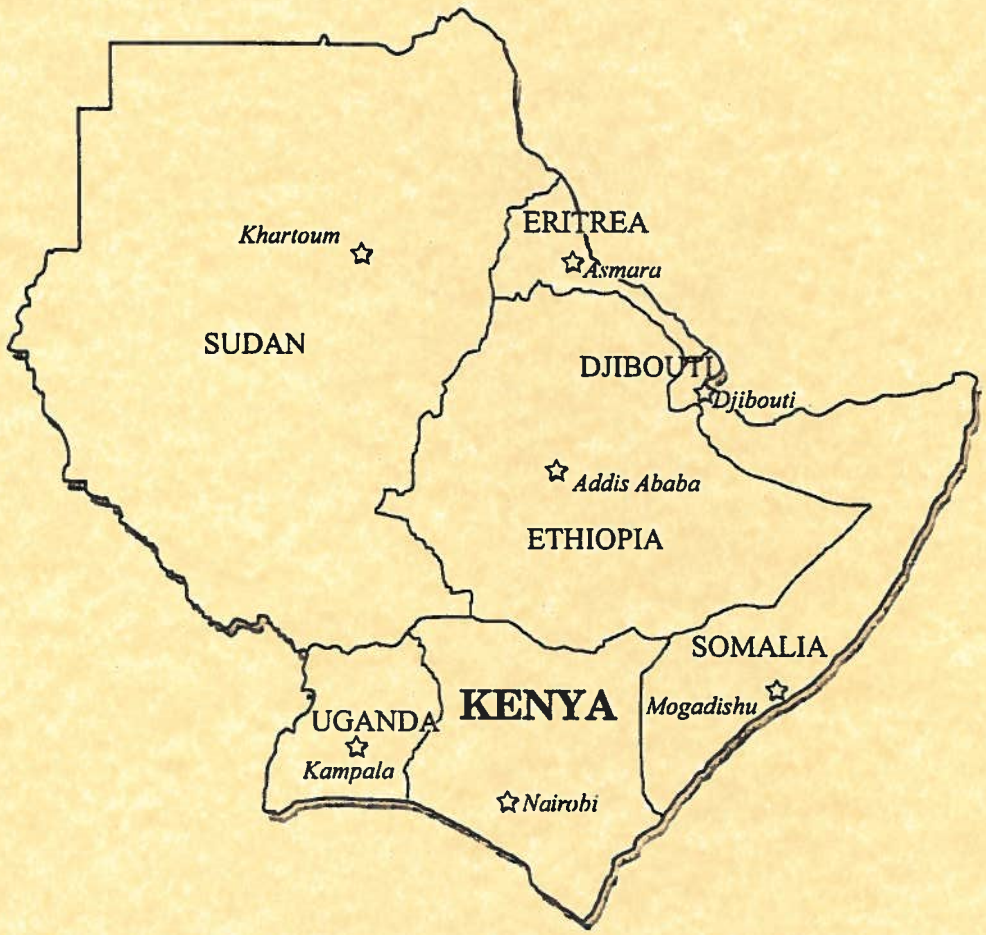
Agricultural Technology for the Semiarid African Horn



Country Study: Kenya

IGAD/INTSORMIL/USAID-REDSO

Revised January 2001

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IGAD

The Inter-Governmental Authority for Development

INTSORMIL

Grain Sorghum/Pearl Millet Collaborative
Research Support Program

USAID/REDSO/ESA/AGR

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Country report (revised) from INTSORMIL Publication 00-3 - Volume 2

IGAD (the Inter-Governmental Authority for Development)

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

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

The three volumes in this series are the output of one of the 17 follow-on projects. They attempt to review the constraints and opportunities confronting the diffusion of new higher-yielding crop technologies into the semiarid areas of the IGAD mandate area in the Horn. The first volume is a synthesis report; the second and third each include reports for three countries. [This report for Kenya was excerpted from Volume 2 and revised in January 2001.]

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Kenya

Early Progress and Recent Stagnation

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Table of Contents

Page

Acronyms i

Economic Conditions 1

Cropping Systems in the Semiarid Regions 2

New Technology Introduction 4

- Water Retention 4
- Fertilization 5
- New Cereal Cultivars in Semiarid Regions: Maize and/or Sorghum 8
- Grain Legumes and Market Expansion: The Pigeon Pea Case 10

Evolution of the National Seed Market 12

Functioning of the Research System 14

Functioning of the National Extension System 17

- Rise and Fall of the State Extension Service 17
- Expansion of the Extension System: The Emerging Roles of the NGOs 18
- Implications for the Future 21

Gender Roles in Technology Adoption 22

- Sorghum/Maize 22
- Grain Legumes: Pigeon Pea, Grams, Cowpeas 23
- Progress and Status of Women 24

Responding to Lessons Learned 25

Bibliography 27

Interviews 33

Tables

1. Major characteristics of the agroecological zones of Kenya 2

2. Average production of pigeon pea in Kenya,
1980-82 to 1996-97 11

Figures

1. Agroecological zones, Kenya 3

Box

Results of On-Farm Trials of Drought-Tolerant Crop Varieties,
Muthetheni (1998-1999) 20

Acronyms

AISRED	African Institute for Scientific Research and Development
ASAL	Arid and Semiarid Lands
CABIN	Capacity Building Innovation Network
CARE	Cooperative for Assistance and Relief Everywhere, Inc.
CBO	Community Based Organizations
CG	Consultative Group (IARC Centers)
CIMMYT	International Maize and Wheat Improvement Center
CRS	Catholic Relief Services
CRSP	Collaborative Research Support Program
DFID	Department for International Development
ECHO	Educational Concerns for Hunger Organization
ETC	Extract Tanning Company
FAO	Food and Agricultural Organization of the United Nations
GDP	Gross Domestic Product
GOK	Government of Kenya
GTZ	Gesellschaft fur Technische Zusammenarbeit (German International Development Agency)
IARC	International Agricultural Research Centers
ICRISAT	International Crops Research Institute for the Semiarid Tropics
ILO	International Labor Organization
INTSORMIL	International Sorghum and Millet Collaborative Research Support Program
IFDC	International Research and Development Corporation (Canadian Development Agency)
KARI	Kenya Agricultural Research Institute
KA	Kenya Farmers' Association
MAP	Missionaries in Action Pentecostal Fellowship Church
MAC	Mid-America International Agricultural Consortium
MMDS	Mbaa Muthetheni Development Self-Help Group
MOU	Memorandum of Understanding
NARPII	National Agricultural Research Project II
NEPII	Second National Extension Project
NGO	Non-Governmental Organization
ODA	Overseas Development Administration (British Foreign-Aid Agency)
OPV	Open Pollinated Variety
REDSO/ESA	Regional Economic Development Services Office for East and Southern Africa
SECID	South-East Consortium for International Development
SIDA	Swedish International Development Agency
WAPIA	Women's Agricultural Productivity in Africa

Economic Conditions

Kenya presently has 30. 5 million people and a per-capita income of $232/US per year. The population is growing at a 3% rate. The literacy rate is 89%, life expectancy 60 years, and 85% of the children are presently in primary school (Kirk et al., 1999, p. 3).

Agriculture contributes 33% of GDP, 70% of total employment, and it generates 60% of foreign exchange (Kirk et al., 1999, p. 3). There are three million smallholder families in Kenyan agriculture of which 80% have less than 2 ha of cropland. Smallholders are responsible for 70% of maize production, 65% of coffee, over 50% of tea, over 80% of milk, and over 70% of beef and minor crops (Republic of Kenya, 1995).

In the '90s the agricultural growth patterns for Kenya were reversed from the excellent progress of the two preceding decades. In the '70s and '80s agricultural GDP grew at 3. 6 and 3. 4% rates. By the mid-'80s the public support for agriculture began declining. The degree of governmental intervention in input and product markets increased, distorting prices and economic behavior. Management quality and services declined. Real public expenditures in agriculture have been declining since 1986-87 (World Bank, 1995). In the '90s the contribution of agriculture to GDP growth has been negative, a 1. 4% decline. Similarly there was a decline in public support for research and diffusion in Kenya on the primary staple, maize. Maize yield increases fell from a 1.5% increase over the 1975-84 period to 0. 3% over the 1985-91 period (Hassan and Karanja, 1997, p. 84).

The end of the '90s is an appropriate time to evaluate the successes and failures of technology introduction in the semiarid zone and to identify the key constraints and critical investments for the next decade. In this report, we

- Consider the macro-economic context and cropping systems of Kenya.
- Analyze past and present experience with successful technology introduction.
- Review the evolution of the seed market.
- Evaluate the status of the research and extension services, including the NGOs.
- Review some key gender issues associated with new technologies.
- Identify lessons learned and their relevance to moving forward.

Cropping Systems in the Semiarid Regions

In Kenya, semiarid is defined by the rainfall zones between 500-750 mm[1] (Fig. 1, Table 1). Zones I to III include 15% of the crop area and zones IV and V 20%, leaving 65% defined as arid (zones VI and VII). In the semiarid and arid zones, 9.4 million people and half of the livestock live (Vaetozold and Schmidt, 1983).

Table 1. Major characteristics of the agroecological zones of Kenya

Zone	Altitude (m)	Rainfall (mm)	Climatic definition	Growing days	Farming system	Natural vegetation
I	1,000 - 3,000	1,000 - 2,000	High rainfall	180 - 365	Cash subsistence crops, pyrethrum, tea, coffee	Forest
II - III	1,000 - 2,000	750 - 2,000	Medium to high rainfall	110 - 180	Cash subsistence crops, wheat, barley, maize, oilseeds	Moist wood land, bush, savanna
IV - V		500 - 750	Semiarid	75 - 110	Drought-tolerant crops, maize, sorghum, millet, cowpea, pigeon pea	Dry wood land, savanna, semi-deciduous bush
VI - VII		250 - 500	Arid	<75	Semi-desert dwarf scrub	

Note: The study is focused on zones IV-V (semiarid). The Arid Semiarid Lands (ASAL) exhibit a wide range of diversity in topography, ecology, people, and cultures. Therefore, there are many definitions. For comparison purposes, rainfall and/or growing period have been considered.

Source: From data in Vaetozold and Schmidt, 1983 and Chabeda, 2000.

With altitude, rainfall, and soil variation, Kenya has substantial regional diversity in the crops planted and the cropping systems (Table 1). In the higher-rainfall regions of the semiarid zone, maize is the dominant cereal. Other cereals (sorghum and millet) are used as a hedge against rainfall risk and to better utilize farm-level soil variation. As rainfall declines in the semiarid regions, the role of sorghum on heavier soils and millet in sandy soils increases. Generally, the

[1] In other countries, semiarid crop production is also found in regions from 350 to 500 mm rainfall. Another way to define the semiarid zone is where drought-tolerant crops are found, specifically sorghum, millet, and the drought-tolerant legumes, including cowpeas and pigeon pea.

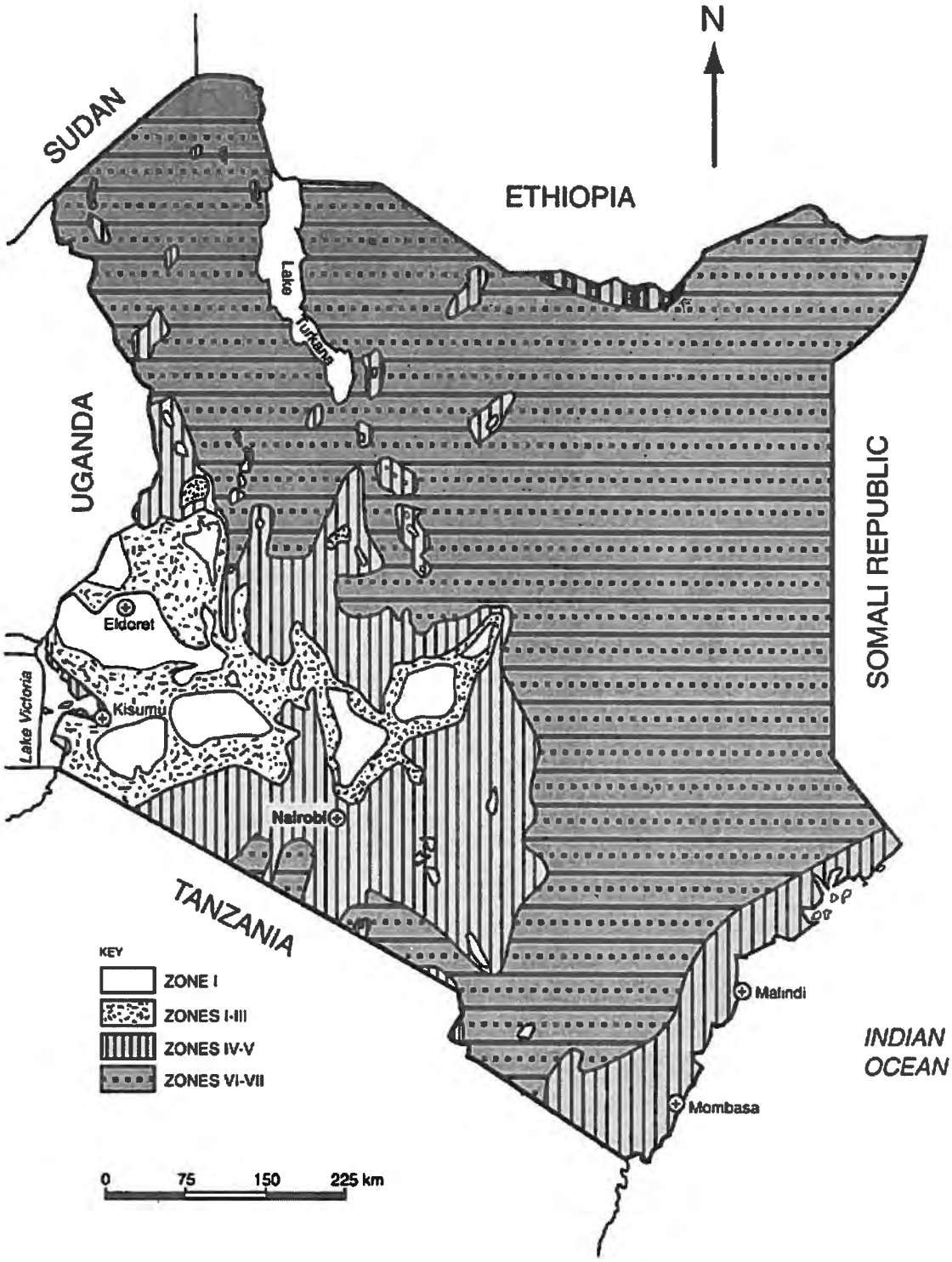

Figure 1. Agroecological zones, Kenya

Source: KARI files.

farms are small, with large families and many small animals. They generally produce grain legumes, especially the more drought-tolerant cowpeas and peanuts. The semiarid crop area has declining soil fertility since the fallow system has been breaking down without being replaced by higher use of purchased inputs. As altitude increases, the crop mix changes, with wheat and barley becoming principal cereals. Grain legumes and other crops also vary substantially with attitude and rainfall.

New Technology Introduction

Water Retention

Water-retention techniques can be divided into two stages. Stage I is usually done in regions with degraded soils where there are few alternative opportunities for farmers. These Stage I techniques involve very high labor inputs undertaken outside the crop season, such as the dikes or bunds (ridges usually done on the contour to slow water run-off), the zaï (traditional Mossi system of digging holes in the field out of season to trap water during the crop season) in West Africa and, on steeper slopes, terracing. The water retention is generally accompanied with increased use of organic fertilizers, such as manure and crop residues. The effects on yields are large relatively since yields are often very low absolutely prior to the use of Stage I techniques due to the soil-fertility depletion. But the absolute yield gains are low, hence the returns to the large labor inputs are small. For example, increasing yields from 200 kg/ha to 400 kg/ha is an enormous relative increase of 100% but only a very small absolute increase of 200 kg/ha.

Stage II technologies involve improved water-retention techniques that need to be done within the crop season. Stage II techniques are generally adopted by farmers already using Stage I techniques or whose soil has not been as degraded. Hence, the opportunity costs of these farmers are not as low as for those using Stage I techniques. These Stage II operations include improved land preparation, ridging, tied ridging, and better incorporation of organic matter into the soil. Since other labor demands are high at the times required for these operations, animal traction and sometimes new implements are required. The water-retention techniques are generally combined with moderate levels of inorganic fertilizers. Yield gains are larger absolutely than with Stage I techniques but smaller relative to initial yields since these initial yields are not as low as with the depleted soils in the Stage I case.

Terracing in the Machakos region has become an internationally famous example of Stage I (Tiffen et al., 1994).[2] On these hillsides there has been substantial labor investment to prevent the farms

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[2] In an attempt to institutionalize water-retention investments in 1974 the Swedish International Development Agency (SIDA) began a pilot program that evolved into the National Soil and Water Conservation Program (Republic of Kenya, 1996, p. 6) . It focused on bunds, basins, and catchments for water and reports new construction in the annual reports of the Department of Agriculture (A. Chabeda,

from being washed down into the valley. The terracing and vegetative barriers are combined with soil-fertility improvements, manure, and crop residues. Terracing is very labor-intensive so it is employed where population pressure on the land is high and alternative opportunities for farmers are limited. The region has benefited from good access to the Nairobi market.

Terracing is the essential first step for sloping lands. Unfortunately, neither the research nor the extension systems have become actively involved in moving into Stage II water-retention activities. This is unfortunate because KARI has been a strong agency and has scientific capacity in these soil-fertility/water-availability techniques. This movement to Stage II techniques is the critical next step for utilizing the semiarid regions. KARI scientific leadership needs to provide support for adaptive testing of different water-harvesting/soil-fertility strategies and actively encourage their diffusion through extension and NGOs. Donor and governmental overemphasis on the prime regions (Table 1, I-III) and hybrid maize appear to be factors in this under-investment in research and diffusion of Stage II activities for the semiarid zones.

Fertilization

During the '70s and '80s Kenya increased inorganic fertilizer use on export crops (coffee, tea, sugar cane), high-value crops (horticulture, fruit), and on hybrid maize and grain legumes in the prime rainfall regions (Table 1, I-III). There was substantial donor support for increasing fertilizer use but this disappeared with structural adjustment in the '90s. Over the 1987-1991 period, donors financed 54% of imported inorganic fertilizers. Over the 1996-1999,period the donor share of financing fertilizer imports was only 9%.

Increased fertilizer imports did not develop the private fertilizer market because the subsidized imports were distributed through a parastatal, the Kenya Farmers' Association (KA). Besides fertilizer, this organization provided extension support. With the phasing-out of donor fertilizer subsidies, the KA has largely ceased to exist as a fertilizer distributor. It has been replaced by private importers, distributors, and stockists. A private fertilizer industry is in place, servicing cash crops, higher-rainfall regions, and irrigated areas.

With removal of subsidies and with the new marketing organization, real fertilizer costs increased substantially in the '90s. The positive factors affecting fertilizer use in the '90s are the replacement of the KA distribution by the private sector, and the elimination of fertilizer subsidies with only a contraction but not a collapse of fertilizer use. Farmers in the prime areas have recognized the advantages of fertilizer use. Imported inorganic fertilizer imports were 314,000 metric tons in 1995-96,declining to 211,000 mt in 1997-99 (A. Chabeda, 2000).

2000). This utilization (often) of off-season community group labor for water and erosion control is a useful first step. But there still is a concentration on Stage I water-retention techniques.

In semiarid regions, except where some type of water harvesting is undertaken, there is much less use of inorganic fertilizers. One national maize production survey found 8 to 10% of maize farmers in semiarid areas using inorganic fertilizers (Hassan and Karanja, 1997, p. 86). For the semiarid zone, low-input strategies are frequently advocated. These strategies entail a continued search to substitute manure, other organic materials, rotation, or inter-planting of cereal/legume mixtures for inorganic fertilizers.

The traditional soil-fertility management practices include the use of crop residues, manure, and cereal/legume intercropping. These practices are technically sound in maintaining soil fertility, but they are quantitatively deficient. Crop residues are used for animal feed, fuel, fencing, and construction materials. Because of water stress and highly depleted soils, the biomass production is limited. Therefore, the practicality of using crop residue as a soil conditioner is almost nil. Manure is seldom available in sufficient quantities and is bulky to transport.

The option of improving soil fertility by the use of grain legumes, either as a sole crop grown in rotation with cereals or intercropped, is constrained by the high harvest index of the grain legume. Relatively little organic matter and N are added to the soil since most of the above-ground dry matter and almost all of the N are removed from the field in the grain. The low P content of most soils, particularly in the highlands and hilly areas, also inhibits successful grain legume growth and their N fixing ability. These factors limit the contribution of grain legumes to soil-fertility maintenance.

Fallowing is another traditional soil-fertility maintenance practice, but this option is not practical because both human and livestock population increasingly put pressure on the land available. Okigbo (1991) concluded that population pressure in a typical semiarid area in eastern Kenya has generated a rate of depletion of soil nutrients that cannot be supplied by a conservation/biological strategy. Adequate sustainable production is possible only with inputs external to the farm, specifically mineral fertilizers. Unfortunately, organic fertilizers and rotations are not substitutes but complements to inorganic fertilizers. The best strategy for food security and sustainable agriculture is a strategy to augment traditional soil-enrichment practices with moderate amounts of inorganic fertilizer. Otherwise low inputs of essential mineral nutrient, especially inadequate N and P, will mean low outputs.

Therefore, the primary focus for increasing crop production in semiarid regions needs to be the combination of more water and moderate levels of inorganic fertilizers. Elsewhere we have shown the yield effects and profitability of this combined strategy in various semiarid regions (Sanders et al., 1996; Georgis, 1999; Shapiro and Sanders, 1998). The lowest-cost sources of the critical nutrients of N and P are in a wide range of cases from inorganic fertilizers (Sanders, 1989). Organic fertilizers have a supplementary effect; they provide improved water and nutrient retention, improved soil structure, and other complementary effects to the inorganic fertilizers. Little of the two principal nutrients, N and P, are available from organic fertilizers unless they are applied at very high levels. The option of using organic fertilizers at high rates generally does not exist because

supplies are inadequate and there are alternative uses for crop residues. With the deficits of N and and continuing soil degradation in these semiarid regions, it will be increasingly important to use moderate levels of inorganic fertilizers combined with compost and improved rotations.

When dryland farmers take advantage of one or more of the available techniques for water harvesting, they can reduce the risks and increase the returns to fertilization. The profitability of inorganic fertilizers for farmers will then depend upon their degree of market access in order to reduce the cost of inputs and increase their product prices.

To accelerate fertilizer use in semiarid regions, the combined activities of the research and extension systems in regional adaptive trials[3] of various types of water harvesting and moderate use of inorganic fertilization are essential. These combined effects need to be evaluated and economic analysis undertaken for the range of relevant prices as well as simulation for the different possible states-of-nature.

As the economy resolves some of the problems of governmental failure (undue extension into the productive activities of the economy and interference with the price system), market failure problems will again become important. For example, the private sector (input suppliers, marketing agents, truckers) tends to be most interested in larger farmers and higher-rainfall regions. This orientation to larger farmers is natural; it saves information and distribution costs for private firms.

Nevertheless, developments in the private sector that reduce transactions, information, and transportation costs — especially in the fertilizer, seed, and product markets — will reduce the costs of inputs and increase the profitability of more intensive production techniques in semiarid regions and for small farmers. Therefore, it is important that privatization of the economy continues even though its primary, initial beneficiaries will be the regions and the farmers with more resources.

Also important to overcome this market failure will be other incentives and other policy measures, such as cooperatives, to encourage the private sector to become involved outside the prime regions and programs to restore some comparative advantage to small farmers.

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[3] A principal characteristic of Kenyan agriculture is a wide range of agricultural conditions because of rainfall, soil, and altitude differences. Hence, a central emphasis of all technology development has to be on regional adaptation of agronomic practices and addition of new cultivars to this improved agronomic environment. In 1994 the German International Development Agency (GTZ) began a collaborative program to move away from blanket or national fertilizer recommendations to region-specific ones (Republic of Kenya, 1999, p. 12). The construction of regional soil-testing laboratories was an important component of this activity. Insufficient emphasis has been put on the necessity for the combination of the water harvesting and the soil-fertility increasing techniques.

New Cereal Cultivars in Semiarid Regions: Maize and/or Sorghum

Maize is the principal staple and the predominant food crop with approximately 1. 5 million ha of production annually over the period 1994-98. Over this same period the next two cereals, wheat and sorghum, averaged annual areas of 150,000 ha and 142,000 ha, respectively (Crop Production Statistics, 1994-1998).

Successes in maize technology introduction have been very impressive. From 1965-80 maize national yields were doubled, the area tripled, and production increased fivefold (Hassan and Karanja, 1997, p. 90). These gains were based on new cultivars, principally hybrids, and higher levels of inorganic fertilizers. Productivity gains were concentrated in the higher-rainfall regions, initially among larger farmers but reaching smallholders. Use of new varieties became pervasive among small farmers but with lower use of inorganic fertilizer (Hassan and Karanja, 1997, pp. 82-86).

There also have been successes with the introduction of open-pollinated varieties of maize for the semiarid regions. Katumani Composites A and B were introduced in 1966 and 1968 and Dryland Composite I in 1989. In a survey of maize producers in the semiarid zone, 57% utilized improved cultivars in 1985-1991 (Hassan and Karanja, 1997, p. 84). Of the maize producers sampled, inorganic fertilizer use was much lower than the adoption of improved varieties, with fertilizer being used on only 11% of the farms.

With an excessive research focus on maize and continuing migration of smallholders from the higher-rainfall highland, maize is being pushed into marginal rainfall regions where it is an increasingly risky activity. Most of Kenya government and NGO cereal crop research and development activities have been concentrated on maize. As population pressure in the highlands has resulted in increasing rural migration into the lowlands, migrants have often brought their staple crops, maize and common beans, *Phaseolus vulgaris*, into the more marginal rainfall regions. The rapid push of maize into semiarid regions as a substitute for sorghum has been a widespread phenomenon of the last 30 years, accompanying the rapid increase in sales of improved maize seed (Hassan and Karanja, 1997, p. 88)

However, maize and field beans are much more susceptible to drought and low soil fertility than are the indigenous crops of the semiarid zone — sorghum, millet, pigeon pea, and cowpeas. Maize has not been that successful in semiarid areas; farmers there talk about losing their maize in 4 of 10 years and even as high as 7 in 10. In the normal adjustment process when yields collapse in areas of inadequate moisture and soil fertility, maize farmers have to adjust. If the collapse of maize yields is accompanied by increased food aid from NGOs, there is little pressure on farmers to adjust by growing crops that are less risky in irregular, low-rainfall regions. In economics this is called moral hazard, where individual entrepreneurs are not pushed by market signals to make socially optimum decisions but are encouraged to make risky decisions because others — often the public sector, but here the suppliers of food aid — cover the risk.

Breeding programs have responded with shorter-season maizes but drought escape does not help when the rains are irregular during the season instead of starting late or ending early. Shorter-season cultivars have a disadvantage when rainfall is normal or good. They have less potential to respond to inputs, especially inorganic fertilizers and increased water availability.

CIMMYT has been working with more basic characteristics of the maize plant, attempting to develop drought tolerance by shortening the silking-anthesis interval. This technique has demonstrated higher yields of maize under water stress. However, there still is a fundamental question for the semiarid regions: Is it more feasible to change the maize plant to be more tolerant of drought stress or to develop markets for sorghum and millet plus reducing the processing and preparation requirements for women?

Reasons for the substitution of sorghum with maize are more complicated than just the food preferences of migrants, which are reinforced by relief agencies and the much higher previous research investments in maize among the cereals. Other factors are: (1) serious production constraints in sorghum, (2) greater market opportunities for maize, (3) advantages to women in processing and cooking of maize, (4) incentives from public policies, and (5) providing a critical food source that is available in the hungry period before the other cereals are harvested (J. Lynam, Rockefeller Foundation, personal conversation, Nov. 1999; also Eliud Omolo, personal conversation, Nov. 2000).

Most serious of the sorghum production problems is the bird problem, especially in the Rift Valley, the probable center of origin of the Quelea bird. Farmers are still purchasing the descendants of brown-seeded sorghum cultivars. These cultivars are adaptations of the brown-seeded sorghums first developed in Uganda for bird resistance by Hugh Doggett in the '50s and '60s.[4] Kenya Seed Company lists Seredo and Serena as two of the four improved cultivars of sorghum sold presently.

The main innovations in sorghum breeding have been increased yields, white-seeded cultivars, and earliness. The white seeds improve consumer quality and the earliness gives drought escape.. These characteristics increase their attractiveness to birds. Outside the Rift Valley, the bird problem is less serious and there is some control from devices, including the strategic use of small children to scare away the birds[5] and wide-scale planting of sorghum maturing at the same time. There are several white sorghums on the market (sold by seed producers), including IS 67 and KARI/Mtama 1. Lawrence M'Ragwa, promoter of the latter sorghum and responsible for some of the seed

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[4] The brown-seeded cultivars of sorghum do not have bird resistance, just non-preference. For the Rift Valley there is the possibility of looking for other bird-resistance mechanisms besides the tannins associated with brown seed color. Tannins create digestibility problems for both birds and humans.

[5] As their incomes increase, farmers are expected to become concerned with the opportunity costs of their children being out of school.

production activities for KARI,[6] claims that there is now excess demand for the high-quality white sorghums and that he often buys sorghum from other countries to respond to the higher prices from this increasing demand. High-quality white sorghums make excellent flour and Kenya has been able to produce only half, 300,000 metric tons, of its 600,000 metric-ton annual demand for wheat, in recent years (Watson and Mwangi, 1999).

Greater ease of processing and preparation is another important component of the shifts to maize. With the white sorghums, these advantages are disappearing; these are high-quality human foods. Several processing techniques from other cereals can be applied, such as parboiling so that sorghum can be cooked like rice. Time-saving techniques for processing and preparation can become more widely available to women through private-sector activities, as is occurring with millet in Senegal and starting in Kenya.

With advances in the agronomic environment of more water and inorganic fertilizers, improved cultivars of cereals and grain legumes can be introduced. Breeding programs for both maize and sorghum are not adequately responding to the potential of these new environments. In 1997, Katumani Composite B (released in 1968) was found on 5.3% of the Kenyan maize area, whereas the only recent innovation for the semiarid zone, Dryland Composite I (released in 1989) occupied only 0. 2% of the maize area in 1997 (Hassan and Karanja, 1997, p. 83). Since responses require human-capital formation in the agricultural sciences, much of which has already been done in KARI, plus the very low-cost connection to international networks, this failure to continue to invest in semiarid technologies seems especially unfortunate. Once agronomic improvements are made (more water and increased soil fertility), there is substantial potential to increase yields in semiarid regions.

Grain Legumes and Market Expansion: The Pigeon Pea Case

Besides shorter-season maize and sorghum, grain legumes are a prime option for expansion in the semiarid regions when market conditions are favorable. For decades, pigeon pea has been hailed as a wonder crop, a perennial legume that can produce much-needed protein on poor soils while fixing nitrogen and taking up nutrients from the subsoil. The legume has been vulnerable to devastating diseases, such as *Fusarium wilt* and *Cercosporam leaf spot*. More recently, improved early cultivars and the opportunity to produce pigeon pea throughout the year have opened up new market opportunities, including the export of fresh peas to Asian niche markets in the United Kingdom and dry grain to India where supplies often fail. Plant-breeding research has also

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[6] In the late '70s in a FAO (Food and Agricultural Organization of the United Nations)-supported program, Pinto and Whiteman selected a white sorghum from ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) material in Kenya trials. This material, named KARI/Mtama 356, went into pre-release in 1978 and 1979 and later became KARI Mtama I (E. Omolo, Kenyan maize breeder, from information in KARI files).

incorporated other market characteristics, such as preferred grain size and color in addition to high yields, into an early maturing pigeon pea variety. The dual-purpose crop appears to be especially popular among women. The fresh green pigeon pea is less perishable than the other vegetables they grow. Even if a buyer for the green pods cannot be found, the crop can be left to mature and be harvested later as grain.

Since 1995, NGOs collaborating with ICRISAT have conducted on-farm trials of these pigeon peas with several thousand farmers, with the number of female participants between 60 and 70% (CRS, personal communication, Nov.1999; ICRISAT 1998, 1999a,b). New varieties of pigeon pea widely adopted by female agriculturalists in the Makindu region (near the Kiboko Research Station under ICRISAT supervision) are successfully being marketed through small family firms, such as the Makindu growers for whom they produce the crop under contract. Family members load the producers' cartons of fresh pods into pickup trucks and then drive them to Nairobi where the crop is put onto a plane bound for London.

By far the most successful evidence of adoption was a highly innovative attempt to link local producers with large-scale exporters of agricultural produce, specifically the Fresh Produce Exporters Association of Kenya and Everest Enterprises Ltd., an established exporter of horticultural produce. Everest Enterprises signed marketing contracts with some of the established women's groups in the different districts that had previously worked with ICRISAT researchers. The entire production was harvested and delivered to Everest Enterprises.

Even though the market is still small, there appears to be scope for expansion of these export sales. The annual growth rate of pigeon pea production was 4. 7% in Kenya (Table 2). In 1995-1996, India imported 82,000 tons. In 1996, this rose to 132,000 tons with estimates for the 1998-1999 season as high as 200,000 metric tons (Jones et al., 1999).

Table 2. Average production of pigeon pea in Kenya, 1980-82 to 1996-97

Production	**mt**
Production average, 1980-82	28,845
Production average, 1995-97	44,874
	ha
Area average, 1980-82	66,337
Area average, 1996-97	147,510
Annual growth rate in production, 1980-97	4. 7%

Source: Jones et al., 1999

In the absence of these brokered overseas marketing arrangements, prices for the new varieties on the local markets appear to be less than prices paid for traditional varieties (ICRISAT, 1999). The new short-season varieties will require some modifications in the traditional farming systems. The long-season pigeon pea is grown intercropped with maize in the bi-modal rainfall regions of Kenya. The maize is harvested in the first season, which allows the pigeon peas to further develop and be harvested in the second season. Short-season pigeon pea needs to be mono-cropped and would require spraying to control insects.

NGO officials involved with the trials confirmed the view of ICRISAT officials that one of the most important immediate constraints to increased production of pigeon peas is the shortage of seed and lack of commercial incentives for private seed companies to invest in developing quality seed. One option is for the marketing companies to do seed production. [7]

Evolution of the National Seed Market

In the process of African development, governments have often attempted to achieve welfare objectives by setting up centralized, state-controlled organizations. These organizations have become expensive with large bureaucracies. They have reduced incentives for private entrepreneurs and have stifled the creative forces of competition. Most development programs are increasingly tying their activities to the further evolution of the private sector or privatization.

Historically, Kenya Seed Company has been a strong agency, as demonstrated by the successful diffusion of improved maize cultivars — especially hybrids for the higher-rainfall regions (Hassan and Karanja, 1997, p. 88). A number of open-pollinated varieties, including Katumani and Dryland Composite, have also been successfully produced and distributed by the Kenya Seed Company. Up through 1992, KARI and the extension service were providing new cultivars and demonstrations.

The Kenya Seed Company concentrated on marketing, promotion, and distribution of new cultivars. The new cultivars were not sold individually but as a package with fertilizer and pesticides. With decline of donor support to the extension and research services, especially after 1992, the Kenya Seed Company began its own research division. Meanwhile, the extension service has curtailed its promotion and demonstration activities, further increasing these costs for Kenya Seed Company.

Kenya Seed Company was 51% owned by the public sector but divestiture of the public-sector share is now taking place. The advantage of a public agency is that it has a mandate to be concerned with social welfare as well as with profitability issues. As the seed sector privatizes, seed production and distribution ultimately will increase efficiency. Seed-quality control will evolve as

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[7] Jones et al., (1999, p. 12) discuss the serious problems of encouraging private investment in the development of seeds for minor crops, such as pigeon pea.

cultivar names become associated with specific companies. The problem is how to insure that small farmers and the semiarid region benefit from the privatization of the seed and fertilizer markets.

Pioneer and Monsanto are entering the seed industry and there are new national seed companies, such as Western Seed Company. The first two are primarily evaluating their participation in the Kenya market, beginning with hybrid maize production for the medium- and high-potential markets. Cargill preceded Monsanto and tried unsuccessfully for four years to obtain a seed-merchant's license. Monsanto took over the Cargill operation and applied for a license, paying the fee of 75,000 Kenya schillings ($1,000) in December 1998. To date it has heard nothing from the government.

Nevertheless, Monsanto is in the pre-release stage with two maize hybrids. This means that the company can sell 5 metric tons (first year), 25 mt (second year), and 50 mt (third year). One hybrid, CG 4141 (120-140 days, earlier than 511), is now being released. Further advances in earliness would also result in cultivars of interest in the semiarid zone, taking advantage of hybrid vigor. The two international seed companies expressed interest in semiarid regions if more water were available.[8]

In contrast, Pioneer took on a Kenyan partner (Fresco), which already had a license. Pioneer has been importing maize hybrid seed from Ethiopia and Zimbabwe for two years. In the second year of sales, the seed imported from Ethiopia sat in Mombassa because floods cut off the roads. Hence, germination rates were very low and Pioneer seed was discredited.

Some requirements to increase the capacity of the seed industry to respond to the needs[9] of farmers in the semiarid sector are: (1) increase incentives for entrepreneurs to engage in small niche markets to satisfy emerging domestic or international markets, such as that for pigeon pea; (2) breeders' rights, with a percentage for the scientist and not just for the research agency, would encourage entrepreneurial activity from breeders and other agricultural scientists; (3) public funding, as to the Kenya Seed Company, for some of the dryland orphan crops until the private sector becomes interested; and (4) well-managed, scientifically based community seed production with NGOs for OPVs and other orphan crops as a temporary measure with a plan for turning over activities to the private sector.

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[8] With the addition of more water, as with water-retention techniques and higher soil fertility in the drylands, there will often be incentives to shift to higher-value products, such as horticultural crops, grain legumes for export, and maize in place of sorghum.

[9] There are crops with a public good component, such as the dryland cereals, on which the nutritional welfare of many rural poor people depend. A public good provides benefits not only to individuals using the services, in this case individuals improving their nutrition, but also to other members of the society. There are many disadvantages to a society from malnutrition, especially the deterioration of human capital with increased incidence than expected of unemployment, crime, and various types of welfare payments.

Functioning of the Research System

Based upon its broad regional coverage, its development of scientific human capital and physical infrastructure, and its successful diffusion of technologies into the higher rainfall regions, KARI has been an impressive success story. KARI has 15 national stations, 6 regional stations, and 10 research sub-stations all manned with multi-disciplinary teams. In 1997 there were 4,964 employees with 464 research scientists, 42 top managers, and 1,521 administrative support staff. In 1989 employment was 6,200, so there has been a 20% decline in the last eight years as funding levels have been cut back. Nevertheless, the scientific capacity of the staff has increased. In 1997 there were 103 Ph.D.s as compared with 16 in 1986 and 287 M.S.s as compared with 215 in 1986 (Wakindiki, 2000).

Technology diffusion successes associated with KARI have been impressive in hybrid maize, wheat, horticultural crops and fruits, cut flowers, fertilization, and some intensive livestock operation, such as zero-grazing dairy (Waithaka and Cusack,1999). To date these successes have been concentrated in higher-rainfall zones or with irrigation and are principally produced by larger farmers. Success in the semiarid zone has been predominately with maize. There a sample of maize producers indicated that 57% are using improved cultivars and 11% fertilizer (Hassan and Karanja, 1997).

KARI has not kept up the momentum of new maize cultivar production for the semiarid zone. Maize technology introduction for semiarid regions effectively ceased with introduction of Katumani Composite in 1968. The pace of hybrid maize introduction also slowed but new cultivar release continued as the higher-rainfall region was the focus of KARI and national extension activities.[10]

Nor have the breeders in KARI done better with sorghum. There have been no advances of sorghum breeders from the brown-seeded derivatives to avoid devastation from the bird problem. Much more is now known about nutritional problems from the tannins for humans and animals. But the breeding work still is built on the concepts of Doggett from the '50 and '60s. The big initiative of sorghum breeders of an early white with much better nutritional characteristics, KARI Mtama 1, was first provided to farmers in eastern Kenya in 1991 but not officially released until 1998. Adoption rates are still reported as very low.[11]

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[10] High-altitude maize hybrids are concentrated in the 1,800 to 2,200 meter range.

[11] In impact studies undertaken in the '90s, some limited diffusion of KARI/Mtama 1 plus Seredo and Serena was reported but no seed production or sales data were available (Waithaka et al., 1999; SECID, 1999, p. 55). Note that the white-seeded nature of KARI/Mtama 1 is very important for human nutrition and opens up markets for the sorghum, but both earliness and the absence of tannin make it more susceptible to birds. New pearl millets with bristled ears have been developed for bird control. The millet variety ICMV-221 has been pre-released (SECID, 1999, p. 5. 5).

Despite repeated probing of the former DG of KARI (Dr. N'Dirito) and the main promoter of this white sorghum, (Lawrence M'Ragwa), we could not ascertain the KARI strategy to get these sorghums out to farmers and seed companies. In summary, both the short-season whites and the brown sorghums have been around for over two decades and apparently there is no systematic promotion program to get them onto farmers' fields in semiarid regions. Nor does it appear that there have been successful breeding efforts to respond to new biotic constraints in sorghum, such as *Striga* and *Midge,* or innovations besides tannin for bird control.

One of our most immediate recommendations for KARI is to better connect with the networks of researchers working in the semiarid zone. Sorghum with some individual resistance is available in several places in the rest of the world (including ICRISAT and Texas A&M and Purdue universities). The U.S. Agency for International Development did support a sorghum-breeding program in the '90s through MAC, but getting new sorghum material onto farmers' fields has apparently had a very low priority for KARI, the extension service, and seed companies. It is not clear why KARI is not better connected to networks of scientists working in the semiarid zone both in Sub-Saharan Africa and in the rest of the world. Genetic material with a broad range of traits is available for the cost of postage.

KARI has the human-capital capacity and the stations to be active in adapting water-retention/soil-fertility techniques to a wide range of soil, altitude, and crop-system characteristics in the semiarid zones of Kenya. The high returns from these combined activities have been frequently demonstrated (see the references in the technology section of this report). There has been some investigation by KARI of drip irrigation for female-farmer vegetable producers and of better utilization of micro dams for households, animals, and supplemental irrigation (interviews with soil-water professionals in KARI). However, KARI is largely ignoring what is going on elsewhere in the rest of the world in water retention/soil-fertility management and has no systematic research plan to remedy this deficiency for the drylands.[12] With the deficits in agronomic research and with the lack of breeding improvement, little applied or adaptive research is being done for crops in the semiarid areas.

Most of our recommendations have been in the applied fields of agricultural research. However, ongoing basic research is also being undertaken on the molecular basis for drought tolerance in many institutions, including CIMMYT, Texas Tech University, and ICRISAT. KARI needs to maintain contacts with the individual researchers and institutes. CIMMYT is involved in new exploratory activities on drought tolerance in both wheat and maize. Translating the basic science concepts into useable products needs to be on the future agenda for the drylands in KARI. In the

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[12] KARI headquarters had no research plan on water-retention/soil-fertility to give us, but we obtained a copy of the "Soil and Water Management Research Programme" from the Katumani station. It reported research done in the mid-'90s. This report did not recognize the basic interaction between investments in water retention and soil fertility but tried to separate them. If both sufficient water and soil nutrients are lacking, it should not be surprising that overcoming one or the other of these constraints is not a profitable endeavor.

meantime, there is a substantial backlog of applied work in other regions that needs to be tested and then diffused in the Kenya semiarid zone.

There is another more basic problem that KARI has been unable to resolve. Since the Kenyan elections of 1992, donor funding has been cut back; the donors are negotiating with the government of Kenya to increase the efficiency and transparency of their expenditures[13] and other structural reforms. In the private sector, a sharp decrease in operating funds would result in a large decrease in employment. Adjustments of this type are more difficult in the public sector. With restrictions on cutting employment, KARI expenditures on staff have become disproportionately high relative to operational expenses. With declining funds and unable to make drastic adjustments to employment, KARI is in crisis. This is indicated by its inability to pay bills. And its many employees, with morale low, are looking for ways to supplement their salaries. Agencies, such as KARI, need flexibility to reduce employment and to sell more of their services to respond to the cyclical pattern of donor demand for their services. Another approach is to make a more convincing case for higher, more stable national support. Both strategies need to be pursued.

Since 1986, an Agricultural Research Fund was established to support applied activities with a competitive bidding process. Various donors — including USAID, the World Bank, and the Kenya Seed Company — have put money into this pot. Now the fund is open to KARI and non-KARI scientists. Presently per year, USAID puts in $250,000, ODA $80,000, and the World Bank $4 million through loans to the Government of Kenya. Ultimately, the donors want to establish an endowment fund. To obtain these research funds, KARI scientists have to compete. But many of them have not successfully made the transition to a competitive bidding system.

Presently, there is renewed interest in the poverty/nutrition problem in East Africa with all the recent published data on stunted growth among children. KARI has the opportunity to make some new initiatives for the semiarid zone. It can refocus its research and develop closer ties with NGOs and the state extension service so that these agencies can do more adaptive research and testing. KARI can also do much more by charging for services in the high-rainfall regions and among the larger farmers. Some of KARI's staff could then specialize in serving this pay-for-service clientele. The threat is that KARI would then neglect the public-good component of its research and provide inadequate servicing of the clientele that cannot pay for services. Before completely succumbing to the bureaucratic disease of (a) inflexibility to respond to changing circumstances, (b) poor operating support to technical people, (c) little public responsibility, and (d) low morale, KARI needs to identify how it became so successful in the high-rainfall regions and adapt its institution to the problems of semiarid regions now that poverty and malnutrition are back at the top of donor agendas.

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[13] A recent Kenyan publication pointed out that during the last decade, 60 billion Kenya shillings (833 million US$ at an exchange rate of 72 Kenya sh/$) of public funds has been misappropriated every year on average, earning Kenya a high rank among the most corrupt countries in the world, according to Transparency International (see "Is Kenya a Terminal Case?"*Market Intelligence*, p. 14).

Functioning of the National Extension System

Rise and Fall of the State Extension Service

Whenever there is a breakdown of the agricultural research/extension system, as at present, and with the failure to deliver new technologies to farmers in semiarid regions, the least eloquent members of the establishment end up taking the blame. The research system has produced little in breeding or agronomic innovations for the semiarid regions. Agricultural policy has been biased against the semiarid area in the Kenyan attempt to privatize and mainly service the high-rainfall regions. This is most obvious in the evolution of the seed industry where the major development has been increased availability of improved hybrid maizes. Both researchers and public policymakers eloquently pass the blame on to the public extension service for the failure to develop semiarid agriculture.

Without new technologies or sufficient support from public policy for the semiarid zone, extension agencies retreat to slogans, such as the promotion of indigenous technology[14] and the myth of local-variety superiority. These two concepts are now being heard all over the country and were frequently repeated in our field trip to Machakos. These two concepts can be summarized as the diffusion of best-farmer practices and this can be useful. However, the big gains from agricultural technology are with the application of science to agriculture, especially the rapid response to biotic constraints as they emerge, the utilization of higher input levels, and shifts to more valuable crops. These techniques need to be applied to semiarid regions unless the public-policy goal is to leave most farmers mired in poverty until, with falling birth rates and industrialization in one or two decades, they can be attracted off the farm.

As with KARI, the public extension service has been successful in the high-rainfall regions and had a boom period with World Bank funding in the '80s. During this time (1982-1992) the training and visitation model system (T&V) of extension was implemented. With high funding levels, extension employment increased.

After the 1992 elections, donor funding was substantially reduced. As with KARI, the extension service has had difficulty reducing employment; hence, operations and services had to be decreased with consequent declines in morale and an inability to maintain services, especially in the drylands. With insufficient operational funds, lack of technology from the research system to extend, and little

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[14] Another point of view also expressed by the team was that the semiarid zone should first take advantage of best-farmer practices, especially (1) in the area of water retention, such as bunds, terraces, and the equivalent of zaï; and (2) in soil fertility in the improved use of manure and crop residues through corralling and composting. Then these areas would be ready to move into Stage II water-retention technologies, inorganic fertilizers and new cultivars.

public policy to support, the extension service was effectively paralyzed in the semiarid regions, leaving the field to the NGOs.

This is unfortunate since the structure of a strong service is still there with a total staff in 1999 of 11,912 of whom 7,197 are front line (deal with farmers). Of the staff, 3,159 have advanced training of at least a university degree (Chabeda, 2000). The T&V system with World Bank financing built up the cadres and increased investment in human capital. Unfortunately, the system was not sustainable and has the same problems when it tries to implement a reduction in force, as discussed with respect to KARI above.

Individual extension agents increasingly have made their services for hire available to the NGOs. The NGOs meanwhile had their own sources of outside funding but needed the technical support (and national legitimacy) from either KARI or the national extension program. There was a natural marriage and also increasing diversity in local research and extension activities. However, NGOs tended to be even more likely to settle for best-farmer practice diffusion than was the extension service prior to1992. NGO performance in reporting feedback from new technology performance, after it took technologies from KARI, was even worse than that of the national extension service. KARI found itself with reduced demand for new technologies and even less farmer feedback on the technologies that NGOs did move into the field. Given the current weakness of the state extension service, any short-term strategy to increase the diffusion of new agricultural technology into the semiarid zones will have to emphasize development of more effective two-way communication channels with a much more diverse array of state, private and NGO extension actors.

Expansion of the Extension System: The Emerging Roles of the NGOs

There has been a dramatic expansion of the role of international and national NGOs in agricultural extension during the last five years. An analysis of two districts found that although the Ministry of Agriculture and other Kenyan departments continue to be the main sources of agricultural information in both districts (26-40%), NGOs (including churches) are the next most important sources (12-40%), followed by farmer-to-farmer interactions and neighbors/friends (1-26%).[15]

A number of factors are driving this trend toward increases in the number of persons in extension and agricultural input supply. Especially important has been a major shift in donor objectives toward increased privatization of functions once performed by the Ministry of Agriculture and a renewed emphasis on the state agricultural ministry's developing more rigorous financial accounting

[15] Community-based organizations (CBOs) were reported as significant sources of information in both districts (9-23%) as were mass and print media (6-19%) and stockists (retailers) and traders (1-9%). One of the key differences between the high-potential Trans-Nzoia division and the semiarid West Pokot division was the much larger number of community-based organizations in the former than in the latter (260 vs. 80).

systems. In this revised policy context, the traditional role of government as an executor of agricultural development interventions has been redefined to put more emphasis on facilitating partnerships between local agricultural communities and a much wider range of government, NGO, and private-sector partners.

The national extension service of Kenya, under the Ministry of Agriculture, continues to oversee decentralized-division-level-trained male and female extension workers (with backup support from national-level specialists) who have direct ties with approximately 200,000 farm extension groups nationally (over 75,000 in the districts classified as semiarid).[16] In the '90s the extension staff has experienced inadequate financial support for transport, travel, or routing operating costs for carrying technical messages to farm groups.

Responding to the decline in donor funding for extension, NGOs have been trying to fill this vacuum and have experienced substantial increases in demand for their services. Reflecting their historic commitment to social welfare issues, most NGOs see their role in agricultural development (technology development and extension) as part of a commitment to community development and food security.

There is extremely wide variation in the size and complexity of programs between and within NGOs. At one extreme are the large international NGOs, such as CARE, World Vision, and CRS, which coordinate multi-million dollar donor-funded disaster and development programs as well as smaller initiatives for specific districts. Of the 10 districts in the semiarid region in which World Vision supports agricultural development, all 10 of World Vision's programs are classified as Area Development Programs with annual budgets that range from $100,000 to $300,000. At the other extreme are a large number of small national NGOs, many of them religious-based, that receive small grants from the international religious organizations to which they belong. In addition to size, the Kenyan NGOs vary widely in terms of the sophistication of their agricultural programs.

The very simplest programs involve the provision of seeds and tools. The NGOs' most important sources of information on new technology and improved seeds are KARI and its research stations. The NGO desire to promote "seeds and tools" and improved agronomic practices creates their demand for extension workers.

Some NGOs (national as well as international) train and hire their own agricultural extension staff. Others "borrow" government staff by paying the costs (fuel, transportation, food, and expenses) of extension workers' time on specific interventions in the NGO programs within the extension workers' mandated zones. This type of collaboration is widespread and occurs with the tacit approval of the Ministry.

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[16] In addition, there were a number of youth groups. Senior women in the agricultural extension unit described several specific instances in which youth clubs in the semiarid areas had been successful in passing new information about crop varieties or livestock production techniques to their elders.

The IARCs, CRSPs, and KARI recognize that NGOs have direct contacts at the grassroots level, which facilitate their ability to work with local farmers for the development and extension of new technologies. They note, however, that the results of this collaboration have been mixed. One of the shortcomings most frequently identified by NGO, extension, and research leaders was that many NGOs failed to extend the recommended practices coming out of KARI.

Especially egregious in the eyes of many researchers is the traditional aversion of most NGOs to inorganic fertilizer, which in semiarid regions often needs to be combined with water-harvesting technologies. The technological naïveté of many of the NGOs is reflected by their almost complete failure to report farm-level results from the cultivation of seed they obtain from KARI. There are a number of notable exceptions (box below; Omanga 1999; Onyango and Umaya, 1999; CIMMYT et al.; KARI, 1997; Odhiambo and Otto, 1997; Njuguna et al.,1996).

Results of On-Farm Trials of Drought-Tolerant Crop Varieties, Muthetheni (1998-1999)

Before the rainy seasons of March 1998, October 1998, and March 1999, the Mbaa Muthetheni Development Self-Help Group (MMDS) under a development program of the Missionaries in Action Pentecostal Fellowship Church (MAP) in Mbaani (Machakos district) with financial assistance from Dorcas Aid International Africa, distributed seeds of drought-tolerant crop varieties of maize, sorghum, millet, beans, and cowpeas to 40 farmers. These farmers tested the varieties in small quantities, rated the performance of these varieties, and then disseminated the results of their experiences to all 420 farmers of the MMDS (divided over 10 sub areas). The results of these trials, including a detailed analysis of farmer trials in the Muthetheni area and in comparison with similar tests in the Yatta plateau region of Machakos district, were published in a detailed report (Van Tol, 1999).

The KARI, extension, and NGO staffs involved in successful programs with farmers (including export of pigeon pea discussed earlier) cited a number of common features of those exceptional programs, which had been successful in building ties and promoting technology from KARI including:

1. A relatively high level of technical capacity within the NGOs in terms of both senior and junior agricultural development staff

2. Elaboration of concise memoranda of understanding (MOUs) to clearly elaborate the roles and financial expectations of each of the partners

3. A high level of technical support and backstopping from their international leadership[17] for the religious NGOs[18]

The recently expanded role of NGOs in Kenyan agriculture has precipitated a great deal of interest among NGOs and foreign donors. One example has been the collaboration of IDRC with World Vision and the Kenya-based Capacity Building Innovation Network (CABIN) to strengthen agricultural NGO financial management and strategic planning skills.[19] Other efforts include Christian-worker conferences organized on agriculture, such as the ECHO/AISRED conference on Agriculture and Food Security in Eastern Africa (held in Kenya, Oct.12-15, 1998) which brought together 98 agricultural specialists from small- and medium-sized NGOs in East Africa with the largest representation from Kenya.

Implications for the Future

The increased diversity of actors participating in technology diffusion presents a host of new opportunities and constraints. To date, however, there are only the first tentative movements to adapt strategic planning and administration to this recent shift. Although donor-funding through NGOs presents KARI and the extension service with many new opportunities for funding demand-driven research, there are only a few examples of this taking place, such as the pigeon pea case.

The trend toward informal division-level exchange between the Minister of Agriculture and the NGOs is even more pronounced than the informal relationships between the NGOs and KARI. These relationships gain in flexibility from the high level of division-level informality but lose in terms of missed opportunities for further strengthening from trained Ministry staff. These informal

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[17] The Catholic Relief Services (CRS) leadership in Baltimore, Maryland (USA) observed that their agricultural programs in East Africa have some of the strongest collaborative ties with the International Agricultural Research Center (IARC) system of any of their programs worldwide. One factor which they consider to have reinforced this collaboration was the agency's decision to create a new position of regional agricultural advisor, based in Nairobi.

[18] One example is ECHO (Educational Concerns for Hunger Organization) a non-profit, Christian organization based in Fort Myers, Florida (USA) which strengthens missionaries and national churches as they assist small-scale farmers. ECHO has been a major source of technical information and support for the NGO networks affiliated with AISRED (African Institute for Scientific Research and Development) in Kenya (see AISRED, 1998; Post and Ole Sena, 1999; Mbatia and Ngechu, 1999).

[19] Although CABIN capacity-building efforts have not focused specifically on agricultural technology, the director has a Ph.D. in agronomy and sees the potential for this specialization.

arrangements may even increase costs since the NGOs often have to hire to fill positions that could have been filled by members of the extension staff either through a formal loan arrangement and/or some arrangement to simply pay their operating costs.

For NGOs to fully engage in the system, they must address the issue of technological capacity up front. Specifically, donor agencies and the international offices of these agencies need to be much more cautious in supporting agricultural development in NGOs that do not have the requisite technical leadership and ties to supportive agencies (including KARI, the IARCs, CRSPs, and the national extension service). KARI could facilitate this process by making itself more accessible through a series of division-level presentations to NGO group meetings as well as group meetings of the major NGO networks such as CABIN, the food-security NGOs, AISRED, and ECHO's Kenya affiliates.

Gender Roles in Technology Adoption

Sorghum/Maize

Women play a major role in the rapid diffusion of new cereal cultivars. A recent survey of 1,400 maize growers in Kenya found that more than 40% of the maize farms in Kenya are managed by women. Despite less access to inputs and other agricultural services, female maize managers achieved 90% of the yield levels realized by male managers. The researchers concluded that while women cultivated smaller plots and had less access to education, credit, extension, and mechanical means of cultivation, they adopted improved production methods at rates similar to those of male farmers. Women can, therefore, be considered as prepared as men to adopt new technologies. With less effort by extension, female farmers can achieve gains similar to those of male farmers in maize productivity (Salasya and Hassan 1998, p. 77).[20]

Part of the explanation for the rapid switch of urban and rural preferences to shorter-cycle maize can be attributed to women's preference for the less labor- intensive processing attributes of maize. The differences in processing and preparation times is an important issue for women in determining their choice between maize and sorghum/millet.

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[20] This confirms the results of an earlier three-district survey of 706 randomly selected households in the districts of Kakamega, Muranga, and Kilifi (Saito et al., 1992, p. 79) which showed that with existing endowments (e. g., lower educational and training levels as well as less access to inputs and credit), men's mean gross value of output per hectare was only 8.4% higher than females'. This study suggested that "if women had the same access to resources as men, the value of their output would increase by 22%, which would make their productivity higher than that of male farmers" (*ibid.*).

Grain Legumes: Pigeon Pea, Grams, Cowpeas

Women farmers are likely to play a large role in the dissemination of new higher-yielding, drought-resistant grain legumes, which are "women's crops" in many semiarid zones. One outstanding feature of these crops, which they share with popular horticultural crops and small-scale livestock operations, is that the ability to harvest over an extended period facilitates independent marketing by women.[21] Many senior women extension specialists were concerned that large-scale government and foreign-donor investment in the development of new higher-yielding grain legume varieties and market development might encourage farmers to convert them to "male crops," as happened with introduction of early maize as a male crop in the 1970s and 1980s.

One positive factor in women's maintaining control of these new activities is the demonstrated ability of highly organized women's groups to overcome the marketing constraints associated with new crops. For example, the Everest Food Company contracts enabled several women's groups to market almost their entire production of fresh pigeon peas at competitive prices even with a steady increase in the number of women farmers moving into these joint production efforts.

Women's groups have long been a key feature of women's survival strategies in both rural and urban settings. In addition to their role in labor-sharing, emergency aid, and the institution of the merry-go-round (circular savings group), they provide one of the few socially acceptable ways to retain household income for personal and children's expenses, such as school fees, health care, and improved housing. The size and dynamism of these traditional groups — which already were a pronounced feature of the Kenyan social landscape at independence — were given impetus by the decentralization of extension and research that occurred as a result of the 1984 rural development legislation.

The Kenya government has emphasized the critical role of contact groups for extension. Under the Second National Extension Project (NEPII) utilizing the T&V method, all front-line extension staff were instructed to meet groups rather than individual farmers at each contact point. Women's groups received extension advice through mass-media programs and quarterly workshops at the local level. At the workshops, group representatives met with local farmers and were introduced to new technologies and information which they then passed to their group members (Saito et al.,1992, p. 58). The T&V program in the national extension service helped to strengthen the pre-existing base of women's groups' adoption of new higher-yielding cultivars and associated technologies.

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[21] There was widespread consensus among the senior female extension agents and researchers interviewed that women prefer investing in crops (labor-intensive as well as less labor-extensive) which produce harvests that they themselves can market. Cereal crops (which tend to be quite bulky) require them to rely on paid labor and/or male kinsmen for marketing; this reduces their control over the profits.

Presently, 25 years after the first concerted efforts to strengthen female groups as part of the national extension effort, the national extension service estimates that its district-level extension officers have direct contacts (past and present) with 233,692 registered extension groups. More than 70,000 of these registered groups are in districts characterized as semiarid, according to the Home Economics Division of the Ministry of Agriculture, Nov. 1999. The Ministry of Agriculture production unit responsible for collecting and analyzing all production data in the country estimates that 95% of these groups are comprised exclusively of women (others are characterized as mixed).

Progress and Status of Women

Since independence, the Kenya government has made substantial progress in making the agricultural extension service more useful for smallholder farmers in general and women farmers in particular. The findings of a well-known study of smallholder farmers in western Kenya in the mid-'70s found that there was persistent and pervasive bias against women farmers in the delivery of agricultural services (ILO, 1986). More recent research, conducted as part of the Women's Agricultural Productivity in Africa (WAPIA) survey, found that female farmers were as well-served as male farmers (Saito et al., 1992, p. 54). An estimated 13% of farmers surveyed by WAPIA — both male and female — were in contact with the extension services, the same percentage reported in a T&V evaluation (Saito et al, p. 55).

The official number of women contact farmers increased from 10% in 1986 to one-half of all contact farmers (in 1989-1990) as a result of a concerted effort by the Ministry to target women farmers as part of the T&V program. Especially important as a result of the targeted hiring practices of the 1970s and 1980s is that an estimated one-third of the extension agents in the Ministry today are women. One important result of the WAPIA survey was to suggest that the gender of the extension agent was not perceived by either male or female farmers as a major constraint on communication, except on certain themes (Saito et al, p. 59).[22]

The results of this impressive investment by the Kenya government and international donors in the 1970s and 1980s represent a major asset that can be capitalized upon to address some of the technology concerns identified in this study. Indeed, our initial interviews within the Ministry and NGOs suggest that a great deal of this expertise is already being accessed through the district-level extension service's willingness to collaborate with the expanding base of national and international NGOs. Any concerted attempt by the national government in general, and KARI in particular, to

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[22] Three-fourths of both men and women in the WAPIA household survey and over two-thirds of female farmers in the WAPIA extension survey in Machakos and Muranga indicated that they were comfortable with either male or female extension agents, and over three-fourths of the agents in the Machakos and Muranga division had no gender preference in terms of their target audience. On the other hand, a substantial number of male agents (42%) indicated problems working with individual women and had difficulty delivering messages of particular relevance to women, such as labor-saving issues, nutrition, and childcare *(ibid*, p. 59).

unlock this potential must explore new ways of negotiating district-level cooperation between the better-funded NGOs[23] and the national extension service.

One major advantage of Kenya, compared with many of its neighbors, is its strong base of educated female scientists (approximately one-fifth of the agricultural scientists in KARI). In the absence of affirmative action targets, the KARI female scientists have not benefited from the same access to educational advancement as the men. At the Ph.D. level, women are only 10% of the male number and 28% at the M.S. level. Unfortunately, with the general contraction of research funding, female scientists are obtaining fewer opportunities for educational advancement, are winning few competitive grants, and appear to be discriminated against in government line funding. These skewed educational and funding patterns appear to be more a response to scarce resources rather than any deeply entrenched pattern of gender discrimination. Nevertheless, they can have very negative impacts by creating new patterns of gender discrimination.

Responding to Lessons Learned

Improving incomes in the low-rainfall zone has not only a welfare effect in this region of concentrated rural poverty[24] but can also help take some of the population pressure off the medium- and high-potential zones. However, the principal reason for developing the semiarid region is its agricultural potential. When slightly more water is made available and soil fertility is increased, semiarid regions have a comparative advantage of more sunlight and less disease over higher rainfall regions, as demonstrated in California, Israel, and Australia.

1. Given Kenya's traditions in water harvesting, it is especially unfortunate that the government of Kenya has not continued to do adaptive research and then promotion with state extension and NGOs of different combined water-harvesting/soil-fertility improvements in the various semiarid agroecological zones. Especially serious is the failure to move to Stage II water-retention techniques and to combine water-retention and soil-fertility improvements in both research and extension activities for the semiarid zone.

2. Since the '60s, the plant breeding establishment has not supported the semiarid regions in developing new cultivars for the improved agronomic environment that respond to (a) increased water availability and higher soil fertility (1 above), (b) new biotic constraints in the cereals and other crops of the drylands, or (c) even in moving along seed-production activities in the private sector so as to make the new white-seeded sorghums more widely available.

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[23] The better-funded NGOs have more technically trained NGOs as well as excellent contacts with farmers.

[24] Poverty rates for the country are 46% in rural areas and 29% in urban areas. Poverty was defined in 1994 as 1490 Kenya Shillings per month in urban areas and 978 in rural areas (Kirk et al., 1999, p. 3).

3. An important lesson from the pigeon-pea exporting case is the focus in the early introduction process on (a) identification of the markets and (b) making contacts between exporters and producer groups. System interactions from markets to production have created substantial interest in research and extension organizations.

4. Kenya has a tradition of entrepreneurial activity. It has a breeders' rights law to generate revenue for KARI. It is privatizing the Kenya Seed Company but has done almost nothing to insure or increase the availability of high-quality seed for the semiarid zone.[25] Individual scientists or extension agents support the community-based seed-production activities.

5. Neither KARI nor the national extension service has responded to donor cutbacks after 1992 by making substantial employment reductions. Hence, services have necessarily been sharply curtailed. Therefore, both agencies are now fairly ineffective, especially in semiarid regions. The two agencies have impressive records of technology development, adaptation, and diffusion, especially in the high-rainfall regions. They are capable of orienting more of their activities to semiarid zones with organizational changes and some financial support.

   Organizational changes that would help strengthen KARI include better networking with IARCs, universities, and other organizations working for the semiarid regions and developing new relationships, and even financing so that more of the adaptive research required in so many different agroecological systems can be done by the state extension service and NGOs.

   For the state extension service, an especially important potential contribution would be activities, such as more trials of the combined inputs of water retention, fertilizers and new cultivars, to facilitate the growth of the input (seeds, fertilizer) and product (identifying and facilitating demand growth for semiarid agriculture) markets.

6. A number of NGOs have come in to fill the gap in research and extension services in the semiarid zone. Unfortunately, most of them have substantially under-invested in their own technical expertise in agriculture. They also have not provided feedback to the research establishment on the farm-level performance of the new technologies which they obtained from KARI or other sources. Government officials and NGOs have generally recognized these deficiencies and have been attempting to resolve them.

7. Women have benefited from the processing and preparation advantages of maize and rice in the substitution of these cereals for sorghum. For the new white sorghums there are nutritional advantages and now the processing-preparation technologies are becoming available for

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[25] The exception here is M'Ragwa's work with small producers to increase output of KARI/Mtama 1. As noted before, we could not get any data on production, sales, or where the seed went, other than the informal report of much of the output going to NGOs for southern Sudan.

sorghum. Some private sector and public home economics interventions are needed to communicate these techniques.

8. With strong women's groups and strategic production and marketing information, it is possible to increase the income received by women, as illustrated by the increased exports of pigeon pea. It will be interesting to see if men attempt to take over this crop as exports continue to increase, as occurred with the early maize varieties.

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