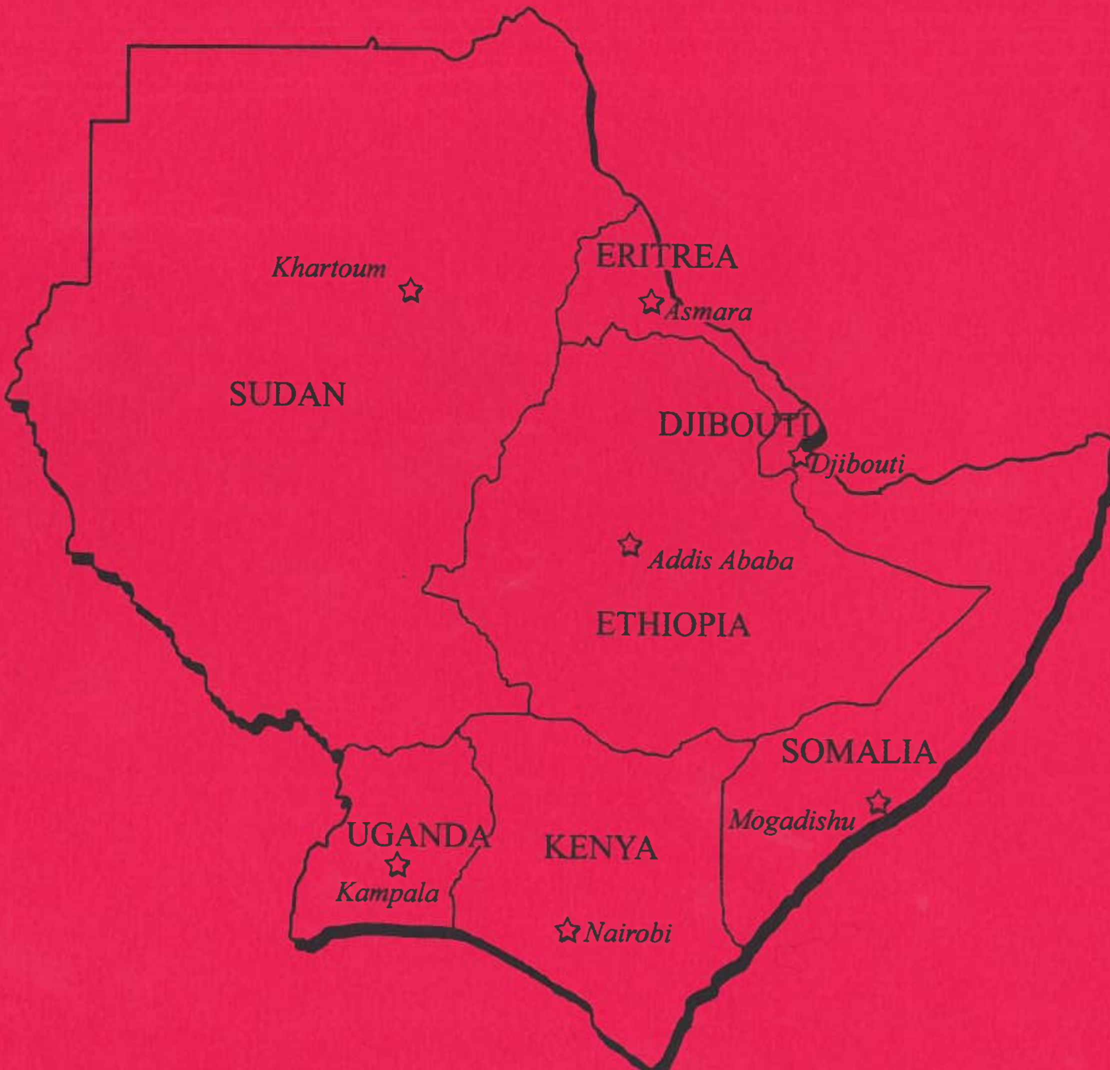
Agricultural Technology for the Semiarid African Horn



Vol. 1: Regional Synthesis

IGAD/INTSORMIL/USAID-REDSO

July 2001

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

IGAD (the Inter-Governmental Authority for Development)

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

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

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

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
Department of State
Washington DC 20521-8900
or
Ksarani Rd.
P.O. Box 30261
Nairobi, Kenya
Ph: (254) 286-2400
Fax: (254) 286-0949
Email: dmccarthy@usaid.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

Agricultural Technology for the Semiarid African Horn

IGAD
The Inter-Governmental Authority for Development

INTSORMIL
Grain Sorghum/Pearl Millet Collaborative Research Support Program

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

Editors
John H. Sanders, Purdue University
Della E. McMillan, University of Florida

This publication was made possible through support provided by the U.S. Agency for International Development, under the terms of Grant No. LAG-G-00-96-90009-00.
The opinions expressed herein are those of the author(s) and do not necessarily reflect the views of the U.S. Agency for International Development.

INTSORMIL Publication 01-4 - Volume 1

Prologue

The Inter-Governmental Authority on Development (IGAD) includes seven countries of the Horn of Africa, Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan and Uganda. This synthesis report volume summarizes the output from the IGAD project on "Promoting Sustainable Production of Drought Tolerant High Yielding Crop Varieties Through Research and Extension". The overall objective of this project is to enhance food security in the dryer parts of the IGAD region through sustainable crop production in the Arid and Semi-Arid Lands (ASALs). The specific objectives are:

- to identify and document technological, economic, and social constraints to improved food security in the ASALs of the IGAD region;
- to contribute to the enhancement of food security in the ASALs of the IGAD region through the promotion of sustainable production of drought tolerant crops;
- to strengthen both public and private research centers and extension services that can promote the production of the desired crop varieties; and,
- to promote linkages with international research institutions that work on dryland crops.

INTSORMIL has been developing new sorghum and pearl millet cultivars and associated technologies in Africa with collaborative research for over two decades. INTSORMIL submitted a proposal to undertake this study in the spring of 1999. Fieldwork commenced in November 1999. In this project IGAD requested a diagnostic study to include all crop technologies for the semi-arid zones. IGAD defined the objectives for the country analysis as: describing the cropping systems; identifying technology successes, potential successes, and constraints; analyzing the adequacy of the national, regional, and international research systems; evaluating the extension systems especially the linkages with farmers and researchers; examining seed supply and crop marketing issues; identifying the role of women with regard to the present farming system and new technology introduction, and reviewing agricultural policies. This two volume series is directed to those concerned with research policy directions and with the diffusion of new technologies. The study is expected to be of interest to donors, policymakers, research administrators, researchers, and those involved with moving technology onto the farm.

The study was funded from the REDSO/ESA Office of USAID in Nairobi, directed by IGAD and implemented by INTSORMIL from Lincoln, Nebraska. A core team of five professionals was contracted by INTSORMIL with IGAD concurrence. The core team was multi-disciplinary and multi-national being composed of an economist, a maize breeder, a pathologist, a dryland agronomist, and an anthropologist. Two national scientists from each of the countries, except for Somalia, were contracted to review research and extension in each country. Details on the names of all the personnel on the core team and the national consultants are available in Volume 2.

Volume 1 is the regional synthesis of Volume 2 (Country Studies for Djibouti, Eritrea, Ethiopia, Kenya, Sudan, and Uganda) which identifies potential technologies for semi-arid areas in the Horn countries. The country studies in Volume 2 are based upon field visits and interviews by both the core team members and national consultants for research and extension. The country studies include a bibliography of the relevant literature acquired in the field and Washington, D.C.

The Regional Synthesis, Volume 1, provides specific background details on the specific objectives of the project and discusses a technology development strategy for the drylands of the Horn and analyzes the markets and institutions serving dryland agriculture in the Horn.

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

Table of Contents

Tables

Boxes

Acronyms

CBO	Community-based organizations
EARO	Ethiopian Agricultural Research Association
IARC	International Agricultural Research Center
ICARDA	International Center for the Development of Arid Lands
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IDA	International Development Assn. (Development Division of World Bank)
IGAD	Intergovernmental Authority on Development
IITA	International Institute for Tropical Agriculture
INTSORMIL	International Sorghum and Millet Collaborative Research Program
KARI	Kenya Agricultural Research Institute
KFA	Kenya Farmers Association
NARO	National Agricultural Research Organization
NGO	Non-Governmental Organization
NPK	Nitrogen, phosphorus, potassium
REDSO	Regional Economic Development Service Office
SAARI	Serere Agricultural Research Institute
UNDP	United Nations Development Program
UNICEF	United Nations Children's Emergency Fund
USAID	United States Agency for International Development

Untapped Potential in the Horn: Crop Technology Introduction in Dryland Areas*

Summary Statement

To orient technology and policy for the drylands of the Horn we have to challenge two fundamental recommendations for agricultural development of the past decade. First, invest agricultural research/extension resources primarily (or even exclusively) in the adequate and high rainfall regions as the returns to research/development are the highest there. Secondly, eliminate parastatals and encourage the growth of private firms. Substantial progress has been made in the past decade in African countries based upon these two policy prescriptions. Unfortunately, there are no universal truths in development. So both of the above need to be reevaluated for their appropriateness to the drylands.

First the highest returns and most prosperous agricultural areas in the world are in the former drylands, note California, Israel, Australia, Spain and South Africa. Many techniques besides irrigation have been applied for water harvesting in these countries but all employed the same combination of first increasing water availability, then utilizing inorganic fertilizers, and finally new cultivars. All obtained the same substantial multiplicative effects from the combined inputs. Returns are very high to these combined inputs in the drylands and developing countries can take advantage of this. So the start of a development strategy for the drylands of the Horn is the movement away from the cultivar alone strategy to a Water-Soil Fertility-New Cultivar approach applied both to research and extension.

To implement the technology development strategy will require improved functioning of input and product markets servicing the drylands and a new integration of research-extension-NGO activities. In neither the seed nor the inorganic fertilizer industry of the Horn has the private sector been interested in the drylands. Now that governmental failure has been addressed over the last two decades in developing countries, we are back to market failure especially in the seed industry. The problem of getting the input (seed, fertilizer) markets working for the drylands requires new incentive structures and probably some public action for orphan crops.

Concern with the evolving and the potential product markets for the traditional cereals (sorghum, millet, teff and maize[1]) is the other principal policy prescription of this report. More

---

* All the Core Team members participated in the evolution of the ideas expressed here and all had the opportunity to react to earlier drafts. So no individual authorship is assigned. The core team members responsible for this report are John H. Sanders, economist, team leader, Purdue University, USA; Eliud Omolo, maize breeder, co-team leader, Egerton University, Kenya; Kidane Georgis, dryland economist, EARO, Ethiopia; Peter Esele, plant pathologist, NARO, Soroti, Uganda; and Della E. McMillan, anthropologist, University of Florida, USA. The core team benefited from its interactions with IGAD national consultants, NGOs, and a large number of researchers, extension workers, private-sector representatives, and farmers in the six countries of the Horn. We are grateful for the insight of them all. Extremely useful, critical comments were received from REDSO and from John Lynam of the Rockefeller Foundation responding to an earlier draft.

[1]Maize is for the higher rainfall areas. Shorter season maize cultivars can be used in more marginal rainfall areas as long as the rains start late or finish early but are no help for mid-season drought stress. When these short season maize cultivars are used in semiarid regions, they either often fail as in Kenya, making farmers even more

technology introduction-market development work on the drought tolerant, grain legumes and oilseeds is also recommended as an income earning plus useful diversification strategy. Nevertheless, it is important to note the greater danger for saturating the markets here than with the traditional cereals.

Finally, increasing the number of and the feedback from demonstration and adaptation trials will hasten technology diffusion but requires the further professional development of NGOs and the national extension services.

Project funding needs to concentrate on facilitating the diffusion of the three-part strategy especially the improved access to water. The improved functioning of Input and Product markets is another fundamental component here. Moreover, better utilization of both the national extension service and NGOs in adaptation and demonstration trials is a new institutional approach.

I. A Technology Development Strategy for the Drylands of the Horn

The Emerging Economic and Political Concern with Dryland Agriculture in the Horn

In the Horn countries, with significant areas with adequate rainfall, the concentration of agricultural research, extension and public policy during the last two decades has been on these regions. Donors have pushed them in this direction arguing that this focus will give the highest return on research and other resources invested in agriculture. Several countries have been very successful in these prime regions. Kenya substantially increased maize production and productivity in the '70s and '80s (Hassan and Karanja, 1997, p. 88). Ethiopia, after being a major food aid recipient during the early '90s, exported maize in 1996 (IGAD/INTSORMIL/USAID-REDSO, Country Study: Ethiopia, 2001). Eritrea has also been successful in the '90s in increasing production of their basic cereals (IGAD/INTSORMIL/ USAID-REDSO, Vol. 2, 2001).

The definition of the drylands follows the UNDP definition of regions subject to drought conditions (Table A-1). In the drylands of the seven[2] Horn countries there are 46 million people, 32 % of the population. This dryland area (dry sub-humid and semiarid) is 73% of the total potential crop area.[3] Moreover, three of the countries (Eritrea, Somalia, and Djibouti) have all of their potential rainfed crop area in semiarid zones.[4] In the big three of Sudan, Kenya and Ethiopia 61 to 87% of their area is drought prone (Table A-2). With almost three-fourths of the potential crop area in the Horn countries being dryland, these countries need to be

---

dependent upon NGO relief, or are grown only on the small areas near the household where the household refuse is thrown and animals kept at night. These practices increase the fertility and water retention capacity of these small areas.

[2] Besides the six countries mentioned above Somalia is generally included but no interviewing was done there due to the continuing civil wars.

[3] This calculation excluded the arid and hyper-arid categories in Appendix 1.

[4] Irrigation can extend the potential for crop area so we are focusing on other methods for increasing water availability in this paper. Irrigation potential requires another study though we discuss it briefly in the case study for Djibouti.

concerned about increasing productivity there. The low population concentration relative to the area is indicative of the failure of these societies to develop these dryland areas as well as the popular perception of a lower resource base. However, the agricultural potential of these regions tends to be seriously underestimated.

Drylands or Semiarid

In the individual country reports we have concentrated on semiarid. In the Appendix to the Synthesis semiarid and dry sub-humid are separated with estimates for area and population in the seven countries of the Horn. But both are considered by the UNDP as drylands. In this overview it is also useful to add in the dry sub-humid for Sub-Saharan Africa since these areas will also benefit from the combined technologies recommended here. Moreover, due to the generally low use of inputs and poor soils, the crops characteristic of semiarid zones, i.e. sorghum, millet, cowpeas, and peanuts, often occupy a high proportion of the area in the dry, sub-humid zone. As input levels (water and fertilizer) increase in both the dry sub-humid and the semiarid, these crops with drought tolerance would be expected to become more concentrated in the semiarid zones.

Conventional wisdom was that dryland resources were fewer and farmers too poor and too risk-averse to successfully intensify production. Hence, various types of low input strategies have been proposed involving little risk and minimal income increase. Low input strategies usually included new cultivars and/or some improved agronomic practices such as inter-cropping and fertilization with local materials. Fertilization strategies generally included only manure, crop residues, and rock phosphate. Inorganic fertilizer was considered too expensive and too risky. If irrigation schemes were not feasible and there were no traditional water harvesting techniques such as terracing, bunds, pits or zai, then water was not even mentioned.

What happened? Why are we looking again at the drylands? There are welfare and efficiency arguments for reconsidering the agricultural potential of the drylands in the 21st Century.

First the welfare story, in the decade of 2000 there is a shift of donor interest back to poverty eradication and nutritional concerns (Lupien and Menza, 2001).[5] This apparently results from the increased visibility of poverty as a result of the Poverty Assessments conducted in the mid-1990s as well as improved national systems for monitoring poverty and social indicators. This trend has special relevance in the Horn given the extremely high rates of malnutrition, infant stunting and wasting, and underweight mothers, especially in semiarid zones.

During the last two decades the drylands have become a concentration site for rural poverty. Migration has been continuing out of the mountain highlands with adequate rainfall where population concentration had become very high into the more marginal rainfall regions in Kenya, Ethiopia, Uganda and Eritrea. Food aid has become concentrated in these dryland areas

[5] In the '70s the principal concern of development policy was poverty reduction before being replaced by Structural Adjustment in the '80s and '90s. Now poverty alleviation is making a comeback and there is even discussion of evaluating projects by their nutritional effects on the low income and vulnerable groups.

and better measurements have been taken about the consequences of malnutrition. National governments (and donors) have become upset with this deterioration in the human capital capacity of the populations, especially the effects of extreme poverty and malnutrition on women and children.

The seriousness of the stunting problem and malnutrition is clear in Table 1 ranging from one quarter of the child population underweight in Uganda to almost one half in Eritrea and Ethiopia. Other nutritional measures indicate similar deficiencies concentrated in the vulnerable sectors of the population.

Table 1. Underweight children in six IGAD countries.

Country	% under Age 5
Eritrea	44
Ethiopia	48
Kenya	23
Sudan	34
Uganda	25

Source: UNICEF, 1998,p.34.

Ethiopia demonstrates the evolution of welfare concern. In spite of their substantial successes in the second half of the '90s in increasing aggregate food crop production, adverse climatic conditions in 1997 and 1999 precipitated crises in the drylands. In both years aggregate food production only slightly declined. The purchasing power[6] of the poor in the drylands was not helped by the good harvests in the adequate rainfall regions. Rather in 2000, almost 8 million people were at nutritional risk even with total production only 9% below the record crop year of 1996 (IGAD/INTSORMIL/USAID-REDSO, Country Study: Ethiopia, 2001). Clearly, public policy and research can no longer neglect the drylands by assuming that transportation and communication will move food supplies between regions. When poor people lose their sources of income, in this case from declines in crop and animal production, specific measures are needed for them

Most countries are embarrassed by increasing dependence on food aid. Breakdowns in the ability of societies to feed their populations frequently lead to the fall of governments, as in the case of Haile Selassie in Ethiopia in 1973 (Sen, 1982). Hence, in the last few years public policy makers (and donors) have begun challenging the strategy of concentrating agricultural research and public policy on the adequate rainfall regions and asking why technology has not worked better in these low rainfall regions.

There is also an efficiency argument for investing in the drylands. In California, Texas, Israel, the Iberian peninsula, and Australia a wide range of techniques are utilized to obtain more

[6] Successfully introducing new technology in the higher rainfall regions does not necessarily help the poor and undernourished unless their access to food is improved (Sen, 1982). Increased food aid has been the alternative chosen, but this food aid disrupts natural market evolution by depressing food prices. A better alternative is increasing the purchasing power of the poor. Providing dollars for food purchase within the country rather than the food could enable the poor to obtain food without depressing the incentives to intensify agricultural production.

water and to better control available water. Irrigation of various types is the best known but is only one technology option. Furrow dikes (tied ridges) have been rapidly extended on the high plains of Texas as the water levels of the aquifers have declined. There are many other techniques for water harvesting depending upon the soil type. The zai, tied ridges, and the dirt and rock bunds of the Sahel are being introduced in other areas of Sub-Saharan Africa (Wubeneh and Sanders, 2001).

Once there is more effective management of available water (not necessarily from irrigation), the returns to soil fertility improvements are increased and the riskiness of this activity reduced. With a little more water and improved soil fertility, drylands have a comparative advantage over higher rainfall regions due to: (a) reduced disease pressures; and (b) more sunlight. The highest crop yields in the world are then obtained in these areas once water availability is moderately increased and supplemented with inorganic (and organic) fertilizers. This new agronomic environment also gives a much higher return to plant breeding.

The logical next question of public policy makers in the Horn countries is: are there ways that the potential comparative advantage of the dryland regions can be captured here? To respond we first review the experience in technology introduction to the drylands in the Horn. This serves as background to introduce our proposed technology development strategy. A second section will then review the institutional evolution in the region with regard to Input and Product Markets, national research and extension organizations, the NGOs and gender considerations. After some of the major analytical sections, brief project proposals are introduced.[7]

Previous Experiences with Technology Introduction in the Dryland Regions of the Horn

In Ethiopia there was a three-part strategy based upon new cultivars, inorganic fertilizer, and tied ridges with an animal traction implement for the government programs beginning in the mid'90s. New cultivar introduction and increased manure were successfully introduced. (Wubeneh and Sanders, 2001). Inorganic fertilizer was not accepted for the early cultivars. The tied ridger was too heavy and awkward. The tied ridger was returned to the experiment station at Nazret, simplified, made lighter, and then released in 1999 (IGAD/INTSORMIL/USAID-REDSO, Country Study: Ethiopia, 2001) by EARO to a private company for manufacture. Meanwhile other community-based techniques for water capture are being rapidly diffused with three-fourths of the farmers surveyed in one region of Tigray using dikes and/or hand-constructed tied ridging. They also used manure and new *Striga* resistant sorghum cultivars (Wubeneh and Sanders, 2001).

In Eritrea there have been rapid gains in production based upon the introduction of new cultivars (sorghum and millet) and inorganic fertilizers. With the wartime shortage of labor, tractor hire systems have been subsidized and widely available. The government has been

[7] This synthesis is based upon the fieldwork in six Horn countries analyzing the agricultural and institutional performance in the drylands and making recommendations for the input and product markets and for institutional evolution. The six country studies are available in Volume 2. The regional analysis and implications are then presented in this synthesis leading to the Project Proposal(s).

supplying the seeds and fertilizer and had difficulty in responding to the rapidly increasing demand. Little attention was paid to increasing the water availability.

In Uganda the focus has been on the introduction of new cultivars, especially cassava, cotton, millet, and grain legumes (peanuts, cowpeas, and pigeon peas). Of all the Horn countries Uganda has the lowest proportion of semiarid zones with only 8% of the crop area in this zone as compared with 42% in Kenya and 66% in Ethiopia (Table A-2). Outside of the Karamoja district with 400-800 mm., rainfall is not very low (generally above 800 mm.) so water retention is not as important as in the drylands of the other Horn countries. Nevertheless, attempts to push the Sasakawa 2000 new maize cultivar-fertilization program into the semiarid regions of Uganda resulted in a 60% dropout rate concentrated in the drier zones. (IGAD/INTSORMIL. USAID-REDSO, Vol. 2, 2001).[8]

In Kenya the boom period for new maize and wheat technology introduction was in the '70s and '80s. The largest impacts were in the adequate rainfall regions but technology production and diffusion also extended into the drylands. Katumani Composite B, an open pollinated maize, was released in 1968 and covered 5.3% of the Kenyan maize area in 1993. Fifty-seven percent of the maize producers in the drylands used improved maize cultivars in 1993 but only 11% employed inorganic fertilizers (Hassan and Karanja,1997). After the boom technology production period of the '60s and '70s the release of new maize varieties has stagnated especially in the drylands. Nevertheless, Katumani Composite is appreciated outside Kenya and is still being sold by seed companies in both Uganda and Ethiopia.

Also in Kenya, there have been a large number of pilot projects on water harvesting of various traditional types (Steve Twomlow, ICRISAT Soil Scientist, personal communication, 2001). However, there was no research program from KARI evaluating the combination of water harvesting and soil fertility improvement and no national diffusion programs from the extension service on water harvesting in spite of the international fame of the Machakos experience. There has also been a collapse of the breeding activities during the last two decades especially in the dryland regions.

In Sudan success in the drylands in increasing output has been concentrated on the irrigated areas and in the rapid mechanization of the previously unsettled dryland, vertisol regions. The government has been heavily involved in the initial development and in the product market performance in the two regions. In the irrigated zones the government has also been efficient in providing seed, fertilizer and credit. In the mechanized, rainfed zone the principal input market of public concern was for machinery. There has been no attempt to encourage inorganic fertilizer use there. Yields have been low and falling here leading farmers to settle new areas. There has been minimal support for the small farmers in western Sudan.

[8] Note that maize is much more sensitive to inadequate water availability and low soil fertility than are the traditional cereals (sorghum and millet). A perennial complaint from Kenyan dryland farmers is the high probability of losing the maize harvest in the lower rainfall areas.

So the technology introduction process in these countries indicates: (a) slower rates of technology introduction in semiarid regions than in the higher rainfall regions[9]; (b) the failure to combine investments to increase water availability with fertilization; and (c) outside of Eritrea and Ethiopia an attempted reliance on a cultivar alone strategy sometimes supplemented with local fertilization schemes such as manure.[10]

How? Three Components of A Technology Development Strategy

(#1) Emphasize Water-Harvesting and Soil Fertility First: No Miracle Varieties

Most researchers now agree that a principal constraint to increasing crop productivity in the drylands is soil fertility, especially the principal nutrients, nitrogen and phosphorus. However, fertilization is risky if there is insufficient water. Increased water availability is a prerequisite for improving soil fertility by increasing the yield response to soil-fertility amendments and by reducing the yield variability. Where irrigation is not feasible or economic, a series of water-harvesting techniques can be utilized. These include ridging, tied ridging, terracing, rock or vegetative bunds, zaï, catchment basins, and other techniques. Terracing and bunding are two techniques that also accumulate water behind them and can be combined with soil fertility improvements. In traditional practices they are generally combined with manure.

The appropriate water-retention technique depends critically upon the soil type (Shapiro and Sanders, 2002). On the heavier soils with some clay and low organic matter where crusting is a problem, runoff needs to be reduced with one or more water-harvesting techniques before soil-fertility amendments are applied. On sandy soils, the problem is often rapid percolation (water passing rapidly through the soil), with water moving out of the root zone and therefore not available to the plant. Methods to increase the organic matter in the soil can contribute to increased water retention in the root zone. For sandy soils, higher plant density and fertilization also have been shown to increase water-use efficiency (Shapiro and Sanders, 1998).

On very heavy soils with high water-retention capacity, such as the vertisols (very important in Sudan and Ethiopia), water-harvesting devices, such as tied ridges, often have to be knocked down during the season, if rainfall is higher than normal, to prevent water logging.

Many water-retention measures are extremely labor-intensive. There are traditional methods, as the zaï done by hand, and more modern ones, such as tied ridges, done with an animal or

---

[9] Excluding Eritrea and Djibouti, which did not have higher rainfall regions. In Sudan the concentration was on irrigated regions and subsidizing the large farmer, mechanized schemes.

[10] Whereas researchers and policy makers are often concerned with the cost of inorganic fertilizer and farmers' failure to use inorganic fertilizers in the lower rainfall areas, fertilization was rarely linked to the prerequisite of water harvesting. In sandy soils, where the water retention problem is the rapid percolation of the water through the soil, the appropriate water retention technologies hold the water longer in the soil and can include fertilization and higher densities and any other measure to slow percolation, such as increasing organic matter in the soil. This has led some scientists to argue that on these sandy soils, the problem is soil fertility, not water. Since higher densities and fertilizers increase the water use efficiency, this argument misses the point that slowing percolation can also increase water use efficiency.

tractor power implement. The traditional, most common operations (bunds, zaï) are undertaken outside the cropping season. However, the most effective techniques, such as better land preparation and tied ridging, need to be done during the crop season, generally when the demand for labor and the requirements for the timeliness of operations are most crucial. Hence, there is a need for mechanizing these operations with animal traction. For the tied ridges, the authors know of four animal traction prototypes available in different regions of Sub-Saharan Africa. A frequent constraint is the ability to adapt and repair these implements. Therefore, there is a need to invest in the local level capacity to do these operations as occurred in the Punjab in repairing the tubewells.

When more water is available in the root zone of the crop, the returns to fertilization are increased and the variability of yields between production seasons is reduced. We have shown that the cheapest method of fertilizing, per unit of N and P, is often with inorganic fertilizer (Sanders, Shapiro, and Ramaswamy, 1996). Manure is generally insufficient to provide adequate amounts of the principal crop nutrients, N and P. Other techniques frequently recommended, such as legume/cereal rotations or intercropping, still require P application in the P deficient soils. In any event, the important point is the ordering and combination. First, increase the water availability. Combine that change with increases in soil fertility, beginning with inorganic fertilizers[11], and then complement them with organic fertilizers or soil amendments. Finally, introduce the new cultivars.

Increasing the availability of water and major nutrients in the root zone of the crop creates a new agronomic environment. Traditional varieties in dryland regions are selected over time for yield stability under harsh conditions. Some of them can respond to slightly improved agronomic conditions. But as these agronomic conditions continue to be improved, the local varieties often lodge or do not respond with a yield increase to higher fertility levels. Research institutions should be developing new cultivars for these improved agronomic conditions. The cultivar-alone strategy may at first give a small yield improvement, especially if the soil-fertility constraint is not pressing, but this approach is not sustainable if soil nutrients are being depleted (Sanders, Shapiro, and Ramaswamy, 1996, pp. 130,131). Soil nutrient depletion is ubiquitous in Sub-Saharan Africa.

A method is needed to get the major and minor nutrients back into the soil as continuous cropping exhausts them. It is not reasonable to ask breeders to select or develop new cultivars that are drought-tolerant, tolerant to soil-fertility stress, have disease and insect resistances, increase yields, fit into the farmers' production niches, and taste good. Some of the changes to increase yields need to come from an improved edaphic environment for the plants so that breeders can focus on higher yields and resistance to insects and disease.[12] Breeding for biotic

[11] Frequently, countries in Sub-Saharan Africa suggest their local sources of rock phosphate be used as phosphorous component. This apparently attractive solution, in terms of developing local resources and saving foreign exchange, is generally hampered by the very low solubility of the rock phosphate and the high cost of transportation and of combining it with acid to make it soluble. In areas with acid soils and high rainfall, this rock phosphate becomes more soluble. Otherwise, it sits largely inert a long time.

[12] There has also been successful breeding work on abiotic resistances including heat and cold tolerance and some tolerance to drought. However, multiplying the breeding objectives rapidly diminishes the probability of success. Moreover, even drought tolerance still often needs to be combined with some more water and increased soil fertility to substantially increase crop yields.

resistances and yield increases are the two areas in which breeders have been most successful in their introductions during the past three decades.

(#2) Improve the Connections between National Agricultural Research Scientists and the Rest of the Scientific World

Besides this basic problem of needing a more effective approach focusing on water and soil fertility before introducing new cultivars, the Horn countries have not even kept up in their scientific response to emerging problems in the drylands by utilizing the techniques and cultivars available in the rest of the world. Successful research systems take advantage of innovations in applied science in the rest of the world. Agriculture is characterized by biotic changes and these cause crises. Research systems need to develop the capacity to respond to these crises.

Continued failure to use scientific knowledge available in the rest of the world in dryland agriculture is a major defect of the research systems of the Horn. Symptomatic is the local-variety myth, i.e., that local cultivars combine all the good characteristics (grain, stalks for fodder, taste) that farmers need and out-yield introduced cultivars. This is just a rationale of an inability to do sufficient adaptation trials of the large amounts of new materials that are continuously emerging from research systems in the world.

Two examples are useful here. Devastating problems for sorghum are the parasitic weed, *Striga,* and the insect pest, midge. Both can substantially reduce yields if not eliminate the crop in the field. There are sources of genetic resistance or tolerance to these pests that have been embodied in new cultivars that are available in several different institutions at minimal information and postage costs. Yet most national research institutions in the Horn do not take advantage of the improved germplasm (or of other useful generic materials) in breeding programs in maize, sorghum, and grain legumes. All of this is available with networking.

Networking requires substantial investment in human capital, generally Ph.D.s. National agricultural research systems in the Horn have a moderate number of Ph.D.s. With Ph.D.s, scientists feel comfortable obtaining material from other scientists and doing their own adaptation trials. Often scientists with lesser degrees are so concerned about being used to conduct someone else's trials that they do not network very well.

There are particular problems in Kenya, Ethiopia, and Eritrea where the mountains, rainfall and soil differences result in a large amount of agro-ecological variation requiring substantial regional adaptation testing. Often breeding programs, especially for the dryland regions, do not have the manpower or the funds for all this regional adaptation. One solution would be to upgrade the extension services and NGOs so that they could undertake and analyze adaptation trials, perhaps of three to five new materials with repetitions on different farms.

The example chosen to illustrate the importance of borrowing from the rest of the world was that of new cultivars in breeding work. Similar examples can be found in other agricultural sciences of the failure to borrow and regionally test in the drylands not just of new cultivars but also of processes and concepts continually being developed in the rest of the world.

(#3) Facilitate Demand-Driven Research and Extension

A recent emphasis in technology development has been on demand led growth. To many this has meant looking for new export crops. Green beans in Burkina Faso and flowers from Kenya come to mind. In Kenya new cultivars of pigeon peas were introduced simultaneously with a search for the niche market of "dhal" for Indians in Great Britain and India (Jones, Freeman, Walls, and Loudner, 2000). This focus on specific consumers and producers will undoubtedly continue to benefit small segments of producers and primarily consumers in the developed countries.

What about the traditional food crops? Cereals are the predominant crop activities in semiarid zones. Farmers know how to grow them and traditional cereals are firmly entrenched in consumption patterns even with some small losses in market shares in recent years. Many have pointed out the price collapses[13] with good weather and the introduction of technological change. However, these are the crops that have been adapted over time to the production environments.

This price collapse is a major policy problem and needs to be directly addressed with market expanding research along with the technology diffusion process. Technological change in the drylands requires a simultaneous increase in water availability and soil fertility. It will be necessary to utilize purchased inputs (inorganic fertilizers) on the basic food crops and often very labor-intensive, water-harvesting techniques. A price collapse as this process starts would shut down diffusion of these new technologies. Hence, attention needs to be focused on demand expansion activities. Fortunately, this is not difficult.

The new white sorghums[14] give a whole new range of marketing opportunities for human consumption in high quality flour and in a series of adaptations of processing techniques such as parboiling to give the preparation qualities of rice.[15] Presently, a couscous and a porridge are being sold in supermarkets in Dakar and Bamako, both products based upon millet and prepared with boiling water. Also a cracker company in Bamako is using sorghum and several firms have tried to introduce weaning foods made from millet and cowpeas.

---

[13] In economic terms this results from the low price elasticities of demand. People can only eat so much of their basic staple so sudden increases in quantity can result in a price collapse. Similarly, though substitutes exist, it may be difficult to rapidly increase their availability in the short run so prices can substantially increase in adverse weather conditions. It is necessary to expand the demand through alternative uses to moderate these price collapses and to thereby increase the incentives for the use of new technologies with these traditional food products.

[14] The bird problem with sorghum should not be understated. Earliness and the higher food quality, white seeded characteristic both increase attractiveness to birds. Bird problems are regionally concentrated and especially serious in the Rift Valley so specific regional strategies need to be developed. High tannin levels (brown seeded cultivars) were the solution of the '60s of Doggett and Doggett derived cultivars are still widely sold. New tolerance mechanisms need to be identified and incorporated as the drought tolerance of sorghum and millet is very important for the drylands.

[15] One of the advantages of rice has been the reduced time requirements for preparation thus appealing to urban women due to the higher opportunity costs of their time than in rural areas.

The big changes, though, will be with the dietary shifts to higher quality foods, especially more animal protein as the economy grows. When these dietary shifts start taking place, poultry demand alone often increases at 8 to 10% annual rates for over a decade (unpublished data from Brazil, Spain, and Honduras. Note the increasing number of chicken-specialty, fast-food restaurants in Nairobi). No developing country going through this dietary transformation has been able to respond rapidly enough internally to these demand shifts without large-scale increases in feed grain imports.

Sorghum and millet are excellent feeds and have a comparative advantage in drought prone regions. This shift to poultry is commencing in Kenya and will be arriving soon in Uganda and Ethiopia. So it is not too early to begin responding to this potential demand shift and even to encourage it given the positive, potential impacts on the dryland cereals.

The crux of the demand expansion strategy with the emerging rapid increases in demand for feed grains for poultry and egg production is to concentrate on the domestic production of the traditional cereals[16] given their inherent drought resistance. Getting market shares for traditional cereals in feed grain markets requires a strategy. One excellent laboratory of this potential change for the Horn is Senegal, where the production of broilers and eggs is increasing rapidly with the feed grain base of imported maize. Pearl millet is an excellent feed and is produced in the sandy soils all over Senegal. Farmer coops would probably need to assure quantity and quality to the local feed producer to encourage him to substitute the more drought resistant millet for the imported maize. There are also adjustments in the grinding equipment required as both the size and the variability of size are greater than in maize (B. Eddleman, personal conversation).

A secondary activity is to expand the grain legumes. They are important in the diet as a source of vegetable protein. With repeated cultivation, they can increase soil fertility with nitrogen formation and are very useful in a cereal-based rotation to reduce the build-up of disease and insect pests. Many of the grain legumes have rapidly expanding niche[17] domestic or international markets. In West Africa demand is increasing rapidly for cowpeas and cowpea hay. Pigeon peas not only have a deep root system but also a rapidly expanding niche markets for "dhal" in India and Europe. So diversification of activities is necessary to: (a) moderately decrease the concentration on the drought-tolerant cereals and obtain the gains with respect to nitrogen fixation and more disease and insect control resulting from crop diversification and (b) expand the production of the drought-tolerant grain legumes with good marketing prospects. Besides cowpeas and pigeon pea, groundnuts and mung beans can be included, depending upon the development of the markets. In spite of initially favorable prices the limited size of these markets means that once the production starts rapidly increasing, the market can become saturated and prices can completely collapse as has been frequently observed with other crops such as tomatoes or mangos.

[16] Where there is sufficient rainfall and/or short season cultivars this could include maize. In the more marginal rainfall regions the concentration would need to be on sorghum and millet. Note the continuing importance of the traditional cereals in the feed industries of developed countries as well as their production advantages in the dryland regions.

[17] Generally, niche refers to a market of specific customers defined by income levels such as high income urban in developed countries for flowers or ethnic as the Indian market for "dhal" from pigeon pea.

Finally, there is the category of the high-risk but highly profitable activities, such as maize, field beans, and field peas. These crops are often brought in by migrants from higher-rainfall regions. Short-cycle cultivars are introduced for drought escape. Unfortunately, unlike the drought-resistant cereals and legumes, these crops have no inherent drought-resistant mechanisms. They can tolerate late rains or, if planted early, the early cessation of rains, but not the mid-season droughts. Without some supplemental water source, these crops substantially increase farmers' risks in semiarid regions. Maize is generally considered a moderately better feed than sorghum and millet. The price ratio of sorghum to maize is normally around 0.9:1 in the U.S. reflecting these perceived quality differences in feed. However, with recent innovations in high quality sorghum and millets the feed quality differences have disappeared.[18] The principal problem is that maize cannot be grown in more marginal rainfall regions without incurring much higher risks than sorghum or millet.

Project Proposal 1: Water Management Research.

Justification. The principal priority for the drylands is to increase water availability. This does not refer only to irrigation or supplemental irrigation but to the whole array of available techniques for reducing run-off, slowing infiltration, and collecting water and making it more available for crop production. These techniques include ridging, tied ridging, catchment basins, bunds, terraces, zai, and a series of other techniques. These need to be adapted to the soil types. All of these techniques increase the returns and reduce the riskiness of fertilization. The combination of increased water availability and higher soil fertility then provides an optimum environment for high returns to the breeding activity.

Organization: Among the six national research organizations in the Horn countries a committee will be organized to decide upon the awarding of proposals for research and extension in this area. The emphasis will be upon extension. Donor(s) will provide the seed money for individual grants. The funds could be held in IGAD if they can provide the necessary international accounting standards. Leadership in this committee could be rotated annually and would always be in one of the six NARS of the Horn countries. After a five-year probationary period the system could be evaluated for the feasibility of a more permanent institution located in one of the national agricultural research organizations or at IGAD.

[18] See First National Grain Pearl Millet Symposium, 1995 and Andrews, Rajewski, and Kumar, 1993.

II. Markets and Institutions Serving Dryland Agriculture in the Horn

Input and Product Markets and Supporting Public Policy

In all the Horn countries there has been a push to do away with parastatals over the last decade and encourage the evolution of the private sector. Some of the parastatals including the seed production agencies in Kenya, Uganda, Sudan and Ethiopia worked reasonably well in providing services (high quality seed) to farmers. A number of the other parastatal organizations such as the Kenya Farmers' Association (KFA) and the irrigation authorities in Sudan (especially Gezira and Rahad) provided the main network for distributing subsidized fertilizer provided by donors in the '80s. In general, however, the parastatals have maximized employment and often have not been able to do the social functions they were assigned.

When the donors stopped subsidizing fertilizer, the KFA had serious management problems and they are now in the equivalent of bankruptcy for a semipublic agency. The KFA's functions have largely been taken over by private stockists. Fertilizer consumption in Kenya has dipped with the removal of the subsidies but has not abruptly declined as farmers have seen the advantages of fertilization. The private sector fertilizer distributors have not been providing as much information and technical services as the KFA had done.

In the push toward privatization it is easy to overlook some of the useful public services that the parastatals did perform. A number of these are not being continued by the private sector and this is especially difficult for the drylands. For example, the Ethiopian Seed Enterprise had produced reasonably high quality seed including teff, grain legumes and oilseeds. With the governmental directive of 1994 to become profitable they have focused on hybrid maize and wheat and have largely discontinued the production of seed for the drylands including teff, the principal staple of Ethiopia. Teff seed production decreased from 24,000 quintales in 1994 to 2,400 in 1999 (IGAD/INTSORMIL/USAID-REDSO, Country Study: Ethiopia, 2001). The Ethiopian Seed Enterprise now imitates private sector behavior and could be called Pioneer II and as with Pioneer itself has no interest in seed markets in the drylands.[19] Their seed producers tell them that teff is difficult to produce and yields are low.

A difficult sector to rebuild after the demolishing of the public sector from the Structural Adjustment programs is the seed sector. The public sector seed programs suffered from the usual problems of state enterprises involved directly in a productive activity. [20]Unfortunately, for the dryland crops Sub-Saharan Africa has now returned to private market failure. The private seed sector in the Horn countries has not shown interest in the cereals, legumes, and oilseeds of the drylands. Private seed companies want to produce hybrid maize and seeds for the adequate rainfall regions. The seed sector of the Horn is definitely neglecting the drylands with the privatization push.

---

[19] Unless they have water and use fertilizer (Ethiopian Pioneer representative).

[20] As a result of maximizing employment they often ran out of funds to do the specific jobs they were created for, were slow to respond to changing economic circumstances, and by keeping prices too low they discouraged the entrance of the private sector.

A similar process has been going on in Kenya and Uganda. The Kenya Seed Company is still producing Katumani composite and four sorghum cultivars, including two brown seeded sorghums, Serena and Seredo, and an ICRISAT derived white but has shown no interest in KARI/Mtama 1 (the short season high quality white sorghum presently promoted by KARI). In Uganda the government reduced subsidies to the Uganda Seed Company in 1993. Seed sales of millet were 5% of 1991 levels in 1999 and peanut sales declined by more than half over this period (IGAD/INTSORMIL/USAID-REDSO, Volume 2, 2001). The government continues to pressure the Uganda Seed Company to provide emergency seed and took most of their maize and common bean stocks in 1999 (industry sources) so their present status is somewhere between a parastatal and a private company.

The response to the departure of the parastatal seed companies in the region has been for the extension and research service and the NGOs to support community seed production. The substitution of many small farmer, seed producers in Community Seed Production programs even with NGO financial support (and often national extension or research personnel technical support) will not consistently produce quality seeds. There are two serious problems with this alternative. First, maintaining quality seed production is an educational process especially for small farmers. Roguing and isolation are generally difficult for them to do. In the short-term, technical services can be provided by researchers but unless they are compensated for this, this is only a short-term solution until they are again pressed to go back to their principal activities. In the long run the private sector tends to work better to maintain quality because they have a brand name to defend and they respond better to rapid demand shifts. Unfortunately, community seed programs put up barriers to future entry of the private sector by undercharging for the seed. Community seed programs often charge a 15 to 25% markup over grain costs whereas private companies look for a 8 to 10:1 ratio between seed and grain prices to pay for their costs including promotion and development costs.

Even in the short-run, quality seed production makes a big difference in yields and in the long-run it will be essential for the principal program advocated, i.e., the water retention-soil fertility-new cultivar combination. Hence, governments need to do some innovations to encourage specific private sector developments and to review their treatment of the parastatal seed enterprises. First, to encourage entrepreneurial activity in small markets in the drylands Breeders' rights laws could be expanded to not only include compensation to the research agency as is presently being required by law but not always implemented in Kenya and soon will be in Uganda, but also compensation to the individual scientist (breeders and other scientists). This could encourage these scientists to become more entrepreneurial in seed production and the formation of private companies for small markets. Other inducements to the private sector for small market seed production would also be useful. However, for the orphan crops that the private sector cannot be induced to enter, governments need to find ways to subsidize these public or private companies. But this needs to be undertaken in such a way that the profit margin for seed production is sufficient by charging sufficiently high prices for the seed so as not to discourage the future entry of a private company.

The evolution of fertilizer distribution systems into the drylands is easier. With the increase of water availability, it will be more profitable and less risky for farmers to use inorganic fertilizers in the drylands. Demand will increase for fertilizers and the stockists will locate there in the regional trade centers. The public sector contribution is to improve transportation and communication. This increases the profitability of agricultural intensification by lowering the prices of purchased inputs and increasing the output price received by the farmer by reducing his transportation costs and giving him (or his cooperative) access to a wider market.

Equally important to the drylands as the input markets are the product markets. Food staples tend to have inelastic demand, which means that with good weather or rapid technological change, prices collapse. With the excellent weather conditions and continuing technology introduction the maize price in Ethiopia collapsed by 60% in 1996 and more than that in 2001. Clearly, this discourages farmers attempting to purchase more inputs and make qualitative investments in their land (some forms of water retention). Hence, the public sector needs to be evaluating present and potential markets at the same time that they are developing specific new technologies. Ultimately, the private sector will take over these functions. Present public sector intervention should be in ways that will facilitate rather than impede the ultimate entrance of the private sector.

A useful case study is the collaboration between KARI/ ICRISAT/Technoserve in the identification of a new annual pigeon pea. Export outlets and an export company were identified for "dhal." The company was put in touch with women's cooperatives and the cooperatives were provided with a new pigeon pea cultivar and helped to maintain quality in getting the product to the exporter (IGAD/INTSORMIL/USAID-REDSO, Country Report for Kenya, 2001; Jones, Freeman, Walls, and Londner, 2000). This is a model that needs to be imitated in other commodity research programs of putting public resources into identifying markets and getting potential producers in touch with the private sector early in the technology adaptation and diffusion process. The lesson is clear that producer risks from price fluctuation are increased if the research and extension personnel are not concerned with the present and potential markets and do not actively intervene.

Project Proposal 2: Increasing the Financing for Agencies Evaluating Product Market Development.

Justification. As important as the evolution of the input markets is the expansion of product markets. The pigeon pea case of KARI/ICRISAT/ Technoserve supporting market development by putting exporters and women producer coops in contact to facilitate the introduction of a high yielding annual pigeon pea is a model for the public sector and the national research and extension agencies to study closely to identify appropriate future activities. There are several grain legumes (besides pigeon peas, cowpeas, and peanuts) adapted to the drylands with the potential for market expansion. Another case for product market development is the different utilization of the crops adapted to the drylands such as the use of sorghum in bread, beer, and livestock feed. The big structural change here will be the use of present food cereals for poultry feed and should be reflected in a concentration of activity here.

Organization. There are already organizations systematically evaluating markets especially export markets. IDEA in Uganda is doing well. There are others and these activities need to be reinforced and expanded. Again a research-extension fund and competitive bidding may draw on a larger number of bidders and more rapidly encourage expanded activity here.

Project Proposal 3: Improving the Functioning of the Seed and Inorganic Fertilizer Markets.

Justification. Special incentives to encourage small market, private seed producers need to be developed. A start would be extending Breeders' Rights to the scientists developing new cultivars and thereby capturing their entrepreneurial energies for the diffusion process. Simultaneously, a special fund may be necessary to encourage public or private sector production of seed for orphan crops. This fund should be discussed with the private sector seed producers so that long-term disincentives are not created for the entry of private firms in the future as certain small market activities, such as pigeon pea seed production, become more lucrative.

All over the Horn the lowest cost source of N and P is expected to be inorganic fertilizer as it has been shown to be in Burkina Faso (Sanders, 1989). The explanation for this is the very low levels of N and P in manure and the difficulty of providing these nutrients with other techniques. So the soil fertility improvement for the drylands needs to begin with an improved functioning of the inorganic fertilizer markets.

The fertilizer industry is less difficult than the seed industry because the main requirement for better coverage of the semiarid sector is increased demand for fertilizer in the region and increased water availability will do that. The extension service will need to do demonstration trials to accelerate the introduction of inorganic fertilizer, and in the long-run, investments in transportation and communication will encourage intensification by lowering the costs of inputs and increasing the output prices received by farmers.

We have not discussed credit because with the highly divisible technologies recommended here the farmer can test inorganic fertilizers and new cultivars and generate his own investment capital once he takes the step of utilizing the combined technology. Fortunately, even small farmers have capital they can use for purchasing inputs. They receive remittances. They work off-farm. They keep their investments in animals, which they can cash in. So the argument here is that the principal barrier to intensification is the need that farmers have to see the results in a nearby region rather than the inability to purchase the inputs.

Organization. This is also proposed as a small grants program to do critical research and extension studies. For example, examining the efficiency and the effects on market structure of the semi-private firms selling inorganic fertilizer in Ethiopia could be a priority project. Another priority research-extension activity is to identify incentive schemes so that the scientists developing new technologies for the semiarid regions would benefit financially from their introduction. The idea here is to obtain more creative energy from the agricultural scientists to be put into the diffusion as well as the production of new technologies. A similar organizational structure to that of the Water Institute is proposed.

Project Proposal 4: Support to Commodity Networks.

Justification: The cereals, legumes and oilseeds with drought tolerance are well known. There is potential for moderate expansion into niche markets of many of the legumes and oilseeds. However, these are small, easily saturated markets. The major source of growth in the drylands will be with the rapidly growing markets for feed grains (broilers and eggs first) of the traditional dryland cereals, sorghum and millet first and to a lesser extent in the drylands, maize. This will take place in the next five to ten years. In the interim there are many processed uses for these traditional cereals. They can reclaim part of the market share lost to rice and wheat in urban areas as the processing-preparation technologies already applied in rice and wheat are then adapted to them. Expanding the demand for cereals, which are already the predominant products of the drylands, is not difficult. The process is well underway in the Sahel. Strategic small investments and better networking would facilitate this process.

Organization: Funding would be provided to the regional commodity networks for use in incorporating the input and product market sectors into the networks.

Critical Institutions: The National Research System

The key to the development of the drylands is the agricultural research system. This system usually revolves around the national agricultural research system. It is complemented by the national agricultural universities, international agricultural research centers, and by other research institutions such as the regional research centers in Ethiopia and the export crop centers in Kenya and Uganda. As the educational levels of the national system scientists increase (to the Ph.D.) and communication improves (email and personal computers) national scientists are increasingly connected to a world network of scientists.

The national research center is an increasingly complicated place. National research center scientists are expected to maintain ties and exert influence as well as take inputs from the extension service, farmers, public policymakers and donors. Moreover, the cost and complexity of agricultural research keeps increasing so networking with other scientists in similar agro-ecological zones becomes increasingly important to enable specialization, reduce the research costs of duplication, and facilitate borrowing and adaptation from all over the world at a rapid rate.

To obtain germplasm from the networks a Ph.D.[21] is usually required so the national research systems have to keep investing in human capital development especially as their well-trained researchers go into administration. In Kenya, Uganda, Ethiopia and Eritrea there are too many agro-ecological niches for the national research systems to do all their regional testing of new materials. So they will need to engage the public extension and NGOs in this process.

[21] The problems are on the side of the national researchers, who do not utilize the networks very much unless they have Ph.Ds. There seems to be a fear of the M.S. researchers, that they will be turned into research assistants for the scientists distributing the material. The Ph.D. trained scientists appreciate the new materials and know how to get what they need from them.

Besides new germplasm, the international networks of dryland scientists can be a source of new techniques and new concepts. National research systems in the Horn have been seriously deficient in utilizing these international network sources of materials, processes and ideas for the drylands. Developed countries still are mainly looked to for financing transportation and infrastructure rather than for scientific collaboration on a continual basis. Moreover, email is presently making information exchange easy and low cost. So as the supply costs for scientific interchange are decreasing, national research systems need to evaluate their demand for this international scientific collaboration by tapping more of the germplasm, processes, and concepts available in the rest of the world.

How have the national agricultural research systems performed? KARI had its glory period with the rapid diffusion of hybrid maizes in the '70s and '80s. KARI has also done well with farm level introduction (with substantial inputs from the extension service) of wheat, cut flowers, horticulture crops and fruits, fertilization and some livestock programs such as zero grazing dairy. These successes are concentrated in the higher rainfall regions or with irrigation (IGAD/INTSORMIL/REDSOO, Country Study: Kenya, 2001).

New cultivar development for the drylands is clearly very deficient in the Horn countries. Variations of Doggett's brown sorghums from the '60s and of Katumani maize released in 1968 are still being introduced and sold in the three Horn countries of Kenya, Uganda, and Ethiopia. Hageen Dura I was introduced in Sudan in the early '80s. Not surprisingly, given the serious lack of new material, there are not enough breeders working in the drylands. For example, Kenya, has two sorghum breeders, Uganda one, none in Djibouti and Eritrea, and a constant departure of breeders from Ethiopia. [22]

Since 1994, there have been impressive successes in Ethiopia in increasing productivity of maize and wheat and to a lesser extent, teff and sorghum, but again with a concentration in the higher rainfall regions and with substantial input from a rejuvenated, expanded extension system, plus consistent strong public policy support for the fertilizer, seed and credit input markets (Quinones, Borlaug, and Dowswell, 1997, pp. 86-90). There has been minimal concern with the expansion of product markets. Maize price collapses became serious crises in 1996 and 2001 as production increased considerably with the combination of good weather and new technology introduction.

Neither Kenya nor Ethiopia has performed well in moving technology onto the drylands. Moreover, in both countries privatization is making it more difficult for dryland farmers to obtain inputs and other services since the focus of national research and extension systems shifted to the higher rainfall regions. Uganda has been more effective in the drylands with a series of new cultivars (in cassava, cotton, millet, cowpeas, and peanuts). The regional research station for the drylands at Soroti, SAARI, was innovative and entrepreneurial in working with local NGOs and farmer groups when the extension system collapsed (1970s, '80s, early '90s) due to the continuing rural violence. However, this cultivar alone strategy practiced here is not sustainable and soil nutrient depletion will become more serious over time.

---

[22] Longe 1 maize was released in Uganda in 1995 and is being sold in the drier regions but it was developed for the better rainfall regions. See Appendix II of this report.

In all the Horn countries, except Djibouti, there are pressures to decentralize to the regions, to undertake more adaptive research, and to connect better with extension, NGOs, and farmers. Uganda seems most advanced in implementation of a regionally adapted research system. Ethiopia's extension system is leading the way for transfer of adaptive research system to farmers through extension. EARO is now attempting to focus their research from regional research centers on more region specific recommendations.

In Kenya, Uganda, and Ethiopia there is increasing discussion and some implementation of the national research organization selling specific services. This could be a useful way to free up resources for more public support of the drylands while hybrid maize, cotton and other cash crop producers pay for their research and extension. However, when this type of program has been implemented as in Honduras, it has led to the virtual disappearance of public research and extension on the basic food crops. So there is a risk here.

In Kenya, for over a decade, a competitive bidding process has been utilized for allocating some of their research funds. This opens up research funds formerly reserved for the national research system to a series of other institutions including the agricultural universities and the international research centers (IARCs). It pushes KARI personnel to be more competitive in pursuing and in finishing research. It can push researchers to be trendy in appealing to the research committee.

None of the systems in these three countries have moved along significantly in developing and extending new technology systems for the dryland, specifically the combined technology systems, including improved water management, increased utilization of inorganic fertilizers and then new cultivars to respond to these improved agronomic environments. This is unfortunate because this is clearly the success strategy in developed countries. Eritrea has probably had the largest concentration and greatest successes in technology introduction for the drylands but has not been concerned with water retention.

Critical Institutions: The National Extension System

The Kenyan public extension service had an important role in the successes of agricultural technology introduction in the '70s and '80s. The Ethiopian extension service has become a model for the region with its rapid growth and impressive successes in the second half of the '90s. Uganda is rebuilding its extension service with a new location in the national research agency (NARO) but district level bases. There will be a focus on research-extension ties and decentralization.

Unfortunately, with minimum inputs available from their research systems, none of the extension services have performed well in the drylands. Since the public extension service tends to be less eloquent than research institutions and public policy makers, whose focus on privatization has also made increasing agricultural output more difficult for the drylands, the extension services have generally taken the blame for the failure to develop agriculture in the drylands.

In the absence of the availability of science-based technologies, extension looks for methods to diffuse best farmer practices. This diffusion focus has been given a number of slogans to substitute for data on achievements. Indigenous Knowledge and Participatory Research are especially popular in dryland regions of the Horn. Local Variety Superiority is another one though without a slogan status. It is frequently argued in the drylands that some local landrace characteristics, such as height, taste, and yield stability, make local cultivars superior to introduced ones even when new biotic constraints such as *Striga* or midge are wiping out traditional cultivars. This failure of research systems to set up the mechanisms to utilize the gains in science from other regions because the costs of regional adaptation in countries with many agro-ecological niches are high is a tragedy for the people of the drylands and neglects an important source of agricultural growth in these countries. Diffusion of best farmer practices has been shown to be one source of increasing agricultural productivity but it leads to much lower growth rates than the systematic application of science to agriculture (Ruttan, 1994, p. 212; also Ruttan, 1988, p. 129).

Over the last two decades, the focus of building up the public extension services with large donor inputs, especially from the World Bank, has been on the extension process, the T&V system, with inadequate attention to the product. Unfortunately, the rapid expansion of the number of extension agents in Kenya and Ethiopia could not be simultaneously accompanied with higher levels of human capital investment as was done in the national research system. So in the public policy debate, extension carries much less influence. Extension has not been able to pressure the national research service or public policy makers to even maintain services for the drylands. Moreover, as the complexity of science increases, appealing to slogans and best farmer diffusion concepts has become increasingly attractive especially in regions where the national research service has under invested.

Ethiopia and Eritrea made wise decisions by requiring that local extension agents be from the local cultures. They both have also very rapidly expanded their extension services. In the future, extension will become even more complicated with much more regional adaptation of technologies hence the need to work closely with the research system. Moreover, the extension service needs to define its role in facilitating the emerging private input and product markets. It is time to move beyond slogans and to increase the human capital investment in extension agents as the application of science to agriculture will be making the diffusion process more complex as well as more regionally varied.

On the lessons learned, the Ethiopian experience of the late '90s apparently demonstrates that the principal barrier to a more rapid diffusion of new technologies is for the farmers to see the technology combination[23] in their fields or nearby fields and to have public support for the demonstration and input utilization process over time (Quinones, Borlaug, and Dowswell, 1997, pp. 86-90). Demonstrations are especially important because combined inputs often have multiplicative rather than additive effects on output due to the interaction of the inputs. In the drylands these interaction effects are even more critical since water availability has to be increased first to have a payoff to inorganic fertilizer and new cultivars.

[23] Note that this is not a test of the credit vs. demonstration debate as credit was also provided to the farmers in the second half of the '90s in Ethiopia.

So the critical requirements for developing dryland agriculture are: (a) how to increase the applied research of the national research systems in the drylands to respond to emerging biotic and abiotic constraints and to build a combined water management-soil fertility-cultivar approach; (b) how to convince policy makers and donors that privatization has short-term adverse effects for the drylands[24]; and (c) how to organize the type of continuous education, training and back-up administrative support that extension agents need to improve their dialogue with the research system and to increase their understanding of the differences between best farmer diffusion and the application of science to agriculture. Note that the first two requirements are out of the control of the public extension service. The positive aspect is that with the rapid advances in science in the rest of the world, catch up strategies have a large number of options and the potential for rapid productivity gains. The Horn countries mainly need to invest in applied research and to support with public policy the introduction of new technologies in the drylands.

The Emerging Role of Non-Governmental Institutions (NGOs)

The role of the NGOs nationally has varied substantially but it has been very similar in the dryland regions of Kenya, Ethiopia, and Uganda. In Kenya since 1992 the NGOs have provided more presence and financial resources for rural areas especially the drylands as both KARI and the extension service have been in public agency crisis.[25] The NGOs have often helped finance extension services and regional trials. In turn the NGOs received national legitimacy and technical inputs from their association with KARI and the national extension service. The system would work better with higher levels of agricultural training among NGOs and with better reporting of extension and research results to KARI. The reporting is critical for KARI to maintain farm level feedback on new technology performance. Human capital upgrading has been occurring in the NGOs especially in the last five years.

In Ethiopia the extension service built up rapidly in the '90s, was well funded with financial incentives for good performance by its agents, and has high morale. By the late '90s the extension service was recognizing the gap in services to the drylands and had created a technical unit with its headquarters staff for the drylands technology problem (IGAD/INTSORMIL/USAID-REDSO, Country Study: Ethiopia, 2001). Meanwhile, some of the prominent NGOs had spent the last decade in these drylands regions but with much less inputs from the national research system (EARO especially) and the national extension service than in Kenya. The Ethiopian public agencies had been very busy with their own programs especially in the adequate and high rainfall regions. In Ethiopia more active collaboration and sharing of experience between NGOs and public agencies is expected to have a high return for the dryland. But the critical input from EARO now is the substantial increase in region specific, applied research for the drylands.

---

[24] It is not necessary to return full scale to parastatals but some of the services formerly provided need to be made available with special incentives for the private sector and/or public funds such as for seed production of orphan crops.

[25] As we discuss in some detail in the Country Reports the cyclical variation of donor funding is very difficult for public agencies. They are generally prevented from making sharp cutbacks in personnel so they reduce services and even basic operating infrastructure when they experience these periodic funding crises. They often don't pay their bills or have sufficient gasoline or vehicle repair funds for fieldwork or visits. This is very difficult for proud, previously successful agencies such as KARI and the Kenyan extension service.

In Uganda the public extension service could not function effectively in the main dryland regions of the north due to the continuing civil strife and their association with the federal government. The national agricultural research service (NARO) directly disseminated cassava and cotton technologies and the regional research branch (SAARI) worked very effectively with NGOs and CBOs to extend new cultivars of millet and grain legumes. Now extension is incorporated within NARO. The extension service is regionally decentralized and NARO is expected to make more region specific adaptations for their technology recommendations.

But the fundamental dryland problem remains in Uganda. The variety alone solution will not be sufficient. Water availability and soil fertility have to be increased so SAARI needs to reorient its applied research approach and let the NGOs and new regional extension agents do the farm level testing.

NGOs are recognizing their roles in the new systems and have made big impacts by helping to shift the focus of agricultural technology development back onto the drylands. They need more technical people and they need better reporting of farm level technology performance to the national agricultural research agencies. Once the national agencies and private sectors can provide the technology and input/output market services to the drylands, NGOs can return to their classic roles in community development and emergency relief. They need to develop programs for phasing out their direct intervention in agricultural research and extension to return these functions to the technical people in the national agencies.

For NGOs or extension services to be successful, they will require measurable technological successes. Moreover, these successes need to be seen—both by policy makers and the public at large. One striking impact of SG2000's excellent system analyzing (and publicizing) the results of its first generation "success stories" with technology generation in Ethiopia and Eritrea was to create the political support necessary for the policy reform and then create the government support needed to expand their programs on a much wider national scale.

Project Proposal 5: Training for NGOs and National Extension Service for Demonstration and Regional Adaptation Trials.

Justification. The regional adaptation requirements are so great for countries such as Kenya, Uganda, Ethiopia, Eritrea, and Sudan with all their soil, altitude and rainfall differences, that the extension service and NGOs need to become involved in adaptation as well as demonstration trials and give better feedback on technology performance to the national research organizations.

In the Horn countries the substantial agro-ecological diversity is a critical barrier to long-term development because of the high cost of testing new germplasm. This testing is necessary to respond to the continuing biotic changes in agriculture. With their Ph.D. scientists most of the Horn counties have gotten over their fear of networking. The barrier now is the capacity to do rapid regional testing.

The NGOs are often well funded and invariably poorly committed to providing systematic feedback to the national agricultural research organizations. Their ability to conduct and analyze regional adaptation trials is a critical input for the NGOs presently. They need to improve their capacity to undertake and report on trials The national extension systems could also undertake these demonstrations and regional adaptation trials, but in some countries such as Kenya they are presently very deficient in operational funds. Moreover, due to lower educational levels and training, extension services often get into sterile debates with the research services as on indigenous technologies, low input strategies, and participatory technology development. There is a considerable educational investment necessary here.

Outside of Ethiopia and Eritrea, where the extension systems are working well, thorough institutional overhauls are probably necessary before there would be a payoff to public or donor funds put directly into the extension systems. Uganda is engaged in this overhaul and it is going on in Kenya due to the funding collapse. But specific funding for these demonstration and adaptation trials is probably the way around these organizational problems following the pattern of Global 2000 and the consequent government programs in Ethiopia.

Organization. Training teams could be set up in national extension organizations with inputs from the national agricultural research organizations to train the NGOs and their own organization in undertaking and analyzing these trials. The Ethiopian experience has demonstrated the importance of also accompanying farm level demonstration trials with support to the inputs of seed, fertilizer and credit.

Institutions to Build On

What are the key institutions that have been functioning well and need further input and collaboration as IGAD develops its regional programs for the drylands? First and key to agricultural development in the dryland areas are strong agricultural research institutes such as EARO (Ethiopia) and NARO (Uganda). The first two have been supporting agricultural development well in the better rainfall areas of the country and morale seemed to be high. KARI has been an excellent institution and will be again when governance improves in Kenya. The ARC (Sudan) also has an impressive tradition but eighteen years of civil war is debilitating to all public institutions.

Among extension services Ethiopia has completely overhauled itself and was doing well in the second half of the '90s by adapting the Global 2000 program. With its rapid personnel growth it now needs large scale training investments. Moreover, recommendations and servicing of the drylands need to be improved. With a war mentality and focus on the drylands the Eritrean extension service has done better in semiarid regions than Ethiopia. All of the crop area in Eritrea is semiarid as compared with 42% in Ethiopia (Shapiro and Sanders, 2002, p. 23).

Uganda is presently rebuilding extension after a long enforced inactivity due to the civil disturbances. The Kenyan extension service suffers from the same breakdown of effective national government as the research service. With financial support from NGOs or donors some extension programs continue to function in Kenya. But the progress from the large scale World Bank T&V financing has disappeared.

The NGOs have been important in filling a vacuum where there have been disturbances, disasters or national system break down (such as research and extension in Kenya and Sudan, extension in Uganda until the last decade). In the Horn the NGOs have been increasingly moving from disaster relief to agricultural development activities.[26] However, NGOs are generally very inadequately staffed with agricultural personnel for this transition. They do not generally understand the basic concepts of applying science to agriculture and they continually look for simplistic solutions. Efforts to integrate NGOs into governmental priorities and to support them with scientific staff are in various stages in the Horn countries.

NGOs are good instruments for delivering emergency aid, for community development, and for starting initiatives, when there are no alternative public institutions functioning. Unfortunately, they are very poorly structured for agricultural development programs. In dryland areas NGOs are often the only active (having a budget and personnel on the ground) agricultural development institutions.

Global 2000 has been a big success in Ethiopia and moderately successful in Uganda. This is a useful model for promoting rapid technology introduction including seed, inorganic fertilizers, and other chemicals. Besides focused extension activity, credit is supplied and public activities to encourage the evolution of the input industries are engaged in. More recently, Global 2000 programs have become more concerned with product markets and with storage.

On the negative side their input recommendations tend to be blanket recommendations for the country. They have been shown to be too high to be profitable for most farmers (Howard et al, 1999). Consequently, there is beginning to be strong pushes for regional trials and adaptation of these high recommendations. As with the other NGOs Global 2000 is very lax in reporting their data except in glossy public relations type publications. So they have not been much use

[26] US dumping of food aid in Africa to finance NGOs threatens the successful development of agricultural incentives by maintaining low food crop prices.

to national research organizations in developing the next generation of technology recommendations. They need to report better their agronomic results, undertake more regional trials at various input levels, do economic analysis, and be more systematically involved with product markets.[27]

Still Global 2000 is a very useful model to build upon for the drylands even if there are more combined technologies (water-soil fertility-cultivars) and more regional adaptations required here than in the prime areas. The introduction of the new sorghum cultivars in Tigray with the switching from Type II to Type I water retention technologies is an important case history (see the Ethiopia report in Volume 2).

The private seed sector is not providing quality seeds for the drylands. The public seed companies were more efficient than most public activities and were providing improved seeds in Sudan, Kenya, Uganda, and Ethiopia. The public seed sector still performs this function in Eritrea. This failure of the private sector and the adequate performance of the public sector in providing seeds for the drylands in the Horn countries, indicates the danger of any ideology. Privatization clearly works better than the public sector in many cases. In other cases, as in seed production for the drylands in the Horn, market failure occurs.

Community seed production has been eagerly taken over by the NGOs to fill the gap. But seed production is a highly technical activity, which needs to lead ultimately to private sector takeover. The NGOs generally are unable to provide technical personnel[28] and not able by their nature to charge high enough seed prices so that ultimately the private sector would be encouraged to enter.[29] Elsewhere in the report we have recommended a series of initiatives for the private and public sectors to get them involved or re-involved in the production of seed for the dryland areas.

---

[27] Elsewhere (Shapiro and Sanders, 2002, p. 29) we have reviewed the performance of Global 2000 in Ethiopia and Mozambique. "There has been a continuing inter-disciplinary conflict between the agronomists managing Global 2000 and economists analyzing field data of these programs. Global 2000 programs assume that technologies are available for the food crops used in their demonstrations, generally make blanket high input recommendations across regions, and do not provide data on farm level performance of the technologies. Global 2000 now needs to adjust regionally their recommendations based on trials on input levels, analyze better the economic performance of their technologies, and support accompanying policy for critical related problems of food crop intensification including the post harvest price collapse and the between year price collapse with good weather and/or technological change. So the interaction between disciplines has been useful as Global 2000 and related programs are starting to do all of the above in Ethiopia and Mozambique.

The advantage in the debate is still with the pro-activist position of Global 2000 in getting things done by extension services and governments for the food crops while economists spend their time pointing out the high inelasticity of demand for traditional food crops and the difficulty of getting credit for input purchases for them. Many economists are also concerned with the sustainability of the Global 2000 programs as initially their programs subsidize the availability of inputs including seeds, fertilizer, extension services and credit before proceeding to phase out the subsidies over time. Clearly the Global 2000 programs will become more sustainable if they continue to pay attention to the economists' critiques (Howard et al, 1999)."

[28] The usual response is to purchase consulting services from the national research or extension service. This works as long as these professional have the time or until the NGOs attempt to cut costs.

[29] In developed countries the seed companies talk about needing a 8 to 10:1 ratio between seed and grain prices. Farmers in developed countries complain about 20% higher prices and NGOs pay too much attention to these short run complaints.

With regard to product market development IDEA in Uganda and the ICRISAT-Technoserve activity with pigeon peas in Kenya have been very useful models. IDEA served as a public agency identifying new markets and organizing farmers. It could evolve into a large farmer organization, which could sell its technical and market recommendations and service niche crops. ICRISAT-technoserve began with the available technology in pigeon peas and the knowledge about the geographical disbursement of Indian populations and their preferences for "dhal".

Essential Policy Support for Agricultural Technology Introduction

For technology to be adopted farmers need to make money but consumers become unhappy when food prices are high or vary substantially. In developed counties a wide range of subsidies are employed in agriculture. In developing countries these subsidies have been associated with the creation of large public bureaucracies and a stifling of private sector development. Policies need to be oriented towards creating a legal and incentive system in which the private sector can develop. This generally means de-emphasizing or phasing out public sector involvement in production activities and eliminating price distortions so that prices can perform allocative functions. Our policy focus is on expanding input and product markets through more information, incentives, and infrastructure.

A fundamental characteristic of most food crops is an inelastic demand. Prices collapse with good weather or rapid technological change. If prices collapse in good years and governments or NGOs bring in food in adverse years driving prices down, then farmers are never attaining prices as high as in the absence of intervention. Under these circumstances why should they invest more in input purchases? A start here to enable farmers to obtain higher prices is to combine any technology introduction program with a market expansion search. This market expansion is designed to moderate the price collapse in good weather years. Research institutes and extension services need to be cognizant of this price collapse problem of basic food crops and to evolve structures for an integrated strategy of technology introduction-demand expansion.

Policymakers need to recognize that higher food prices in the short run are necessary for intensification of agriculture. In the long run continued technology introduction leads to lower per unit, output costs enabling some food price decline with farmers still making money. For example, donors could be encouraged to buy food aid from surplus areas in the country rather than dumping their own food products.

The need for the evolution of input markets in the drylands has been stressed in this report. Market failure of the private seed sector in semiarid areas is pervasive in the Horn countries. Our policy recommendation is that public sector scientists, who develop new cultivars or other technologies, need to profit from their successful diffusion. This would be a method to channel more of their creative energies and to focus them on the evolution of small private seed companies and other related activities. We are also recommending that the public seed sectors be subsidized to continue production of the orphan crops but only after these public seed companies develop pricing and production activities geared to turning over their operations to the private sector over time.

Policy needs to be based on the concepts that: (a) farmers need to make money so a fundamental policy objective is to moderate the food price collapse in good years (or with technological change) and to let prices increase in adverse years[30]; (b) product markets need to evolve on the basis of market research, quality control, and the evolution of farmers' organizations; (c) input markets need to develop especially for seed and inorganic fertilizer. [31]

Gender Issues in Agricultural Research and Extension

The gender situation is much different than it was a decade ago due to the increasing efforts to make credit and other inputs available to female farmers in counties such as Kenya and Uganda. While public programs to increase farmers' access to improved inputs (seeds and fertilizer) benefit all farmers, these programs will need to be supplemented by public information campaigns to increase women's understanding of their rights to benefit from these public services.[32] Presently female farmers are suffering more from the failure to rapidly introduce new technologies in the drylands than from specific discrimination against them.

Research with women's groups offers NARIs an effective, low cost way of refining and demonstrating new technologies. KARI (in Kenya) has developed a highly successful group of technology diffusion programs for women and has published an important edited volume that describes these experiences with its research programs. Uganda's NARO was able to overcome high levels of insecurity and limited extension infrastructure in the north by working through women's groups. New cultivars and associated improved agronomy were tested and recommendations refined with on-farm trials with the women farmers' groups. Both Ethiopia and Eritrea have determined that the gender issues associated with labor and food processing will play a major role in the extension services' success in extending technology packages into semiarid regions.

One feature that distinguishes the current programs to strengthen gender issues in agriculture from the first generation of women in development research in the region in the late 1970s and 1980s is the existence of a growing number of well-trained female national professionals. Some countries (notably Uganda and Kenya) are substantially ahead of others in hiring and promoting women and even, in the case of Uganda, have established quotas. Other countries, such as Eritrea, are trying to build their corps of women professionals and are giving special consideration to them for overseas and in-country training.

---

[30] The demand for food of low income consumers is determined by the food price and their incomes. More stress needs to be put on increasing their incomes rather than on forcing food prices down by food aid.

[31] The credit system also needs to evolve. But we are recommending divisible technologies and pointing out that farmers often have many sources of income so that the principal constraint to new technology is on the demand side rather than the inadequate credit available. Subsidized credit has been overrated, overly discussed, and overly promoted in the last decades.

[32] The same focus on poverty alleviation is supporting the increasing concern with gender issues. There is evidence from UNICEF, UNDP, and IDA comparative research (see the references in IGAD/INTSORMIL/ USAID-REDSO, Volume 2, 2001) that women and children suffer at higher rates from poverty inducing factors.

Especially important has been the recent emergence (in the last 10 years) of a national association of women professionals in agricultural organizations in Uganda, Ethiopia, and Kenya. Over the last decade the Winrock Foundation has helped these organizations to organize women's groups and offered grants for training as well as a lobby for women's issues. The result of this relatively small initial investment has been to develop a network of national organizations for women.

In summary, both males and females have suffered from the national research and public policy neglect of the drylands. The problem is exacerbated for women by the high rates of male absenteeism to find non-agricultural jobs. The best gender policy for both sexes is to increase productivity and incomes in the drylands. Parallel to this, both government and NGO research and extension programs need to strengthen women's ability to access the key agricultural inputs and extension services. Once these fundamental problems are addressed, priorities can be shifted to improving household-level nutrition and income distribution within the household.

The present dilemma of gender analysis is analyzing whether family income increases will be translated into increased welfare for women and children. Clearly, family member welfare cannot be increased without the family income going up. How increased income is allocated within the household then becomes an issue. Hence, our recommendation of more emphasis in the extension service on Home Economics. Specific targeted interventions for women and children is also expected to have a high payoff but that is for the next research project.

Project Proposal 6: Gender Research and Extension.

Justification. The adequacy of technology to improve the welfare of women and children has now passed the stage of focusing concern on the equal access to credit and extension for female farm managers. Now the more difficult part is to evaluate how in the male run households agricultural technology and other policies affect the nutrition, welfare and incomes available to the more vulnerable family members, women and children. Do the more vulnerable groups get their share of the gains? More specific studies now need to be made of the distribution of income and expenditures within households. This type of research has been done in the Sahel (Lilja and Sanders, 1998; Lawrence, Sanders, and Ramaswamy, 1999) and needs to be accelerated in the Horn countries especially in those countries, where there are few female heads of household (Ethiopia, Sudan, Eritrea, and Djibouti). It will also be important to monitor the availability of inputs and extension services to female heads of household in those economies in which females are running some households to make sure that progress continues on equal access to inputs for female household heads.

Organization. Another pool of research funds for which individuals could apply to do specific research or extension activities is the recommended approach. A committee of female scientists from the national research organizations of the Horn countries would be identified for the proposal selection group.

Conclusions

Drylands are potentially, highly productive agricultural areas of countries when more water and increased soil fertility can be combined with new cultivars. Then the comparative advantage of less disease and more sunlight can be exploited leading to substantially higher crop yields. Thus, income expansion in the drylands is based here upon a strategy to attain the comparative advantage in these areas. Hence, this is an efficiency based rather than a welfare oriented strategy. Once more water is available with higher soil fertility a wide range of different commodities can be produced here so continuing evaluation of product markets will have a high payoff.

The focus of the commodity approach is on the traditional cereals (sorghum, millet, teff in Ethiopia, maize in slightly higher rainfall regions), which are well adapted, can recover part of the food markets with improved preparation-processing techniques, and have considerable growth potential as feed grains.

After the traditional cereals, the next priority is the grain legumes for the niche markets including pigeon peas and cowpeas. There is a concern here with the ultimate saturation of these markets and the ensuing price collapses. Nevertheless, in the short run strategies to simultaneously identify markets and introduce new cultivars have been demonstrated to be successful with pigeon peas and can be extended to other legumes. There is an excellent model now in the collaborative work of ICRISAT and Technoserve in Kenya on pigeon pea technology diffusion and export market identification.[33]

Priority marketing areas for the drylands are the improved functioning of input markets, especially seeds and inorganic fertilizers. Structural Adjustment has reintroduced a series of market failure problems in developing countries especially in the seed market. Along with the development of new incentives for seed production, systematic efforts to facilitate the evolution of new product markets is also critical for the drylands.

The national research systems need to be plugged into the international networks of scientists to be adapting to the changing conditions of agriculture. This networking is necessary not only for taking advantage of the production of new germplasm in response to emerging biotic and other constraints but also for borrowing of processes and concepts. Without more efficient networking the maintenance and expansion of research systems will become too expensive for developing countries.

Donors, outside the World Bank, are clearly weary of supporting national research systems in Sub-Saharan Africa. Now there is interest among donors in building up the Universities and tying them better to agricultural research and extension. For financial sustainability, national research institutions need to increase their domestic support. They need to better document their successes to generate public and policymaker support. Some of this documentation has been done in these six country reports.

[33] The seed production problem was still not resolved here.

A popular concept now in developed and developing countries is for national research and extension agencies to charge producers for services. These pay as you go systems generally neglect small farmers, who have more difficulty paying for services. Moreover, there is no internal incentive for these systems to be concerned with public goods[34], such as reducing soil degradation, water and air pollution, and increasing carbon sequestration. A partial shift of the pay for services into export activities and charging large farmers is recommended, while continuing public support for most food crops.

NGOs can be more successful in agriculture if their agricultural training is increased and they are more disciplined about fitting into the overall scientific objectives of the national research systems. They need more basic and applied training in applying science to agriculture. They need to do more and better demonstrations and adaptive trials. They need to provide systematic feedback to the research and extension services from their demonstration and adaptation trials. Even the best NGO, we observed working in agriculture, Global 2000, was seriously negligent about recording and furnishing data from its fieldwork. The assumption that NGOs know the technology and don't need to provide further observations on performance to other institutions is naïve. Donors and national organizations need to change this behavior of the NGOs.

National extension services need to be more engaged in demonstration and adaptation trials. They also will need to make substantial investments in their scientific capacities. In the long run the rebuilding national extension services will take over these NGO demonstration and adaptation trial activities and enable NGOs to return to their areas of comparative advantage, relief and community development.

The NGOs have been heavily involved in poverty alleviation strategies. A better incorporation of national research and extension services in these activities would increase the probability of producing income changes for the low-income sector in rural areas by increasing the focus on technology introduction activities.

The project proposals discussed in this Synthesis involve creating funds to support specific priority research and extension areas. They expand eligibility for receiving these funds to a wide range of organizations and individuals. This will be useful for public organizations to continue to compete for funds. The downside is that research committees are often attracted by trendy projects.

[34] Defined as benefits of public or private investment, that are more difficult (and sometimes impossible) for individuals to appropriate the benefits for themselves.

APPENDIX I

Definition of the Drylands and Estimates of the Population in these Regions

Drylands includes those crop areas subject to drought, including semiarid and dry, sub-humid (Murray et al, UNDP, Nov. 1999). The crop area definition excludes the arid regions. Climatic regions are defined by an aridity index obtained from dividing mean annual precipitation by mean annual evapotranspiration. This gives an index of water potentially available. Actual availability will also depend upon the soil[35] and the farmer's cultural practices. The indices for these definitions of climatic zone are presented in Table A-1. Note the association of aridity indices with the length of the growing period. The combination of these two dryland climatic zones would be expected to correspond approximately with rainfall between 400-800 mm.

Table A-1. Climatic zones by aridity index, length of growing period, and predominant crops.

Climatic Zone	Aridity Index	Growing Days	Typical Crops
Hyper-arid	<0.05	0	No crops, no pasture
Arid	0.05 - 0.20	1 - 59	No crops, marginal pasture
Semiarid	0.20 - 0.50	60 - 119	Bullrush millet, sorghum, sesame
Dry sub-humid	0.50 - 0.65	120 - 179	Maize, beans, groundnuts, peas, barley, wheat, teff
Moist sub-humid	0.65 - 1	180 -269	Maize, cotton, sweet potato, finger millet
Humid	> 1	> 270	Cassava, coffee, banana, enset, tea, sugar cane

Source: Murray, Burke, Tunstall, Griffith, 1999, p.3.

In the seven Horn countries there were 46 million people in the drylands in the late '90s. This was 32 % of the population of the region (Table A-2). The drylands were also very important in the total area of the Horn comprising 73 % of the land area.

Somalia, Djibouti, and Eritrea only had semiarid regions. But the dependence on semiarid zones for crops is very high in the other countries, Sudan (72%), Kenya (66%), and Ethiopia (42%). Uganda has 92% of its crop area outside the semiarid and Ethiopia has 58% outside but the other countries are dependent on semiarid for the majority of their crop area.

[35] On the soils with some clay, crusting and runoff will often be problems. On sandy dune soils infiltration is often so rapid that water quickly passes beyond where the plant roots can tap it.

Table A-2. Land and population in the two dryland climatic zones for the Countries in the Horn of Africa.

Country	Land				Population (mid-'90s)			
	Dry Sub-humid		Semiarid		Dry Sub-humid		Semiarid	
	km^2	%[a]	km^2	%[a]	1,000	%	1,000	%
Djibouti	-	-	266	100	-	-	1	0.2
Eritrea	-	-	41,769	100	-	-	2,306	72.8
Ethiopia	159,276	19.3	342,378	41.6	10,137	18.0	7,706	13.7
Kenya	48,219	13.2	239,472	65.6	4,672	17.2	4,655	17.2
Somalia	-		122,820	100	-		3,325	35.0
Sudan	161,197	14.8	782,155	72.0	1,520	5.7	9,881	37.1
Uganda	41,876	17.3	19,740	8.1	1,867	9.5	261	1.3
Totals	**410,568**	**15.3**	**1,548,600**	**58.0**	**18,196**	**12.7**	**28,135**	**19.7**

[a] Percentage of potential crop area, excluding arid and hyper-arid regions. Note that irrigation makes it possible to convert arid regions into cropland but irrigation is a separate complex issue largely outside the scope of this study. For some brief discussion see the Djibouti report.

Source: Murray, Burke, Tunstall, and Griffith, 1999. Calculated from pages 12 and 13.

APPENDIX II

An Agronomic Review of the Options[36]

Agriculture in these semiarid areas is predominantly a cereal-based cropping system. Any new technologies developed should be focused on the improvement of this system. Four main areas need to be investigated: new cultivars, agronomic practices, soil fertility, and water retention. Other important research areas are storage, processing, and product development.

Sorghum and pearl millet are the principal crops produced in the semiarid areas. Maize, to a large extent, is a transitional crop. It performs better with increased moisture. Sorghum invariably assumes more importance when moisture levels are reduced. Pearl millet dominates in the extremes of both moisture availability and soil-fertility levels. Pearl millet tolerates soils that are less fertile and sandier with lower water-holding capacities than either maize or sorghum. It has a deeper rooting system that makes it better suited to these environments.

Grain legumes, such as pigeon peas and cowpeas, are also suited for the dry areas. Both, especially pigeon peas, have a deep root system enabling them to access moisture and nutrients in the subsoils. These crops provide protein that is lacking in the diets of the people in the semiarid areas. This helps in the fight against malnutrition, prevalent in these areas. These crops can also be used as livestock feed, as building materials, or as a source of fuel.

One of the biggest advantages of grain legumes in the cereal-based cropping system in the semiarid areas is their place in the rotation. They fix nitrogen and so help in restoring soil fertility. They also can curtail the development of pests and diseases that normally occur under continuous cropping, such as *Striga*, stem borers, midge, and smuts.

A wide variety of local cultivars selected by farmers over time are growing in these areas. Their selection is based on their adaptation to the environments and consumer preferences of the farmers. Even though adapted, they have a number of disadvantages: extremely low-yielding (0.8 – 1.5 tons/ha) and very long periods to mature (120 – 180 days). They respond only slightly to improved production practices, such as soil fertility, water, and crop management. In addition, they have low chances of advancement to the increased market requirements, especially nutritional qualities. Therefore, breeding programs need to improve upon the local land races. New cultivars need to be introduced that have better performance and potential over the land races. Practices have to be developed and disseminated to these semiarid areas to improve productivity.

[36] Another viewpoint is to put a primary emphasis on breeding and agronomic improvements with less emphasis on water harvesting. This is especially appropriate where water is less constraining to the response of fertilizer. Peter Esele wrote this very eloquent agronomic synthesis. Note that the semiarid area is much smaller as a proportion of crop area in Uganda than in the other Horn countries here.

What Needs to Be Done

Breeding

During this study, we have found that crop breeding is proceeding very slowly. Seredo and Sekado, grown in Uganda and Kenya, were developed by Hugh Doggett and released in 1985 and 1995, respectively. Varieties Gambella and Dinkmash were released in Ethiopia in 1980. Dinkmash is very popular in Eritrea. The popular variety Hageen Dura–1 in Sudan was released in 1980.

For maize, variety Katumani was released in 1968 and has been the only one grown in the semiarid areas of Kenya, Uganda, and Ethiopia. Even then, the diffusion rates of these cultivars have been very poor. Maize variety, Longe 1, released in 1995 in Uganda, was not targeted for the semiarid areas although it is now finding its way to some of these areas.

One of the reasons for lack of production of new cultivars is the lack of adequate human capacity. In Uganda there is only one sorghum breeder; Kenya has two. In Ethiopia, there has been a constant departure of breeders. Eritrea and Djibouti do not have any. Therefore, there is need in the whole region to recruit breeders. To be effective, the new staff should have Ph.D. or M.Sc. degrees.

Effective breeding programs are necessary to address market requirements and both abiotic and biotic constraints to crop production in the semiarid areas. To compete with other crops, high-quality cereals and legumes are needed that can either be directly sold as grain in the international markets or can be processed into secondary products, such as bread, beer, and animal feed.

Low-moisture adaptation is very important. Equally important are biotic constraints that are constantly emerging. *Striga* is endemic in Ethiopia, Kenya, Sudan, and Uganda. It affects all cereals and cowpeas. Losses due to *Striga* range between 80% and 100%. Among insect pests, stem borers attack all the cereals; midge attacks sorghum; smuts affects sorghum and maize; pod borers *(Helicoverpa)* concentrate on pigeon peas and cowpeas; *Fusarium* wilt and *Cercosporium* leaf spots on pigeon peas; and viruses and rusts occur on cowpeas. In 1998, downy mildew disease wiped out pearl millet in Eritrea, increasing the country's food insecurity situation.

There are many sources of genetic resistance or tolerance to these abiotic and biotic constraints. A good many of them are available at international agricultural research centers, such as ICARDA, ICRISAT, IITA, INTSORMIL, and others. Some resistances may also be available from the land races. We propose the following approach.

1. Introduction of new genetic materials. Through strong collaborative link-ups, scientists can introduce new genetic material from IARCs or other NARs. These can then be subjected to evaluation for adaptation, testing, and selection, and eventual release of the adapted genotypes and varieties.

2. Collection and land race germplasm. The local land races should be collected, evaluated, and characterized. Collections should be made with a clear focus on biodiversity. For example, collections should be made from *Striga*-sick plots, or endemic areas, or with specific bird-resistance mechanisms.

3. Establishment of a crossing program. A crossing program should then be established, combining the best selections from the exotics and the most popular land races. This would generate a stock of breeding lines to improve the land races and ensure a continuous breeding program.

Bird Damage

Solving the problem of bird damage has eluded cereal breeders. The major problem is that the traits that humans prefer in the grain are also those that birds prefer. The reverse is true: high tannins, often present in the red/brown-seeded cultivars and even in the seed coats of the white-seeded cultivars, cause indigestion. Humans and birds do not like this. Increasing glume coverage of seeds reduces the quality of the grain. Bristles were introduced in the sorghum heads. These scare off birds but also hurt grain processors, especially during threshing. Loose sorghum heads normally produce lower grain yields. While sorghum breeders continue to work on this problem, the immediate solutions could be to:

1. Employ human labor to scare birds. This can eventually become too expensive.

2. Grow sorghum outside the bird season. In some countries, such as Kenya and Uganda, this can be done in the second rains. However, this strategy will not work where there is only one cropping season in a year, as in Eritrea and many other semiarid areas across the region.

3. Grow sorghum in very large acreages. Birds cannot finish all the grain. This will become practicable when markets for excess grain become available.

Improved Agronomic Practices

The productivity of some local cultivars can be improved through improvement in crop-management practices. Some of these include optimum plant populations, timely and adequate weedings, increased soil-fertility levels, and more moisture availability. However, for the majority of these cultivars, increased yields will be only minimal.

New varieties coming out of the breeding programs respond very well to these improved practices. The new cultivars with improved agronomic practices have to be adopted as a complete package. Practices such as timeliness in planting, optimum plant populations, and crop rotations can be used at near zero cost to the farmers and can be extremely beneficial. Weed control can be labor-intensive, especially for sorghum and millet. Herbicides are available that can be used either as pre-emergence or post-emergence. Some of the herbicides recommended for pre-emergence application in cereals are Lasso-Atrazine or 2-4-D. Buctril is a selective post-emergence herbicide used for control of broadleaf weeds in cereals.

Animal traction can also be used to reduce labor costs in weed control. A number of oxen-drawn weeders are available. The crops, however, should be planted in rows to facilitate use of this technology. An oxen-drawn weeder can weed an area in four hours as compared to 25 manhours.

Use of Fertilizers

There are a number of non-technical opinions about the use of fertilizers. In Uganda, a myth has persisted that the soils are very fertile and do not need fertilizers. Often purchasing fertilizers is considered an extra burden to the already poor farmers. However, the reality is that fertilizers need to be applied to improve soil productivity. When poor farmers see that fertilizer increases production and there is a market for the product, fertilizer use picks up.

In general, soils in semiarid areas are deficient in nutrient supply, especially nitrogen and phosphorus. These soils also have extremely low levels of organic matter, principally due to the low vegetative cover. Continuous cultivation of cereals alone in these cereal-based cropping systems has exhausted the soils. Animal manure, which would be a ready source of organic matter, often is used as fuel. In Eritrea, Kenya, and Uganda livestock has been depleted because of wars and cattle rustling .

Over time, there have been a series of erratic weather changes. High temperatures followed by torrential rains cause degradation of soil structures. Then the water-holding capacities of the soils is reduced. There can be extensive burning of grass during the dry season. This exposes the soils so when rains fall, there can be extensive erosion and washing away of nutrients.

Improved crop cultivars developed specifically for semiarid areas require application of inorganic fertilizers to insure maximum performance. However, research on use of fertilizers in these areas has not received adequate attention. In Eritrea and Ethiopia there has been a blanket recommendation for use of urea and NPK at the rates of 50:100 kg/ha, respectively, for cereal production. This recommendation was made in Ethiopia in 1968 and is still being used today. But it no longer applies because of changes in soil conditions, including fertility differences in locations, changes in weather patterns, and production of different crops.

Motivation of Scientists

Scientists should be rewarded for good work done. In most countries, scientists' salaries can be alarmingly low. It is one of the reasons that they leave for other jobs. In Ethiopia in 1996, salaries of scientists were doubled after the demonstration programs of the government successfully raised yields, especially of maize.

Another way of motivating scientists is with technology rights. Breeders could be paid cash for new varieties that go onto farmers' fields. Agricultural engineers could be paid for the implements they develop if farmers start using them. Other scientists should equally be rewarded. In this way researchers are encouraged to work better. Some would even be stimulated to enter into the seed industry and start their own companies. Fred Miller, former sorghum breeder at Texas A&M University (U.S.A.) retired and started his own seed company producing high-quality white and low-tannin sorghums. Training to higher education degrees or a series of short courses abroad and participation in scientific conferences and workshops are very good as incentives for scientists.

Policy Support

Except for Eritrea, Djibouti, and perhaps Ethiopia, there is no deliberate, adequate policy by governments to develop agriculture in the semiarid areas as compared to the higher rainfall areas. More attention and resources are given to the high-value crops grown in high-rainfall areas, such as coffee, tea, maize, wheat, barley, and beans. Little attention is given to crops such as sorghum, millet, pigeon peas, and cowpeas. Even the private seed dealers target only the high-value crops that enjoy price support and input subsidies. In Kenya, there were deliberate economic incentives to displace sorghum with maize in the semiarid areas.

Governments need to develop specific policies to target agricultural improvements in the semiarid areas, as was done for California, Israel, and Australia.

Bibliography

Andrews, D.J., R.F. Rajewski, and K.A. Kumar, 1993. "Pearl Millet: New Feed Grain Crop," In: J. Janick and J.E. Simon, (eds), *New Crops*, New York, Wiley.

Hassan, R. N. and D. D. Karanja, 1997. Increasing Maize Production in Kenya: Technology, Institutions and Policy in *Africa's Emerging Maize Revolution*, D. Byerlee and C.K. Eicher, (eds), Boulder CO, Lynne Rienne Pub. Inc.

Howard, J.A., V. Kelly, J. Stenanek, E.W.Crawford, M. Demeke, and M. Maredia, 1999. *Green Revolution Technology Takes Root in Africa*, MSU International Development Working Paper No. 76, Department of Agricultural Economics, Michigan State University, East Lansing, MI, 64 pages.

IGAD/INTSORMIL/USAID-REDSO, 2001. *Country Studies:Djibouti, Ethiopia, Eritrea, Kenya, Sudan, Ethiopia* Publication 01-4. Volume 2, University of Nebraska, Lincoln, Nebraska, July 2001.

Jones, R. B. , H.A. Freeman, S. Walls, and S.I. Londner, 2000. "Improving the Access of Small Farmers in Africa to Global Markets through the Development of Quality Standards for Pigeon Peas, " ICRISAT-ICRAF, Nairobi, Kenya, draft, 20 pages.

Lawrence, P.G., J.H.Sanders, and S. Ramaswamy, 1999. "The Impact and Agricultural and Household Technologies on Women: A Conceptual and Quantitative Analysis," *Agricultural Economics*, 20:203-214.

Lilja, N. and J.H.Sanders, 1998. "Welfare Effects of Technological Change on Women in Southern Mali," *Agricultural Economics*, 19: 73-79.

Lupien, J.R. and V. Menza, Assessing Prospects for Assuring Food Security and Nutrition, FAO. www.fao.org/docrep/x4390t/x4390t02.htm

Murray, S, L. Burke, D. Tunstall, and P. Gilruth, 1999. Drylands Population Assessment II. World Resources Institute and UNDP Office to Combat Drought and Desertification, Draft, 30 pages.

Quinones, M. A., N.E. Borlaug, and C.R. Dowswell, 1997. "A Fertilizer Based Green Revolution for Africa," in R. J. Buresh, P. A. Sanchez, (editors), *Replenishing Soil Fertility in Africa*, SSSA Special Publication No. 51, Madison, Wisconsin, Soil Science Society of America, American Society of Agronomy, pp. 81-95.

Ruttan, V.W., 1988."Sustainability is not Enough," Commentary, *American Journal of Alternative Agriculture,* 3:128-130.

PREVIOUS PAGE BLANK

--------, 1994. "Constraints on the Design of Sustainable Systems of Agricultural Production,"*Ecological Economics, 10:209-219.*

Sanders, J.H., B.I Shapiro, and S. Ramaswamy, 1996. *The Economics of Agricultural Technology in Semiarid Sub-Saharan Africa*, Baltimore, Maryland, Johns Hopkins University Press.

Sen, A. 1982. *Poverty and Famines: An Essay on Entitlement and Deprivation,* New York, Oxford University Press.

Shapiro, B. I. and J.H.Sanders, 1998. "Fertilizer Use in Semiarid West Africa: Profitability and Supporting Policy," *Agricultural Systems*, 56(4): 467-482.

Shapiro, B. I. and J.H.Sanders, 2002. Natural resource technologies for semiarid regions of Sub-Saharan Africa. In C.B. Barrett, F.M. Place, and A.A.Aboud (eds), *Natural Resource Management in African Agriculture: Understanding and Improving Current Practices*. CAB International, London, forthcoming.

Teare, I.D., J. Woodruff, and D.L. Wright, (eds), *Proceedings of the First National Grain Pearl Millet Symposium*, 1995. Tifton, Georgia, University of Georgia Coastal Plain Experiment Station.

UNICEF, 1998. *The Progress of Nations*, New York, N.Y.

Wubeneh, N. and J.H.Sanders, 2001. "Diffusion of the Striga Resistant Cultivars in Tigray, Ethiopia: A Preliminary Report to INTSORMIL," ILRI, Addis Ababa, Draft, nine pages