beyond hybrid maize and the prime regions. This may even ultimately involve moving Ethiopian Seed Enterprise back to the development of smaller, high-risk markets, such as for pigeon pea and orphan crops (those crops in which the private-seed sector is not interested until they become sufficiently profitable to be taken over by private companies).

Fertilizer Sector

One of the main successes of the '90s has been the rapid evolution from a state to a private fertilizer industry, the increasing use of fertilizers, and the phasing-out of fertilizer subsidies for both distributors and farmers. As with the seed sector, the concentration of this industry has been on the higher-rainfall regions where the hybrid maizes and, in the higher altitudes, the improved wheat cultivars have been introduced. Without water harvesting or some technique to increase water availability, fertilizer use is risky in semiarid regions.

Functioning of National and Regional Research Systems

In 1996, with the successes in the high-rainfall regions with new cultivars and fertilization, researcher salaries in IAR doubled. In 1997, IAR was restructured into EARO and the enlarged research/extension system received a $90 million World Bank loan in 1998. Restructuring involved:

1. Expanding the scope of the research system to include the agricultural universities and the regional research/extension systems in the new principal regions of the country

2. An increased focus on regional adaptation of research in response to the problems resulting from the blanket recommendations commonly made for fertilizer and new cultivars in the rapid expansion period of the '90s (note the intensive efforts of EARO in defining agroecological zones and the proposal to construct nine regional soil laboratories)

3. Improving the research/extension/farmer linkages

The failure by IAR and EARO to support much of the research or extension for the semiarid zones presents big opportunities for EARO presently given the interest that donors are again showing, especially the World Bank. Within EARO, five new semiarid centers were created and also a central "semiarid regions" program at the national EARO headquarters. There is also increasing funding for semiarid area components within the present centers, although the basic orientation of these programs remains strongly focused on new cultivar development rather than on water retention and soil fertility.

This program justification is often made in terms of the serious malnutrition and poverty in these semiarid areas. But the principal reason for investing in the semiarid regions is not only for welfare improvement but also for the economic opportunities these zones provide when water availability and soil fertility are improved. Nevertheless, it is worthwhile to look more closely at the welfare aspect, as in the Amhara regions.

The Amhara National Regional State (ANRS) of Ethiopia is composed of 105 *woredas,* of which 48 are drought-prone and suffer from frequent food shortages. Many households in these drought-prone areas within Amhara region can produce only enough food to meet their requirements for less than six months a year; 80% of the children suffer from stunted growth. Of the 15 million people in the region, 89% live in rural, agricultural households,. Cereals account for 80% of cultivated land and 85% of total crop production (USAID, 2000, p.3).

Despite the push for decentralization of research and development in Ethiopia, there is a striking contrast between the resources of the EARO and the agricultural research organization of the National Regional States of Ethiopia. For example, Amhara's region of approximately 15 million people is served by three ANRS agricultural research stations. These are located at Adet, Sirinka and Sheno. In February 2000, scientists trained at these three stations were: 2 Ph.D., 18 M.S., 51 B.S., and 2 DVM (Doctor of Veterinary Medicine). With very limited funds for operational expenses in the ANRS, the highest agricultural research funding priorities are for staff. Little funding is available to support advanced degree training of scientists within the ANRS agricultural research system (USAID 2000, p. 24, 25).

Functioning of the Federal and Regional Extension Services

The fundamental problem of the semiarid regions for the extension service has been the lack of an adequate technology package from the research establishment. We documented above that the early tied ridger had operational problems on farmers' fields. The new version appears to be very effective but production had just begun in 1999 by a private company. The principal focus of research has been on new cultivars. Unfortunately, higher-yielding cultivars will not be successful on farmers' fields without complementary investments in water retention and soil fertility.

Without sufficient support from public policy for the semiarid regions, extension agencies retreat to slogans, such as the promotion of indigenous technology and the myth of local-variety superiority. These two concepts are now being heard all over the country and were frequently repeated in our field trip to Tigray. These two concepts can be summarized as the diffusion of best-farmer practices, and this can be useful. However, the big gains from agricultural technology are with the application of science to agriculture, especially the rapid response to biotic constraints as they emerge, the utilization of higher input levels, and shifts to more valuable crops.

These techniques also need to be applied to semiarid areas — unless the public-policy goal is to leave farmers out there to remain in poverty until, with falling birth rates and industrialization in one or two decades, they can be attracted off the farm.

As a result of its successes in the prime agricultural regions, the extension service has expanded rapidly and is justifiably proud of its achievements. The demonstration trials described earlier are tied to receiving credit and facilitating access to improved seed and inorganic fertilizers. So for the areas with sufficient rainfall, there have been substantial increases in productivity. In these areas, there is good support from farmers, and high morale.

The structure of the extension service includes a small, highly trained federal component with a concentration of personnel in the regions (Tables 3 and 4). A rapid build-up of a more decentralized system then will have an increasing number of extensionists without sufficient technical training. In the search for local extension agents who speak the local language and know the local customs, education-level requirements for the state extension service were reduced. This was a necessary innovation to create a cadre of agents able to function effectively with farmers. The problem now is to continue the education of this new personnel.

Building up the technical capacity of the local agents in the semiarid regions and elsewhere will help them successfully collaborate on introducing technological change, especially as this technical change process becomes more rapid and depends more on:

1. Using new inputs (improved seed and inorganic fertilizers)
2. Water-retention techniques
3. Finding new output markets. Some NGOs may be able to collaborate in this training function.

The role of women is still limited in the extension services and shows substantial regional variation. Given the importance of the nutritional deficiencies in the semiarid regions, building up the home economics section of the extension service needs to be a high priority to encourage more production of vegetable gardens, food conservation, and processing. The development of this division would also be expected to encourage more participation of women in the full range of extension activities, including direct production activities.

Table 3. Number of federal and regional MoA extension staff in Ethiopia, Jan. 1999

Federal, Regional	Total	Male	%	Female	%
Regional					
Tigray	2,393	1,918	80	475	20
Afar	1,082	844	78	238	22
Amhara	10,428	8,529	82	1,897	18
Oromoia	16,672	13,590	82	3,082	18
Somali	721	588	82	133	18
Benshangui	834	626	75	208	25
SNNPRS	10,317	8,333	81	1,984	19
Gambela	790	580	73	210	27
Harari	141	94	67	47	33
Addis (city state)	445	268	60	177	40
Diradawa (city state)	191	128	67	63	33
Total Regional MoA Staff	**44,014**	**35,498**		**8,514**	
Federal					
Headquarters (All divisions of MoA Extension)	817	530	65	287	35
Technical Staff	189	169	89	20	11
Agriculture Extension	52	45	87	7	13
Crop Production and Protection	48	45	94	3	6
Livestock Production and Fisheries	28	25	89	3	11
NRM	58	52	90	6	10
Women's Affairs	3	2	67	1	33
Total Federal MoA Staff	**1195**	**868**		**327**	

Source: MoA, Women's Affairs Department, Addis Ababa, Ethiopia, January, 1999 and MoA, Office of Personnel, Addis Ababa, April 2000 (Melaku and McMillan, 2000).

Compared with other Horn countries, the extension service is well-funded and has a solid base of qualified staff in direct contact with farmers (Table 4). Management provides bonuses to encourage good performance. It recognizes the need for more technical training of its staff, the importance of improving the research/extension linkage, and becoming more participatory.

The biggest single constraint for the semiarid agricultural sector is the need for a series of water-retention/soil-fertility alternative recommendations for the different soil types — for which it needs support from the regional research organizations and EARO.

Table 4. Number of extension agents and supervisors in direct contact with farmers

Regions	Development Agents				Supervisors			DA & Sup.	
	Male	Female	Total	Female %	Male	Female %	Total	DA+ Sup.	Sup.-DA Ratio
Tigray	721	11	732	1.5	103	–	103	835	1:7
Afar	n.a.	n.a.	51	n.a.	–	–	8	59	1:6
Amhara	2964	1025	3989	25	483	18	501	4490	1:8
Oromia	4025	724	4749	15	403	2	360	5189	1:13
Benshangul	125	32	157	20	22	---	22	179	1:7
SNNPRS	3232	795	4027	20	262	5	267	4294	1:15
Gambela	89	2	91	11	11	--	11	102	1:8
Harari	15	2	17	11	n.a.	n.a.	2	19	1:8
Diradowa	n.a.	n.a.	15	n.a.	4	0	4	19	1:4
Sumali	n.a.	n.a.	248	n.a.	n.a.	n.a.	n.a.	248	n.a.
Addis Ababa	5	4	9	44	2	1	3	12	1:3
Total	**7151**	**1871**	**14165**	**----**	**887**	**29**	**1281**	**15446**	**1:11**

Source: MoA, Extension Department, April 4, 2000 (Melaku and McMillan, 2000).

Broadening Extension Activities

NGO Involvement in Agricultural Research and Extension

Many of the constraints faced by the semiarid zones are beyond the mandate of EARO. The MoA will require a partnership approach that links EARO's technical experts to a network of committed partners that includes the area's major institutions of higher education as well as farmer groups, NGOs, and the most relevant international and regional development networks including the CGIAR Centers, CRSPs, and the private sector.

In the short run, the NGOs are likely to be some of EARO's most committed non-governmental partners. A large number of NGOs are working in the semiarid zones and many already are in communication with EARO and even conducting farm trials (see Table 3).[11] These NGOs want the types of technological knowledge EARO has. EARO in turn sees the NGOs as having a comparative advantage in getting technical information to and from the village.

[11] At any point in recent time, there are between 200 and 300 registered NGOs in Ethiopia. Approximately 160 of these are registered with Christian Relief and Development Association (CRDA).

Some NGOs have developed strong working relationships with EARO for adaptive, on-farm research, and the exchange of information. Many of these same agricultural NGOs have played an active role in the conceptualization and revision of the new "Semiarid Agricultural Research Strategic Plan" (EARO, 1999a). There is also a very active agricultural and environmental working group comprised of 15 NGOs that operates under the aegis of the NGO coordinating body, the Christian Relief and Development Association (CRDA).[12]

Between 80 and 100 of the NGOs registered with CRDA have agricultural programs. In contrast to Kenya and Uganda, where many NGOs hire their own extension workers, most NGOs in Ethiopia contract with the state extension services to provide transportation and/or "top offs" (salary supplements) to cover extra travel and living costs and job share between the MoA and the NGO.

Many of the same community-development programs rely heavily on EARO's regional agricultural centers for seeds and technical advice. The most common pattern of obtaining information or genetic material is for an NGO office director and/or the person responsible for the agency's agricultural programs to approach the center specialist on a particular technology. Since a great deal of this new material was still considered to be in EARO's Phase Two of adaptive research, the NGO distributions of new material were considered to be on-farm trials.

One of the most common complaints (on both sides) is that there is no formal mechanism for the NGO to give the EARO research center any sort of structured feedback on the success/failure of particular innovations. This lack of structured feedback from the NGOs is contrasted with the formal channels of communication that are established between the regional MoA extension services and the EARO research centers.

There were, however, a number of NGOs that did manage to work in much closer collaboration with EARO. One outstanding feature of these collaborative programs has been their commitment to detailed reporting of their field results. Reporting was done by Farm Africa, SOS-Sahel, and Agriservice. Activities included new varieties; new cultivation practices (bunds, tied ridging, agronomic practices); soil-fertility management, including tests of organic and inorganic fertilizer; and new methods of participatory on-farm interaction between MoA extension agents and farmers.

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[12] CRDA is an umbrella organization for some 160 indigenous, faith-based, and international NGOs in Ethiopia. About 50% of the members are local NGOs. Since 1974, CRDA has provided an interface between its members and the government. The same organization facilitates communication between its members via monthly meetings and a series of working groups (including one on agriculture and environment) and sponsors training workshops and small-grants activities that are designed to build the technical and administrative capacity of its members. CRDA was recently selected by the Washington, DC-based Interaction Network as an example of "best practice" in NGO coordinating groups.

Factors Affecting NGO Success

Since its inception in 1974, the NGO CRDA has played a major role in facilitating the exchange of information among NGOs and between the MoA and NGOs via:

1. Monthly meetings, which tend to be well-attended by the representatives of the full membership

2. Bi-monthly meetings of its Agriculture and Natural Resource Management working group comprised of 15 NGOs

3. More specialized workshops, such as the 1996 Agricultural Extension Workshop which brought together 71 representatives from the MoA and the NGO community to discuss the government's new policy on agricultural development.

Probably the single most important factor that distinguished the NGOs that have worked most effectively with EARO was the presence of Ph.D. and M.S. level agricultural scientists on its staff. Many of these NGO staff had also worked in EARO or the MoA. The high concentration of CRDA staff (6 of approximately 30 employees) with technical agricultural training — including the Director and the head of the Monitoring division — has increased CRDA's ability to support the agriculture and NRM working group.

A second factor that has substantially enhanced the impact of NGOs on technology transfer has been EARO's recent increased collaboration with a wider range of partners (e.g., research/extension/farmer linkages) since the creation of EARO from IAR in 1997. This new collaboration has been reflected in

1. An increased number of NGOs working with program directors of EARO to identify priority areas for collaborative research

2. A greater number of NGOs attending EARO's strategic planning sessions (for the Soil and Water Research Program and the Arid Lands Program, for example)

3. Increased NGO participation in the formulation of the annual research plans of the regional technology centers

The NGOs are also being invited to comment on specific policy documents, to review EARO strategy documents, and to participate in workshops, such as the National Fertilizer

Workshop. Many of these invitations are made directly to prominent agricultural NGOs, such as FARM, SOS/Sahel, and Agriservice; others are made through CRDA.

A high percentage of NGOs appear to work primarily with the regional research centers because of greater ease of contact. The NGO programs that have been most effective in technology transfer have been those that have combined a commitment to regional-level collaboration (with the MoA and EARO's regional research institutes) with strong collaboration from EARO's central research programs where there is a concentration of the agency's most highly trained manpower.

In summary, the NGOs and the NGO umbrella organization, CRDA, are playing an active role in technology transfer in semiarid agriculture and their role is complementary with that of the research/extension system. To date, however, the full impact of these non-governmental investments in agricultural research, extension, and capacity building has been hampered by the lack of established communication channels between the NGOs and the central EARO program offices. While some of the most active NGOs — with high levels of technical expertise and/or professional ties to program directors in EARO — have been able to carry out this type of collaboration, they are more the exception than the rule.

Gender Issues in the Technology Development Process

Women are responsible for about 40% of all agricultural labor in the country (MoA, 1992). Hailu (1997) found that women in her study areas within the southern nations and nationalities region were responsible for 33 to 37% of crop production and 70% of livestock production activities. She also found that women contributed 15 to 25% of the labor in reforestation and soil conservation programs. Similar patterns were observed in the Amhara and Tigray regions (Table 5).[13]

Recent research in the Amhara region shows evidence of women owning oxen and engaging in plowing (Frank, 1999, p. 10). The same study indicates that women who have adult sons living with them, providing them a labor source over which they have control,"are as effective at farming as men and make the same type of agricultural management decisions as male-headed households"

[13] Sample surveys of husbands' and wives' roles in South Gonder, North and South Wollo, Wag Hamra of the Amhara Region, North Omo of SNNPRS, and in Eastern Tigray showed that each, respectively, contributed 33 and 67% of the overall total labor and time inputs for housework, farm, income-generating, and off-farm activities. When respondents estimated this in terms of percent of contribution in monetary value, husbands and wives averaged 42 and 58%, respectively (Hailu 1999, p.11).

(*ibid.*). Masefield's (1996) research in northern Ethiopia indicated that female farmers (most with absent husbands) plowed their land during the struggle to overthrow Mengistu.

Other studies show that women in the Amhara region who ran female-headed households were entitled to equal access to inputs from the service cooperatives. They had direct access to fertilizer and were rated as food self-sufficient (Frank 1999; see also Tiruneh et al., 1998, p. 8). Another study in the central highlands of Ethiopia (Tiruneh et al., 1999) showed that male-headed households could increase productivity by using more labor and fertilizer while female-headed households could do so by using more land and fertilizer.[14]

Table 5. Percent of labor and time inputs of male and female farmers in crop and livestock production from sample surveys in three regions in Ethiopia

Agricultural Activities	Amhara				Tigray				Southern	
	N. Wollo		W. Hemra		Eastern		Southern		N. Omo	
	M	F	M	F	M	F	M	F	M	F
Crops	50	50	50	50	42	58	53	47	66	34
Livestock	48	52	55	45	23*	52	—	—	33	67

*Children or hired labor usually do herding activity.

Sources: Summarized from Women in Development Program Proposal: UNECA. Amhara National Regional State Vol IX: Eastern and Southern Tigray. Vol. IX 1997 and Vol. IX 1998; and Southern Nations Nationals and Peoples Regional State Vol. IX. 1997. Addis Ababa, Ethiopia (Hailu, 1999).

The process of formulating food security strategies[15] at the federal and regional levels seems to have catalyzed a renewed interest in focusing strategies to address a wider group of gender and equity concerns in agricultural research and research/extension linkages. The growing recognition of these

[14] While male-headed households had a higher gross value of output, the study suggested that the gross value of output would be 1.3% higher for the female-headed households if the average values of the inputs from the male-headed households were used.

[15] These food-security strategies typically outline a series of activities that work to: (a) increase food availability through increased agricultural production and productivity; (b) increase access to food through increased household incomes and more efficient agricultural markets; and (c) improve food utilization through better pre-and post-harvest technologies and nutritional practices. Frank (1999, pp. 2, 4) notes that the written commitment of some of the programs to working with female-headed households — in particular that of the Amhara Food Security Program — contrasts with the lack of any female representation on the program's organizing committee.

gender issues — both as factors that affect diffusion and as factors that affect EARO's ability to fulfill its wider mandate for effective research/extension/farmer linkages — led the agency to identify "gender" as one priority issue to address in the formulation of its five-year strategy.

The Women's Affairs Office is the formal structure within the federal office of the Ministry of Agriculture that is charged with coordinating extension services for women farmers. There is also a Women's Affairs Bureau within each of the regional administrations. Most regions include representatives of the Women's Affairs Division within their zonal and, occasionally, even in their Woreda administrative units. Traditionally, the women's affairs units have had a home-economics perspective that concentrated on hygiene, cooking techniques, and family planning. In contrast to the farm-extension program, the home-extension program was staffed almost exclusively by women and worked with women in male- and female-headed households. Despite their traditional focus on "social themes," the women's affairs departments have played an important role in sensitizing and advocating more broad-based gender concerns.

When the Amhara region closed down its home-extension program[16] in favor of a new unified family-centered approach to extension, the communication of technical messages to women broke down (UNECA, 1998, p.15; Hailu, 1999, p. 6). The Amhara region's home-extension program was recently reinstated and is attempting to rehire some of the home-extension workers laid off (personal communication, Alemu Bogalech, Dec. 3, 1999; Frank,1999, p. 12).

Women at all levels need leadership training to encourage them to participate more actively in public forums (Bogalech, 1999, p. 14).[17] Better reporting on women's activities needs to take place at both zonal and regional levels (Frank, 1999, p. 13). Urging officials at the zonal and regional level to keep information disaggregated by gender will allow trends in women's participation in agriculture to be studied and more informed policy decisions to be made (*ibid.*). Finally extension programs need to address how best to reach women with extension information and how to recruit more women to become MoA Development agents[18] EARO researchers, and technicians (*ibid.*).

The early success of the MoA and Awassa College training and research programs in attaining goals of working with about 3,000 men and women farmers in SNNPRS within its first two years

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[16] Officials claimed that the home-extension program was ineffective and wasted resources (UNECA, 1998, p. 10).

[17] A recent AGRIDEC (1995) study noted women's memberships nationwide were limited: in peasant associations, 12%; service cooperatives, 8%; producer cooperatives, 6%; and leadership within community institutions, virtually nil.

[18] According to the 1992 report by MoA on women in agricultural extension, approximately 5% of development agents were women; at that time no single female held the position of extension agent (MoA, 1992).

of operation provides a powerful example of how quickly Ethiopia's well-developed network of regional-level extension can extend new practices.

One of the long-term impacts of the CIMMYT gender program's support for various training and research opportunities for male and female researchers within EARO in the mid - '90s was to put in place the leadership that is charged with formulating the institution's first gender strategy. This strategy was further strengthened by CIDA (Canadian Agency for International Development) and Winrock's support for EARO's first gender training workshop. In Amhara State, SIDA (Swedish International Development Agency) is helping the MoA experiment with new programs to work with women farmers.[19]

Despite the strong verbal commitment of most NGOs to address gender issues, a high percentage of the Ethiopian NGO-supported agricultural research and extension programs have followed the general lead of the state extension and research programs in focusing on male farmers. The same programs have been hampered by a dearth of women professional employees in general and women professional agricultural extension and research staff in particular. Reflecting broader trends, however, most NGO programs are attempting to increase their consideration of women's crop production, livestock, and food processing. Two important examples for the dissemination of NGO "best practice" for working with women farmers include the CRDA working groups on agriculture and gender.

Lessons Learned in the Semiarid Regions

We have a nine-part explanation of what has been happening and needs to happen in Ethiopia's semiarid areas:

1. Research resources for this region have been few. In the latest World Bank loan to EARO and the rest of the agricultural research establishment, increasing resources are designated for the semiarid regions with the addition of five new semiarid centers. Unfortunately, the regional station concentration was still on the development of new cultivars rather than on water retention and soil fertility.

[19] The Swedish International Development Agency (SIDA) is addressing women's lack of experience in influencing household and community-level decision-making in its rural integrated development program in Amhara region, ensuring that women hold at least half of the decision-making positions within the project committees. Reportedly this is having a profound effect on the way and the types of decisions communities make (personal communication, S. Nigusie, 1999; Frank ,1999, p. 16).

2. Clearly the chief distinguishing characteristic of semiarid regions is their lack of water. For 10 years the Agricultural Engineering Department in the Nazret station has struggled to adapt the predominant implements used by farmers and several new animal traction implements including a seeder. A tied ridger has now been developed into a simple implement, which has been distributed to about 60 farmers. With the ridger alone, maize yields were increased by 50% and to 117% when ridging and moderate fertilization were combined (see Appendix). EARO is now entering into an agreement with a national company to produce this implement and various other simple implements. Making more water available through water-harvesting, catchment, irrigation, or a series of other techniques is the first prerequisite to improving productivity in the semiarid regions.

3. When more water is available, the use of other inputs, especially fertilizers and improved cultivars, gives a higher return and reduces the riskiness of the fertilization. The fertilizer market in Ethiopia has evolved rapidly and could service the semiarid regions once there is diffusion of the water-harvesting technology. The seed market now serves the adequate-rainfall regions fairly well but there is a dependence on the national seed service, Pioneer, and community seed production programs. The Ethiopian Seed Enterprise is still a parastatal but is trying to function as a private company. Its strategy is to minimize the production of smaller-market crops while focusing on wheat and hybrid maize. Ethiopia needs to encourage the entrance of new private seed firms, both domestic and international. With a profitable, encouraging environment, domestic private firms could begin responding to smaller markets and to crops less profitable for the seed industry than hybrid maize.

4. Along with the evolution of the input markets, product markets also need to evolve. One dramatic illustration of the need for concern with the product market was the collapse of the maize price with the excellent harvest of 1996 to 40 Birr/quintal from a price of 80 to 100 Birr. Despite extremely high transportation costs, Ethiopia exported maize to Kenya in 1996. There are a number of other methods to increase the profitability of farmers' production activities. Product development through value addition, such as by producing bread, beer, or animal feed from sorghum, is one example of an important activity for concern for both EARO and the extension service. Similarly, storage is difficult or risky, so farmers sell quickly at the post-harvest price. It is important to identify where research could make a difference. Cereal banks, where the public sector or the village enables the farmer to avoid seasonal low prices by strategically buying and selling grains, could also stabilize incomes from cereals.

5. EARO has done impressive work in distinguishing between the many agroecological zones in the country. Soon it will have nine regional soil laboratories and they can make much more area-specific fertilizer recommendations. EARO needs to extend this soil research to area-specific recommendations for the combined water-retention/soil-fertility alternatives. EARO's regional emphasis and initial steps to tailor technology recommendations puts it in a leadership role in the Horn countries.

6. Once water is available and soil fertility is increased, new cultivars are needed to take advantage of the improved environment. Then there will be a large payoff to breeding activities of new material that can take advantage of the moderately improved agronomic environments. Farmer cultivars in semiarid zones are selected for yield stability under adverse rainfall and soil fertility conditions. New cultivars need to be selected by breeders to respond to these improved agronomic environments without lodging and to incorporate biotic resistances. EARO has been turning out new cultivars with earliness and some biotic resistances but the pace needs to be accelerated.

   All over the world, breeders collaborating with other agricultural scientists have made substantial advances in combining biotic resistances of various types with higher-yielding cultivars. Ethiopia needs to take advantage of this experience by further developing its ties with the networks of scientists working in the drylands and rapidly respond to emerging biotic constraints. EARO needs to rapidly build up its networking with other institutions concerned with semiarid technologies. The cost of bringing in new material is just for the adaptation trials and having Ph.D. breeders on its staff. The regional research units need to invest much more in getting their scientists trained to the Ph.D. level.

7. Once crop yields are increased with the provision of more water and fertilizer, the crop/livestock interaction will become more important, especially the improvement of feed for the livestock. Improved forages will move up the list of research priorities for the semiarid regions.

8. One main contribution of the NGO investment in agricultural development appears to be in providing the research/extension services with additional funds and services at the farm level. The NGOs have a comparative advantage in conducting adaptive on-farm research, especially in some of the most isolated semiarid zones. But they need their technology recommendations to be oriented by EARO and the regional research organizations, as in Tigray and the Amhara regions. The NGOs need to provide feedback on farm-level technology performance to EARO and the regional research organizations.

9. EARO's efforts to develop a gender strategy that is an integral part of its more broad-based research/extension/farmer linkage package is a major innovation. The same model, if successful, will have regional significance within East Africa and the Horn since it is the first such unit to be formally created within a National Agricultural Research Institution (NARI).

A Technology Strategy

Four integrated actions need to be the focus of research and extension and public policy for the semiarid areas. There are three technology actions and governmental policy support:

1. **Water Harvesting.** The water-harvesting technique [20] will depend on soil type, with three primary differences. On soils with slow infiltration, water harvesting is essential to reduce runoff. Tied ridges, zaï, bunds, and improved land preparation are all different approaches to water retention on these soils. In sandy soils with high infiltration, actions to increase the rate of water and nutrient uptake by the plant are critical and necessary. Increases in organic matter and even inorganic fertilization (and higher density) have all been shown to slow infiltration and increase water-use efficiency. On the heavy clays, such as vertisols, poor drainage and sheet erosion can be serious problems. Here the water-retention device often has to be knocked down in high rainfall years.

2. **Soil-Fertility Improvement.** On more sandy soils, where crusting is less important but percolation into the soil can be so rapid that plants have difficulty obtaining water, a different strategy is required. In this case the key priority is to get more organic matter into the soil. ICRISAT trials at Sadore, Niger, have shown that in these sandy dune soils increasing plant density and fertilization increases water-use efficiency (for a review and references see Sanders et al.,1996, pp. 101-106). Agroforesty approaches to get more litter onto the soil, as well as nitrogen fixation, may be useful.

   When more water is available, the returns to fertilization are increased, and risks are reduced. It is then critical to combine water-harvesting with soil-fertility amendments because of the common insufficiency of nitrogen and phosphorus in soils in semiarid regions. Usually the cheapest source per nutrient unit of these two basic macro nutrients will be with inorganic fertilizers. Generally, the supply of manure and other organic fertilizers will not be sufficient for providing the necessary N and P. More complicated alternatives — such as rotation, intercropping with a legume, and inoculation — will generally still require inorganic fertilizer (P and other nutrients) on the legume. The basic rule is to use some inorganic fertilizer and combine it with organic fertilizers and other practices to supplement the effect of the moderate levels of inorganic fertilizer. As noted previously, the objective with the inorganic fertilizer is to take care of most of the basic nutrient requirements for N and P; then complementary

[20] Irrigation or micro catchments are different techniques and generally do not require the simultaneous addition of the various techniques discussed here of modifications to or within the soil so as to catch or hold more water.

measures of increasing soil fertility (organic matter, cereal-grain legume rotation) can be used for other soil-fertility objectives and to reduce but not eliminate the requirements for inorganic fertilizers.

3. **Better Seed.** In this new environment with more water and higher soil fertility, the traditional varieties cannot be expected to respond very well. Traditional varieties (land races) are selected over time for yield stability under adverse conditions with inadequate water supplies and low soil fertility. New cultivars will generally respond better to the improved production conditions. New cultivars will be necessary to respond to emerging biotic constraints, such as Striga and Midge in sorghum production. Both of these were identified as major biotic constraints in our recent trip to Tigray. There are sources of resistances to both with which breeders are working. Ethiopia just introduced two new cultivars with Striga resistances obtained from international collaboration (INTSORMIL and Purdue University). Texas A&M University (College Station, Texas, USA) has developed cultivars resistant to Midge. It is very important for Ethiopia to be in contact with these sources of new genetic material as well as to look for higher-yielding cultivars to put in this new agronomic environment as the impacts of inadequate water and low soil fertility are being reduced. New cultivars with biotic resistances are being released but the pace of both varietal development and diffusion needs to be accelerated

4. **Policy Action.** Ethiopia has done much better in the '90s in focusing on agricultural development than most of the Horn countries. Demonstration trials have been undertaken all over the country. Yields of many of the basic food crops have been increased. There has been a substantial expansion of production credit. Up to four million farmers in 1999 were involved in the various demonstration credit programs (personal communication, Quiñones, Nov. 1999). A privatized fertilizer industry with retail outlets all over the country was put in place in the '90s. The extension service was rapidly expanded. Salaries were substantially increased and morale improved in the federal agricultural research system.[21] In general, policy support to agriculture has been excellent. The government is now beginning to be concerned with alternative policies besides price support to avoid the perennial price collapses of the basic staples resulting from good weather and/or the rapid introduction of technical change.

[21] The regional extension systems still do not have as much technical training, infrastructure, or operational support as in the federal system. (T. Crawford, personal communication, Dec. 2000).

What Needs to Be Done?

Introduce combination of technologies. Presently in Ethiopia, the principal constraint to increased crop production in semiarid regions is the introduction of the combination of technologies for water availability, and soil fertility, and then these two combined with new genetic material. An improved implement for tied ridging has now been released by EARO to the private sector, and many other methods of water harvesting are potentially available. These new technologies need area-specific adaptation. Both the regional research organizations and extension services need to work on them, with trials and demonstrations varying with the soils and the water availability. Similar work needs to be done on the different methods of complementing the use of inorganic fertilizers.

Invest in breeding activities. Substantial investment needs to be made in increasing the breeding activities. Ethiopia is not taking adequate advantage of international sources of germplasm. To do this requires good networks of international contacts and with Ph.D.s among the breeders, pathologists, entomologists, and agronomists working in the commodity teams. Ethiopia needs to build up its capacity to respond to emerging biotic stresses. For example, Striga and Midge are presently reducing yields in sorghum production in Tigray. Developing new cultivars with biotic resistances more rapidly requires good breeding teams, probably in the regional centers, and many adaptation trials because of the substantial agroecological variation found in Ethiopia.

The extension services will have to take a large role in these adaptation trials and in demonstrations. Most demonstration trials for the principal commodities are in the better regions. Once more water and soil-fertility improvements are available in semiarid regions, the stage will be set for releasing higher-yielding semiarid cultivars. The myth of local-variety superiority needs to be directly confronted. The level of awareness in the extension service of the potential of importing superior plant characteristics, especially of pest resistances and higher-yielding features, is a public-education requirement in the extension service and among farmers.

Improve seed quality and supply. The production of sufficient high-quality seed of new cultivars is presently the principal constraint to increasing yields in the best agricultural areas of the country (personal communication, Quiñones, Nov. 1999). The concentration of seed producers on the best-endowed zones has also had some negative effects on the semiarid regions. The public seed company has been told by the government to become profitable and has shifted most of its activities to wheat and hybrid maize, largely abandoning the semiarid crops of drought-resistant cereals and legumes (including teff, the basic Ethiopian staple). Ethiopian Seed Enterprise has emulated Pioneer Seed Company, leaving the semiarid crops to community seed production.[22] Given the

[22] By imitating Pioneer, the public seed company has begun neglecting the other types of seed production normally focused on by public agencies. This is a widespread phenomenon in the Horn countries.

many problems of high-quality seed production (especially the need for isolation and roguing and, in hybrids, the nicking problem), it is unlikely that community seed production can maintain quality control over time without substantial technical inputs from professionals.

Who will pay for these professional inputs? A plan for privatization with trademarks and other market mechanisms to maintain quality control is probably necessary. The public seed sector needs to be re-engaged in the production of seed for the orphan crops, those activities that private seed companies do not presently want to get involved with. Public funds will be necessary for this activity. A requirement here is that the parastatal should have a plan to turn seed production over to the private sector once the demand growth is sufficient to interest the private sector.

Expand grain legume sector. Public-sector intervention will be necessary for an expansion of the grain legume sector in the semiarid areas of Ethiopia. The combined activities of introducing new production techniques with the identification of new export and/or domestic markets has been well demonstrated by the pigeon pea activities of ICRISAT in Kenya. This example of combined activities is a relevant model for Ethiopia in pigeon pea, cowpeas, and probably in other drought-resistant grain legumes. In the early stages, as marketing channels and even advance contracts are sought, the public sector will have to guarantee that there is a market — including being the buyer of last resort — to avoid a price collapse. This is necessary because substantial inputs will be required for grain legume production, including improved seeds, fertilizers, spraying for insect pests, and the control of storage pests. There has been some introduction of grain legumes with earliness and some resistances but again the process of introduction and diffusion has been very slow.

Improve fertilizer industry. With the recent public sector's emphasis on increasing fertilizer consumption, government officials have become entrepreneurs in the fertilizer industry. This is fine as long as a level playing field for full competition is maintained without the creation of special advantages for these new companies, which result in farmers facing higher prices for fertilizers.

Developing countries need to stop referring to semiarid areas as low-potential or even drought-prone and develop better terminology to indicate the agricultural potential of these regions. With the combination of increased water retention and higher soil fertility, the semiarid zones have a comparative advantages over the higher-rainfall regions, i.e., less disease incidence and more sunlight. California, Israel, and Australia did not consider their agricultural sectors as low potential and then under invest in technologies to obtain or utilize water better and then increase soil fertility. Fortunately for them, they made these technology investments before the time when people talked about low-potential or marginal regions.

Privatization is a fine and necessary long-run strategy for Sub-Saharan Africa. In the short run, these governments still need to service the rest of their agricultural sectors and not concentrate just on the high-rainfall, larger-farmer seed demand.

Appendix

The Agronomic Case for Technology Recommendations: Combined Water-Retention/Soil-Fertility Plus New Cultivar Strategy

Water stress is the major cause for low yields and total crop failures in Ethiopia's semiarid areas. The critical first requisite for attaining higher yields in semiarid regions is then to increase the quantity of water available. Some think only of irrigation to improve water availability. However, there are many ways of harvesting rainfall. On soils with poor infiltration, water retention is made possible by improved land preparation, ridges, tied ridges, catchments, bunds, or terracing. On sandy soils, infiltration can be reduced by increasing the organic matter in and on the soil. For the heavier clay soils, such as vertisols, drainage problems with heavy rainfall will occasionally make it necessary to knock down the water-retention device. The specific strategy for obtaining more water will then need to be adapted to the soil type and the farming system (see box below).

Agronomic Responses to Drought

1. **Water harvesting**. There are many methods. On the clay soils or crusting soils the two primary systems are: (a) using specialized soil-management practices, such as tied ridges, zaï, bunds, and improved land preparation, and (b) using tillage to reduce weeds and roughen the soil surface and lower runoff-inducing soil crusts.

2. **Reduce evaporation in relation to transpiration**. More marginal yield-effect practices can complement the above water-harvesting techniques. These are: (a) use of more intensive cropping systems, (b) maintaining a soil cover, and (3) and adopting improved residue and tillage-management practices to maintain mulches on the soil surface that will reduce evaporation.

3. **Cultivar selection for drought tolerance or drought escape**. Earliness can be selected to avoid the consequences of an early cessation of rainfall or a late planting date. Crops that have built in mechanisms to tolerate drought can be grown. Again, this is a complementary strategy to water harvesting. If either 2 or 3 here are used alone, they will have only marginal yield effects.

Soil fertility is the next constraint generally faced in semiarid regions after increasing the available water. The critical point to emphasize is to start with water-harvesting technologies. Why? Once more water is available, the returns to fertilization are increased and the riskiness of purchasing fertilizer is reduced. Once water availability and soil fertility are increased, the semiarid zone has an advantage over higher-rainfall zones because of longer daylight hours and lower disease incidence. Sufficient investment in water harvesting needs to be not only a higher priority for the semiarid regions but also for the entire country.

Rather than the combination of water and soil fertility, the highest priority of the research activities in most semiarid zones has been on the development of new cultivars. *This is our principal explanation for the lack of success to date in increasing yields in semiarid regions.* Building new cultivars through interdisciplinary collaboration has been a much more exciting activity for most experiment stations than developing and introducing water-harvesting techniques and then combining these with soil-fertility amendments.

Unfortunately, even though breeding activities, such as the search for drought tolerance in new cultivars is a scientifically interesting activity, it can increase yields only marginally,[23] especially where there are continuing deficits of N and P. Large yield gains result from the combination of increased water availability and fertilization, as demonstrated by experiment station results (see Tables A-1, A-2, and A-3). Once increased water and higher soil fertility are available, the new cultivars respond better to this improved agronomic environment.

Besides obtaining higher-yielding characteristics, breeders have developed many successful multi-disciplinary activities in response to various disease and insect problems by incorporating one or more resistances generally into higher-yielding new cultivars.[24] Ethiopia and other countries need to be regularly taking advantages of these advances in new cultivars and other practices.

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[23] The basic argument is that all cultivars will require sufficient water and soil nutrients to obtain reasonable yields. Building a shorter-season cultivar or developing some other drought resistance mechanism or biotic resistance does not resolve the soil fertility deficit. A higher-yielding cultivar that is mining the essential soil nutrients is not a sustainable strategy.

[24] Much of the Green Revolution diffusion has been built upon the new cultivar combination of a) higher yielding characteristics and b) biotic resistances. In the higher rainfall or irrigated region where the successes of the Green Revolution have been concentrated, there has always been a stress on increasing purchased input use

Table A-1. Effects of water retention methods (tied ridges) on grain yield of sorghum, mung bean, and maize in research stations of the semiarid areas of Ethiopia

Soil conservation method	Average grain yield t ha^{-1}		
	Kobbo	Melkassa	Mean
Sorghum			
Flat planting (farmers practice)	1.6	0.8	1.2
Tied ridges planting in furrow	2.9	3.0	2.95
Mung bean			
Flat planting (farmers practice)	0.4	-	0.4
Tied ridges (planting in furrow)	0.7	-	0.7
Maize			
Flat planting (farmers practice)	1.2	-	1.2
Tied ridges (planting in furrow)	2.7	-	2.7

Ridge height: 35 cm
Ridge spacing: 80 cm for mung bean
75 cm for sorghum and maize
Ridges tied at 6 m intervals

Source: Kidane and Rezene, 1989.

Table A-2. Mean grain yield (t ha^{-1}) of five improved maize varieties grown in semiarid eastern Ethiopia under unfertilized conditions

Varieties	Grain yield t ha^{-1}		
	Without tied ridges	With tied ridges	Increase (%)
Alemaya composite	2.8	4.8	70.9
KCC	2.6	4.3	67.5
EaH-75	2.6	3.6	38.6
Ca 5	2.3	2.9	26.4
Bukri	2.0	2.9	47.6
Mean	2.5	3.7	51.2

Source: Tamire Hawando et al., 1984.

Table A-3. Mean grain yield (t ha^{-1}) of five improved maize varieties grown in semiarid eastern Ethiopia under fertilized conditions

Varieties	Grain yield t ha^{-1}		
	Without tied ridges	With tied ridges	Increase (%)
Alemaya composite	5.4	7.1	33
KCC	4.7	6.6	39
EaH-75	4.8	6.0	25
Ca 5	3.8	4.7	23
Bukri	3.7	4.0	9
Mean	4.5	5.7	27

Source: Tamire Hawando et al.. 1984.

Soil Fertility

The soils in most of Ethiopia's semiarid areas are severely eroded and are relatively infertile, leading to reduced crop yields (Fig. A-1; Kidane Georgis,1999, pp. 14, 15).Soil erosion is endemic and results in a reduced volume of soil able to retain water and nutrients. Deficiencies in N and P are especially serious and organic matter content is very low, generally less than 1%. An increase in the use of inorganic fertilizers is necessary to break out of this cycle. The inorganic fertilizers have higher concentrations of the basic plant nutrients (N, P, and K) than organic fertilizers and so their cost per nutrient unit is expected to be considerably lower than that of the organic fertilizers. Hence, the organic fertilizers are complements not substitutes for the inorganic fertilizers..

Many of these soils with low organic matter will require a parallel increase in the use of organic fertilizers in order to hold nutrients in the soil and to increase biological activity. There are various methods for extending the supply of organic matter. Crop residues can be put in animal corrals and then the manure put in covered and watered compost heaps. These practices have been increasingly used in the Sahelian countries after the elimination of the fertilizer subsidies in the late '80s. The simplest method is just incorporating more of the plant residues into the soil. The constraints are on how to incorporate them and how to prevent livestock and termites from eating the residuals. The main problem of increasing organic matter is the demand by farmers for alternative uses for both crop residues and manure. Hence, there generally is an inadequate supply of organic fertilizers for providing the basic nutrients. [25]

[25] It is necessary to distinguish here between using the organic fertilizers for complementing inorganic fertilizers and attempting to use them to provide the basic plant nutrients. The latter is much more difficult and would be expected to be feasible only to certain types of farmers, such as those producing large amounts of manure (as with a concentrated poultry operation, moderate to large milking herd, or intensive beef production on a moderate to large scale).

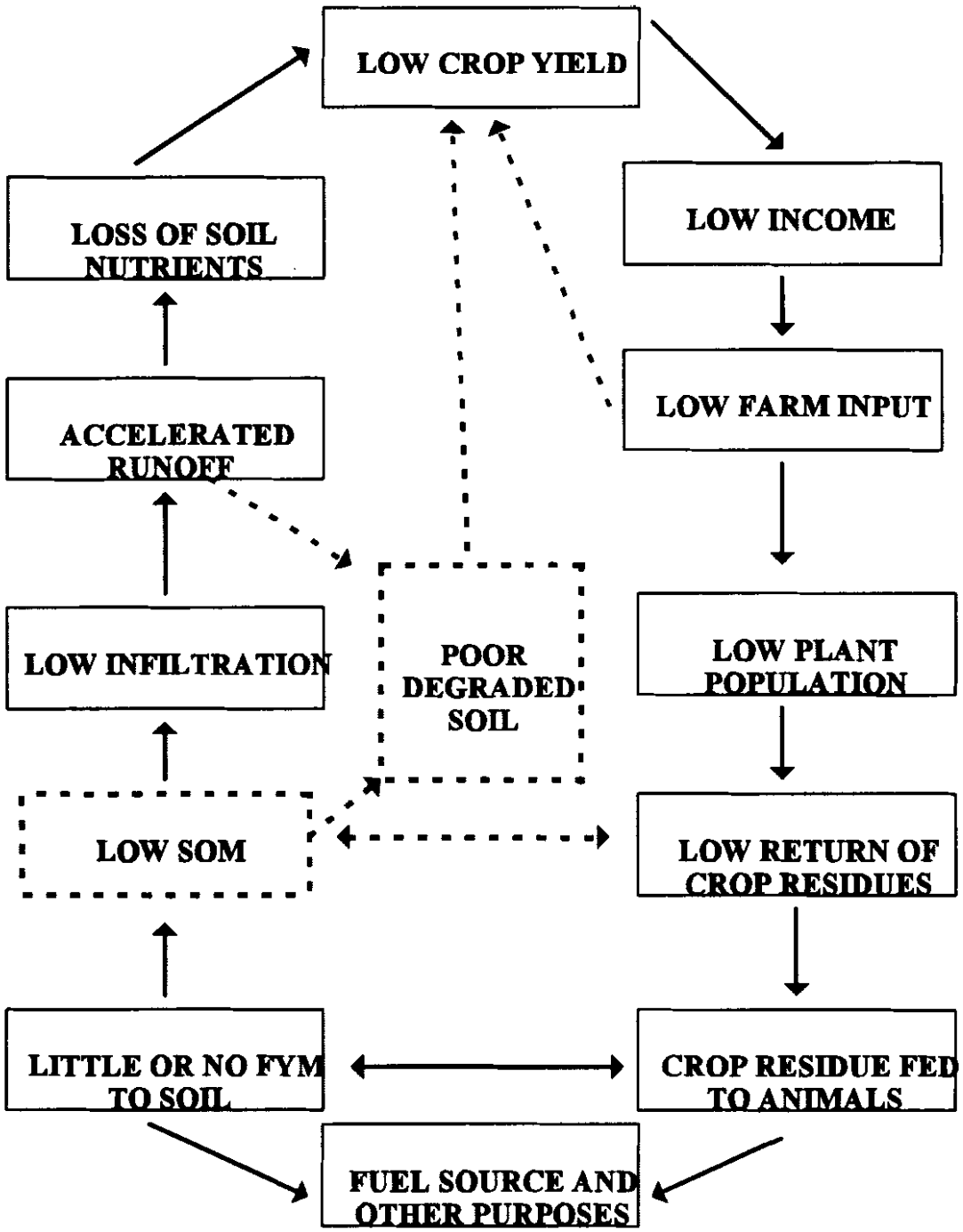

Figure A-1. **The conflicts that lead to unsustainable land use for farmers in the SAT areas of Ethiopia.**

Source: Kidane Georgis, 1999.

New Cultivars

The new cultivars are a very important part of the three-pronged strategy (water availability/soil fertility/new cultivars). They need to combine higher-yielding characteristics to respond to the improved agronomic environment and biotic resistances. The new cultivars are generally some combination of shorter, stockier materials to take higher fertilization without lodging — plus consumer characteristics that are desired plus the resistances to critical insect/disease pests. For example many of the new sorghum cultivars combine:

1. Shorter-season length for drought escape if the rains start late or stop early

2. Higher-yielding, i.e., better responses to inorganic fertilizers and higher grain-to-vegetative material ratios

3. Improved consumer characteristics, such as the nutritionally improved white sorghums

Since several new cultivars have been developed (it takes 5 to 10 years to develop a new cultivar), we provide a brief review of the presently recommended cultivars available for the semiarid region. For the principal cereals, maize and sorghum, these are extremely old cultivars. Seredo is a brown-seeded derivative of Doggett's breeding work in the '50s and '60s and Katumani maize was released in Kenya in 1968 (Table A-4).

To date, very little progress has taken place in the breeding of the two principal cereals (sorghum and maize) for the semiarid region of Ethiopia or to respond to emerging biotic problems. The exceptions have been noted above of the early maize and sorghum cultivars introduced.

This failure to move more rapidly on sorghum is especially unfortunate given the potential of the new white sorghums. Sorghum is widely used as a human food, substituting for teff in the making of injera. These white sorghums are high-nutritional quality and high-yielding cultivars. This important nutritional-breeding advance continues to be constrained by the bird problem in the Rift Valley. Outside of the Rift Valley, birds are not as serious a problem and can be controlled by intensive patrolling activities of children. But the Rift Valley is a principal potential production area and more systematic attention to bird tolerance without using tannins would be a major innovation for the entire Horn region of East Africa.

Crop failures and poor harvests, due mainly to aberrant weather, are common experiences in the semiarid areas of the country. The main problems in these areas are the limited amount and short duration of the rainy period and late season stress. Thus, one principal breeding strategy has been screening early maturing crop species and cultivars which complete their life cycle within the period of adequate moisture. However, a detailed agroclimatic analysis carried out on some of the drought-prone areas of the country indicated that problems relative to semiarid areas are either

Table A-4. Recommended crop species and varieties, actual and potential yields, and growing conditions in the semiarid areas of Ethiopia

Crop	Altitude	Rainfall	Traditional yield	Potential yield
	(m)	(mm)	t ha^{-1}	t ha^{-1}
CEREALS:				
Sorghum				
Gambella-1107	< 1600	350-700	1.2	2.5-5.0
Dinkmash	< 1600	350-700	1	3.0-5.0
Seredo	< 1600	350-700	1.0	3.0-5.0
Mako 1				3.0.40
Maize				
AVC 3 and AVC 6				3.5-4.0
Melkasa 1				2.5-3.0
Katumani	< 1600	350-700	1.6	3.5-4.0
Teff				
Cross-37	1500-1800	300-500		2.8-3.0
Dz-196	1600-1800	300-700		2.5-3.0
DZ-354	1600-2000	300-700		2.5-3.0
Dz-Cr-44	1800-2400	300-700		2.5-3.0
GRAIN LEGUMES:				
Haricot bean				
Mexican-142	1400-2000	350-700	1.0-1.3	1.6-2.0
Awash-1	1400-2000	350-700	1.2-1.5	2.0-2.4
Roba-1	1400-2000	350-700	1.0-1.2	2.0-2.4
GLPX 92				2.0-2.4
Mung bean				
M-76	1000-1600	300-500	-	1.5-2.0
M-1134	1000-1600	300-500	-	3.0-4.0
Cow pea				
White wonder trailing	1000-1800	300-500	-	3.0-5.0
Black-eye-bean	1000-1800	300-500	-	3.0-5.0
OIL CROPS:				
Sesame				
T-85	< 1250	500-700	0.5	0.7-1.0
Kkelafo-74	< 1250	500-700	0.3	0.6-1.2
E	< 1250	500-700	0.3	0.7-1.4
Adi	< 1250	500-700	0.4	0.7-1.7

Source: Kidane Georgis, 1999, p. 26.

seedling drought stress, mid-season stress, terminal stress, or a combination of any two or three of these. Therefore, it is important to consider other drought-resistant mechanisms besides earliness to address the above constraints.

Earliness will not always be sufficient, especially with crops such as maize and field beans that have no inherent drought-resistances mechanisms but depend upon drought escape. The other problem with a short-season cultivar strategy is that it will not leave the plant in the field long enough to benefit from higher-input levels. Shorter-season plants yield less than traditional long-season cultivars in good rainfall years and would not benefit as much as longer-season cultivars when water availability is increased and soil fertility improved.

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Interviews

Africare
Alan C. Alemian

CIMMYT
S. Twumasi-Afriyie, Highland Maize Breeders
Thomas S. Payne, Regional Wheat Breeder/Pathologist
Douglas G. Tanner, Maize/Wheat Breeder

CRDA (Christian Relief and Development Association)
Kebede Asrat, Executive Director
Mitku Abede, Senior Monitoring Expert
Ato Feyra Abdi, Program Director, SOS/Sahel
Solomon Dagnechew, Agricultural Officer, WUE,
G. Endalkachew, Co-Director, FHI/Ethiopia
Workicho Jaleno, Project Officer, Self-Help
Solomon Kilkoi, Program Coordinator, Redd Barna
Membara Lulu, Senior Fund-Raising Officer, Organization for Rehabilitation and Development in Amhara (ORDA),
Belachero Tikrie, Assistant Project Manager, Lutheran World Federation
Abdullahi Sandol, SCF-U
Ato Assfaw Tulu, Agri-Service, Ethiopia
Yeshimebet, G., Program Manager, Oxfam G.B.

EARO (Ethiopian Agricultural Research Organization)
Central Office
Seifu Ketema, Director General
Aberra Debello, Deputy General Manager
Tesfaye Zegeye, Head, Agricultural Economics and FSR Research
Yeshi Chiche, Agricultural Economics and FSR Expert
Teclu Tesfaye, Head, Agricultural Research and Extension
Etagegnehu, G/Mariam Weed Scientist
Selome Tibebu, Entomologist
Senait Yetneberk, Food Scientist

Ethiopian Seed Enterprise
Getahun Alemu, General Manager

Farm Africa
Asefa Woldegiorgis, Country Representative
Gure Kumssa, Senior Agronomist

MoA (Ministry of Agriculture, Republic of Ethiopia)
Ebrahim Mohamed, Head
Dejene Abesha, Team Leader, Dryland Extension
Bogelech Alemu, Head, Women's Affairs Dept.
Gudissa Geyessa Tirfi, Training Expert, Senior Agricultural Extension
Dejere Abesha, Extension Office

Mekele Research Center
Adarajew Hadis, Manager, Breeder-Field Crops
Amare Belay, Research Officer, Agronomy/Physiology
Getaet Dino, Horticulture
Daniel G. Kidan, Agronomy
G. Hiwot H. Mariam, Research/Extension
Kiro Meles, Plant Pathology
G. Michael Negusse, Agricultural Economics
Niguse Tesfamichael, Sorghum Breeder
Abuhay Takele. Agronomy/Physiologist

Mekele University College
Mitiku Haile, Dean of University

Melkassa Research Center
Aberra Deressa, Center Manager
Habtu Assefa, Team Leader, Lowland Pulses Research
Ketema Belete, Senior Sorghum Breeder
Erenso Degu, Leader, Sorghum Research Commodity
Mandofro Nugusie, Maize Breeder for Marginal Rainfall Areas
Gezahegn Bogale, Maize Breeder for Marginal Rainfall Areas
Melese Temesgen, Team Leader, Farm Mechanization Research
Frew Kelemu, Farm Mechanization Research Expert
Fasil Reda, Weed Specialist, Striga

National Bank of Ethiopia
Gebreyesus Gunte, Deputy Director, Economic Research Dept.

National Fertilizer Industry
Zeleke Desalegn

National Seed Industry Agency
Getnet Gebeyehu, Director Manager
Girmu Dabi, Advisor to the General Manager
Lemma Gebeyehu, Expert

ORDA (Organization for Rehabilitation and Development in Amhara)
Membara Lulu, Senior Fund-Raising Officer

Oromo National Regional State
Tirata Bekele, Acting Head, Extension Services
Dereje Tolu, Extension Dept.

Pioneer Seed Company
Werede Wolde Mariam, Manager

SOS Sahel-UK
Elias Eyasu, Soil Scientist/Agronomist; Research Coordinator, Soil Fertility
Feyera Abdi, Program Director

Saskawa Global 2000
Takele Gebre, Leader, Extension Program
Marco A. Quiñones, Project Manager
Mr. Gebrekal, Extension Expert

USAID/Ethiopia
Emily Frank, Gender Specialist
Kurt Rockeman, Team Leader
Dennis Panther, Agriculture Specialist
Tadele G. Selassie, Agriculture and Natural Resources Program

Winrock International/Ethiopia
Hailu Wudnesh, Program Coordinator

World Vision
Tesfaye Bekele, Leader, Technical Team
Thomas A. Payne, Regional Wheat Breeder/Pathologist
Douglas G. Tanner, Maize/Wheat Breeder

Consulted in USA
A. Scythe, Agricultural Specialist, World Bank
Jim McCann, Professor of History, Director, Center for African Studies, Boston University
Stephen Brandt, Associate Professor of Anthropology, University of Florida
Lyn Grace, former missionary, Ethiopia