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Nairobi, Kenya

Voices from the Field

Science for the Poor in Kenya

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The Consultative Group on International Agricultural Research is an alliance of 62 Members that together support 16 international agricultural research Centers. In this book, we do not cite the names of individual CGIAR Centres doing particular work but rather describe all of these Centers as CGIAR Centers.

Similarly, we credit the CGIAR Members who have funded the work described herein in a list at the front of this book rather than name the individual Members who have supported specific activities. We acknowledge here the legion of other unnamed investors that have demonstrated their commitment to Kenya's small-scale farmers through their financial and other assistance. Their help has been invaluable.

Similarly, only CGIAR partners directly involved in current research are referred to by name. This is not to forget the many more partners, both within and outside Kenya, whose supportive work, in research and in the field, is benefiting the lives of many Kenyans.

Please note that the names of some individuals in this book have been changed.

This book is dedicated to the farmers who are at the center of Kenya's development.

The organizers: The field tours for the Annual General Meeting of the CGIAR, on which this book is based, were organized by Bruce Scott, head of the organizing committee for the AGM 2003. The researchers who acted as scientific resources for the tours and for the field chapters of this book were: Steve Staal and Diana Lee-Smith (Nairobi), Ben Odhiambo and Ed Rege (Kenya), Chin Ong (Machakos), Bashir Jama (Western Kenya), Markus Walsh (Lake Victoria Basin), George Karanja and Frank Place (Central Highlands), and Patti Kristjanson (Kitengela).

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PREFACE

by the Minister of Agriculture

and

the Minister of Livestock
and Fisheries Development

This book, produced for the Annual General Meeting (AGM 2003) of the Consultative Group on International Agricultural Research (CGIAR), highlights the role of national and international agricultural research in the reduction of poverty and food insecurity in Kenya. We give prominence here to the voices and images of the clients of our agricultural research — Kenya's 22 million small-scale farmers and pastoralists.

Kenya's economy is heavily dependent on agriculture. Seventy-five percent of Kenya's 30 million people make their living from farming, producing both for local consumption and for export. Despite its high rate of population growth, Kenya is counted among the African countries whose food production has kept pace with population increase. It is only during years of severe drought that Kenya experiences a major deficit in food requirements.

Agriculture, which includes crop farming, livestock farming, fishing, and forestry, makes up about 26 percent of Kenya's gross domestic product directly and about 30 percent indirectly. It is estimated that agriculture's share of informal sector jobs is more than 40 percent. Agriculture brings in a large percentage of our foreign exchange earnings and provides raw materials for Kenya's agro-industries, which account for about 70 percent of all its industrial production. Over 50 percent of export revenue continues to be derived from primary products, notably tea, coffee, sisal, pyrethrum, sugarcane, wheat, and cotton.

Kenya has a wide range of ecological zones, ranging from snow-capped mountains to the deserts of the north. Only 20 percent of the land can be classified as highly suitable for continuous arable agriculture; the rest of the land is arid to semi-arid. Only a very small proportion of Kenya is under irrigated agriculture. Maize is Kenya's principal staple crop, with legumes falling in second place. Millet, cassava, and sorghum are also important crops. Tea is

now Kenya's most important cash crop after a decades-long competition with coffee. Kenya now produces more tea than any country in the world except India and China. Coffee continues to be an important export and the coffee industry is now liberalized in several ways.

Horticultural produce has also emerged as a major cash crop in Kenya, coming second only to tea. Kenya is currently fourth in the world in the export of cut flowers. The country supplies almost 70 percent of global demand for pyrethrum. Agricultural goods are now Kenya's third largest merchandise export. Beef and dairy cattle are also important to Kenya's agricultural economy. It is now well recognized that Kenya has one of the most developed dairy industries in sub-Saharan Africa.

Kenya knows the importance of research to sustain and enhance productivity. Kenya has an impressive array of achievements in the application of research outputs, from superior crop varieties to vaccines against livestock diseases to renowned soil conservation technologies. Examples of technologies developed in Kenya that are now applied all over Africa are the drought-tolerant Katumani maize variety and a vaccine against rinderpest in cattle for which Walter Plowright, working in Kenya in the 1950s, won the World Food Prize in 1999.

Kenya's agricultural sector is complex and diversified. It ranges from the most advanced state of knowledge to produce export flowers and horticultural products for the European markets to methods to intensify and sustain smallholder agriculture for the poorest communities. Our research systems, which include the public and private sectors and our universities, address all of those complexities and issues. We have developed one of the most responsive agricultural research systems in Africa.

Kenya is also the home of two CGIAR Centers, the World Agroforestry Centre (ICRAF) and the International Livestock Research Institute (ILRI). We also host offices of seven other CGIAR Centers and the headquarters of a CGIAR sister institute, the International Centre of Insect Physiology and Ecology (ICIPE). A total of 12 CGIAR Centers are actively collaborating with the Kenyan national agricultural research system, led by the Kenya Agricultural Research Institute (KARI). Kenya now hosts the largest concentration of CGIAR activities anywhere in the world.

Kenya's close association with the CGIAR is deliberate. We recognize the importance of collaboration and partnership. Our association with the CGIAR has enabled our scientists and institutions to gain access to excellent human and scientific resources. The CGIAR has benefited from a very open and healthy relationship with Kenyan institutions — a win-win situation. Recognizing the value of these partnerships, the government of Kenya became a Member of the CGIAR in 1995.

Research and the advancement of science is based on partnerships. These collaborations need to take place at the local community level and internationally if we want to make an impact on the alleviation of poverty. The government has invested in strengthening our national agricultural research environment, which allows us to interact as effective partners internationally. We are proud to be a stakeholder in the CGIAR.

We trust this publication, your interactions with the Kenyan scientific community and farmers, and your deliberations at the AGM will increase your appreciation of our accomplishments in improving the efficiency of agriculture in Kenya and throughout Africa.

Honourable Kipruto arap Kirwa (MP)
Minister of Agriculture

Honourable Joseph Munyao (MP)
Minister of Livestock and Fisheries Development

Children at a poor farmstead in the Central Highlands of Kenya.

FOREWORD

by the Chair of the Consultative Group
on International Agricultural Research

The preeminent twenty-first century challenge facing Africa is to accelerate economic growth that is widely shared, environmentally sustainable, and socially responsible.

Agriculture is a keystone of development, and the dominant sector in the economies of developing countries. This is especially true of sub-Saharan Africa, where the agricultural sector accounts for 70 percent of employment, 40 percent of exports, and over 30 percent of the gross domestic product. An explicit focus on agricultural development must lie at the heart of development strategies in Africa.

For over three decades, the Consultative Group on International Agricultural Research (CGIAR) and its partners have been at the forefront of global efforts to advance agricultural development in sub-Saharan Africa.

This publication celebrates the Kenya-CGIAR partnership, a strong and enduring example of the benefits of mobilizing science for achieving balanced development in Africa. The research successes described in these pages bear testimony to the significant development impacts achieved by the Kenya-CGIAR partnership. *Voices from the Field* offers a range of valuable perspectives from farmers who have gained from an investment in agricultural research, and those who still have much to gain. It is appropriate that as we hold the first CGIAR Annual General Meeting in Africa we take the time to listen to farmers and all our partners in our determination to ensure we are moving forward in the right direction.

As the Kenyan Ministers for Agriculture and for Livestock and Fisheries Development point out in their preface, the challenge for agriculture in Kenya is particularly pressing. The sector contributes an enormous amount to gross domestic product, to the export trade, to

processing industries. Yet only a small percentage of the total land area of Kenya is productive farmland, and population pressure is increasing in these farmed areas. In such circumstances the pooling of resources in dynamic partnerships is vital if innovative ways of raising farm outputs and yields are to be found.

Agricultural research in Kenya has a long and venerable history, which is detailed in the opening chapter to this book. The smooth transition of research institutions to the new government at independence in 1963 highlighted the crucial role these institutions were to play in the building of the new Kenya. Two important trends can be discerned. First, the increasing role played in research by universities and other higher education establishments. And a second and related trend, the burgeoning contribution of Kenyan nationals — both individuals and organizations — to the vast array of research programs currently taking place in Kenya.

I am pleased to acknowledge the special contributions made by Kenyan nationals to the success of the CGIAR. In the past, several Kenyan scientists and policymakers have served on the Boards of Trustees of CGIAR Centers; currently four Kenyan nationals serve in this capacity. In addition, numerous Kenyan scientists, research, technical, and administrative staff are hard at work at the CGIAR Centers developing a slate of new technologies that increase farm incomes, promote growth, and help reduce adverse agricultural impacts.

Perhaps the building of partnerships could be mentioned as a third major trend. Kenya and the CGIAR enjoy a longstanding and fruitful partnership that goes back three decades and is growing from strength to strength. Kenya formally became a CGIAR Member in 1995 and is the only country that hosts two CGIAR Centers: the World Agroforestry Centre (ICRAF), established in 1978, and the International Livestock Research Institute (ILRI), established in 1995. In addition, Kenya is the host to regional offices of five other CGIAR Centers (CIAT, CIMMYT, CIP, ICRISAT, IPGRI) and another Group Member, the United Nations Environment Programme (UNEP).

At the dawn of the twenty-first century, the challenge of poverty eradication in Africa is immense. To achieve the Millennium Development Goal of cutting severe poverty in half by 2015, African annual growth must reach the 5 to 7 percent mark. Agricultural research, conducted within a public good framework, is a proven way of boosting growth in the vital agricultural sector.

Fortunately, the consensus emerging from the 2002 Summits in Rome, Monterrey, and Johannesburg recognizes the centrality of agriculture. We must capitalize on this renewed interest and redouble our efforts.

There is no surer way of seriously addressing the challenges of hunger, poverty, and environmental degradation than by investing in agricultural development. Cutting-edge science targeting the needs of millions of Africans in the rural sector can make a significant impact in tackling the formidable development challenges facing Africa. The triumphs of scientific discovery and beneficial impacts documented here offer ample evidence that science can be mobilized to benefit poor farming communities in Africa and elsewhere.

The CGIAR is committed to mobilizing the best of global knowledge for generating local solutions that meet the agricultural and development challenges facing Africa.

Ian Johnson
Chair, Consultative Group on International Agricultural Research

Harrison Amukhoye describes the soil fertility problems he experienced on his western Kenya farm before adopting the terracing and strip cultivation techniques recommended by agroforestry researchers.

AGRICULTURAL RESEARCH IN KENYA:

A CENTURY OF ACHIEVEMENT

by Dr Romano M. Kiome

Director of the Kenya Agricultural Research Institute

Formal agricultural research in Kenya was initiated in 1903 with the establishment of the Department of Agriculture experimental station at a government farm at Kabete, under the British colonial government. For the next two decades, research capacity slowly developed. Veterinary research laboratories were also set up at Kabete in 1908. By 1924 a number of other agricultural research stations had been established throughout the country. Agricultural research was largely the domain of the local colonial government until World War II, during which time the British government sought a more active role in the promotion of science and technology in its colonies. This led to the creation of several regional agricultural research organizations in East Africa that complemented or partially replaced existing facilities. Three of these, the East African Agriculture and Forestry Research Organization (EAAFRO), the East African Veterinary Research Organization (EAVRO), and the Tea Research Institute of East Africa (TRIEA), were located in Kenya.

With independence in 1963, all national agricultural research agencies were transferred, with few disruptions, to the newly independent government. In the first two decades after independence there were few changes in the organization of agricultural research. The regional research organizations continued to exist until the collapse of the East African Community in 1977. Kenya inherited EAAFRO, EAVRO, and TRIEA. This resulted in an assessment on the performance and structure of agricultural research. The then recently established National Council for Science and Technology advised the government to reorganize all agricultural research and development (R&D) into a number of semiautonomous parastatal institutes, and this led to the creation of the Kenya Agricultural Research Institute (KARI), the Kenya Marine and Fisheries Research Institute (KEMFRI), the Kenya Trypanosomiasis Research Institute (KETRI), and the Kenya Industrial Research and Development Institute (KIRDI).

Institutional developments

Currently there are about 28 agencies engaged in agricultural research in Kenya. These agencies employ a total of 833 full-time equivalent (FTE) researchers and in 1999 spent a combined 3 billion Kenyan shillings on agricultural R&D, equivalent to US$ 135 million at 1993 international prices. KARI accounts for more than half of both total research spending and agricultural researcher numbers. KARI's mandate covers a broad spectrum of agricultural research and includes all crops except tea, coffee, and sugarcane; all livestock and veterinary research; and natural resources and socioeconomics. However, it excludes forestry and fisheries. KARI's research activities are organized into programs by commodities and factors, and its infrastructure consists of a headquarters in Nairobi, more than 21 main centers, and several subcenters covering all agroecological zones in the country.

Four other government agencies conduct agricultural research in Kenya, accounting for 17 and 21 percent of the total financial and human resources respectively. The larger of these are the Kenya Forestry Research Institute (KEFRI) and KEMFRI, employing about 90 and 79 FTE researchers respectively. KEFRI is headquartered in Muguga in Central Province and has a network of 17 research centers spread across the country's agroecological zones. KEFRI conducts research on farm forestry, natural forests, dryland forestry, and forestry plantations. KEMFRI comprises a headquarters in Mombasa, a research center in Kisumu on Lake Victoria, and five research stations. Its mandate covers marine and freshwater fisheries. KIRDI employs about six FTE scientists involved in agricultural research. Kenya's three nonprofit research institutions, the Coffee Research Foundation, the Tea Research Foundation, and the Sugar Research Foundation, accounted for 9 percent of total agricultural R&D spending in 2000.

Kenya has a comparatively large number of higher education agencies involved in agricultural research. By 2000, the 18 higher education agencies accounted for about 17 percent of total financial and human resources in agricultural research. The University of Nairobi's Faculty of Agriculture and Faculty of Veterinary Medicine were responsible for half of these activities, employing 275 faculty staff or — adjusted to reflect time spent on research — 69 FTE research staff. Both faculties have research projects conducted by individual researchers, specifically postgraduate students. Egerton University's Faculty of Agriculture and the Jomo Kenyatta

University of Agriculture and Technology (JKUAT) employed 26 and 12 FTE researchers respectively. The remaining 14 higher education agencies in our sample undertake only limited research, employing between 1 and 5 FTE agricultural researchers each.

Two national companies — the Oserian Development Company and the Kenya Seed Company — are involved in agricultural research. In addition, one multinational company, Del Monte, has a local research program in Kenya. The share of private for-profit companies in Kenyan agricultural R&D spending is about 3 percent.

There is a fair amount of collaboration among the various Kenyan agricultural research agencies, as well as collaboration with regional and international agencies. KARI, for example, conducts some projects jointly with a number of Kenyan universities and has numerous collaborative projects with the private sector, investor organizations, and the international agricultural research centers.

Human and financial resources

During the period 1971–91 the total number of public agricultural researchers increased by 6 percent per year, though an average negative growth rate of 2 percent has persisted since then. This decline was the result of a contraction in total FTE researcher numbers at KARI, KEFRI, and KEMFRI. Total FTE researcher numbers in the higher education sector have increased considerably over the past three decades, though this growth seems to have tapered off in recent years. During the 1990s, total FTE researcher numbers at the 18 higher education agencies in our sample increased by 3 percent per year, considerably lower than the 15 percent annual growth rate recorded during 1971–81. The expatriate share of total research staff consistently declined, from about 50 percent in the early 1970s, to 8 percent by 1991, and most recently to 2 percent.

About 85 percent of the FTE researchers have postgraduate-level training, with over a quarter holding doctorate degrees. Development of research staff to the PhD level was slow in the 1980s but by 2000 this share had tripled to 27 percent of total research staff as a result of KARI's first training plan to upgrade staff qualifications.

By 2000 about 20 percent of all FTE researchers were female, including 17 percent of researchers holding doctorate degrees and 26 percent of researchers trained to BSc level.

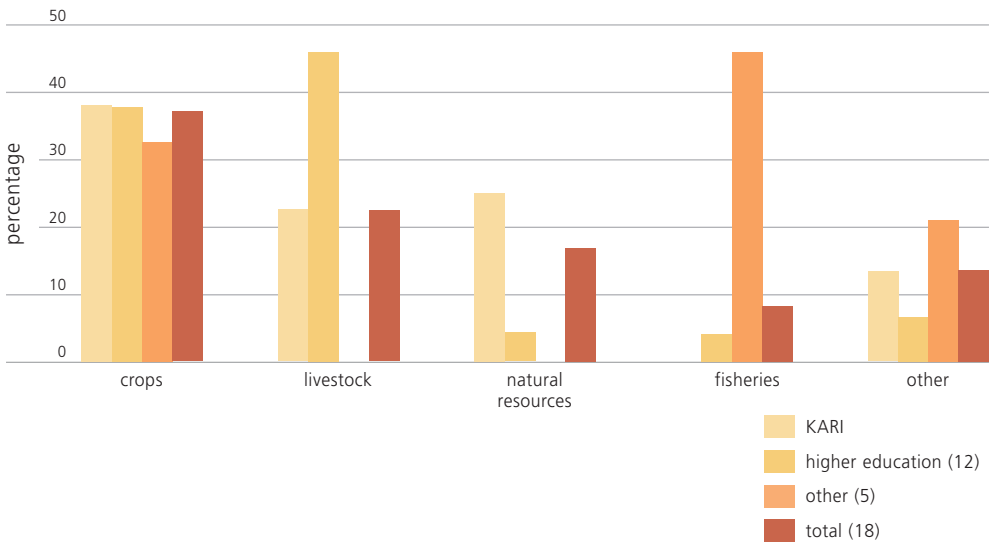
Total public spending as a percentage of agricultural gross domestic product (AgGDP) is a common research investment indicator that helps to place a country's agricultural R&D spending in an internationally comparable context. By 2000, Kenya invested US$ 2.55 for every US$ 100 of agricultural output, which was close to the 1995 ratio for the developed world. This is also considerably higher than the country's ratio five years earlier (1.89 percent) but was actually the result of declining real AgGDP, not increased investment. The 1995 intensity ratio was also high relative to the average ratio for Africa or the developing world (0.85 and 0.62 percent respectively).

Over the last 10 years total salaries have averaged only 41 percent of all spending, while operational costs have accounted for more than 50 percent. This is in contrast to the late 1980s, when the situation was reversed.

Research orientation and outputs

The allocation of resources across various lines of research is a significant policy decision (Figure 1). By 2000, more than one-third of the FTE researchers conducted crop research. Livestock and natural resources accounted for 22 and 17 percent respectively, while 9 percent of FTE researchers focused on fisheries research. KARI researchers spent relatively more time on natural resources (25 percent), while the researchers at the 12 higher education agencies combined spent more time on livestock research (46 percent). Only KARI and a few higher education agencies conducted livestock research; more than one-third of those were working on dairy, while one-fifth were working on beef. Other important livestock items were pastures and forages (10 percent) and sheep and goats (9 percent).

FIGURE 1. Commodity focus: FTE researchers by major program



Currently, 11 percent of the total researchers at KARI are working on crop genetic improvement, while 5 percent are working on pest and disease control (Table 1). The corresponding shares for the other agencies were considerably higher (24 and 23 percent respectively). The remainder of KARI researchers were focused on a wide variety of themes including other crops, livestock, soil, water, and socioeconomics.

TABLE 1. Thematic focus

Theme	Numbers of FTE researchers		Shares (%)	
	KARI	Other	KARI	Other
Crop genetic improvement	52.2	12.8	11.1	24.1
Crop pest and disease control	24.9	12.3	5.3	23.3
Other crop	49.4	10.8	10.5	20.5
Livestock genetic improvement	17.9	0.0	3.8	0.0
Livestock pest and disease control	24.9	0.0	5.3	0.0
Other livestock	44.2	0.0	9.4	0.0
Soil	47.9	1.4	10.2	2.6
Water	24.9	1.4	5.3	2.6
Other natural resources	9.9	0.0	2.1	0.0
Postharvest	9.9	4.8	2.1	9.0
Other	164.0	9.5	34.9	17.9
Total	470.0	52.9	100.0	100.0

Research output has increased tremendously over the last decade. For example, in the case of KARI the number of varieties of crops such as maize and wheat released in the last five years is more than five times the number released in the early 1990s (Table 2). Similarly, the number of vaccines and diagnostic kits released has trebled. It was not until the early 1990s that KARI started undertaking research and releasing varieties of potatoes and grain legumes. At about the same time KARI started taking a serious interest in research into flowers, and it has since evaluated and introduced several varieties.

TABLE 2. Varieties and vaccines/kits released by KARI over time

Varieties and vaccines/kits	Year/units		
	1985–1990	1991–1995	1996–2002
Maize	2	2	18
Sorghum/millet	1	3	16
Wheat	3	6	9
Potato	0	2	4
Grain legumes	0	7	25
Flowers	0	16	42
Sweet potato	0	0	6
Vaccines/kits	3	5	10

Voices from the field

The Annual General Meeting of the Members and stakeholders of the CGIAR in Nairobi in 2003 presents an excellent opportunity to hear from the farmers and researchers who work each day on the critical issues that agricultural research is addressing. Six field trips were designed by the local organizing committee of the AGM to highlight examples of the work now being done by the CGIAR-supported Centers and their partners.

The following field reports provide context for each field trip and an evocative description of the reality with which we work. We hope you find these stories a valuable addition to the more formal discussions of the AGM and that these views from the field offer fresh incentive to redouble our efforts to boost agriculture and reduce poverty.

Decades of agricultural intensification, unpredictable climatic events such as El Niño and prolonged droughts, the imposition of urban sprawl on formerly productive agricultural lands, increasing soil erosion and declining soil fertility, and livestock, crop, and human disease epidemics strain both agricultural and human resilience on the continent.

For three decades, Kenya's agricultural research institutions have worked in partnership with the CGIAR to harness the technologies generated by agricultural research for the benefit of resource-poor farmers.

No single organization can meet the challenges that Kenya and the rest of the continent are facing. Enduring partnerships with longstanding agricultural organizations and new alliances with innovative NGOs and the private sector, in Africa and around the globe, are imperative to meet the needs of the African farmer.

The following field reports show that agricultural technologies derived from Kenya-CGIAR-partner research initiatives have made substantial impacts in Kenya. The farmers, field workers, and scientists interviewed in these stories tell of the challenges they face and the successes they have achieved. The task that remains is daunting, but the challenge is one that can be met through continued research.

The aim now is to scale that research up and out to reach every poor farming community in Kenya and the African continent.

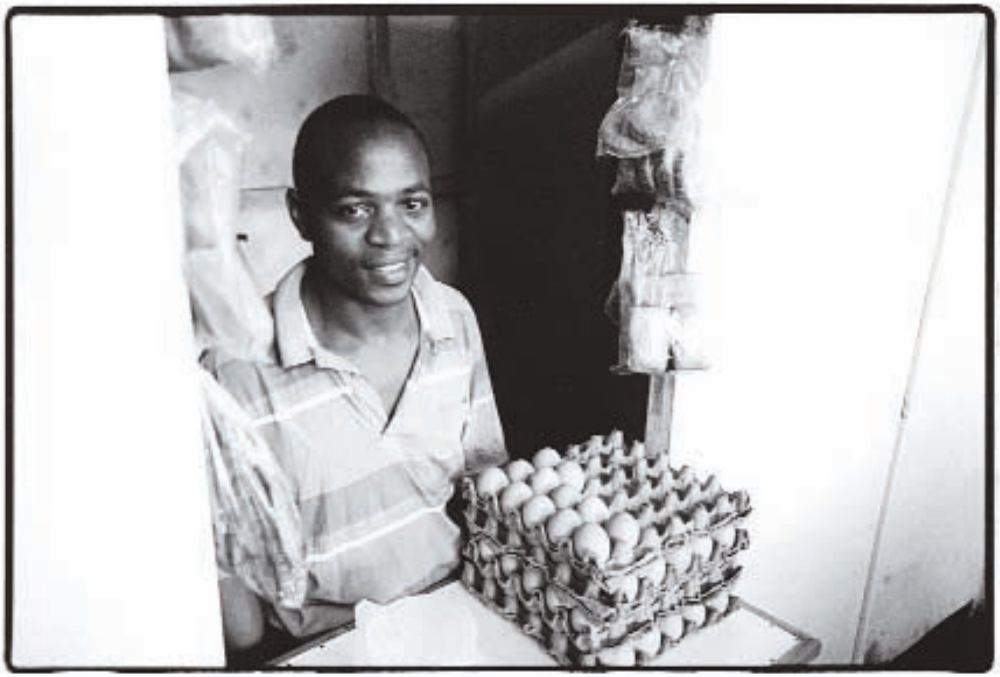
Small-scale urban dairy producers supply
a large proportion of the milk marketed in Kenya.

NAIROBI

The challenges of urban and peri-urban agriculture

At a crowded junction along the road from Nairobi to Garissa, Hannah Kamau and Virginia Wamaitha chase after the buses, selling milk. Their customers hang from the windows, engulfed in diesel fumes. These two middle-aged ladies have been selling milk at the bus stops for five years to supplement their income, which comes mainly from growing and selling vegetables. They collect milk before dawn at four dairy farms in the Thika district and take it by matatu — Kenya's informal minibus transport — and then by boda-boda, a passenger bicycle, to the roadside before the buses roll. Hannah's having a bad morning — only 20 liters sold today. She buys 1 liter at 18 Kenyan shillings and sells it for 20. Today she's made about US$ 0.50.

Virginia, having done much better, has sold 100 liters, which she bought at 17 shillings and sold at 20. It's a lot of hard work for 300 shillings, about US$ 3.80. Both women lose about 100 shillings of that in transport to the market. They sell from six-thirty in the morning and are finished by ten, when they go back home and take care of the household and their small farms. Both women are trying to put kids through school. Between them Virginia and Hannah have dozens of plastic jerry cans to carry their milk and they share one of the new more hygienic aluminum milk containers, designed by a CGIAR partnership with local traders and researchers and produced by a local manufacturer. But at a cost of almost 2,000 shillings, they can't afford more than one. The new cans cost 1,850 shillings to manufacture. "They are worth having," she says. "It's good for transport, no spilling." Over the five years they've been doing this they have become good friends. They make an average of 250 shillings a day and for them it is good supplementary income — more than the minimum daily wage in Kenya.



Peter Karanja graduated from milk hawker to milk bar operator, but struggles with overheads.

The dairy boom

Traditional dairy markets, which handle unpasteurized or "raw" milk, and traditionally processed dairy products such as fermented milk, are behind the dairy boom in many developing countries. In Kenya, where the per capita consumption of milk totals some 100 kilograms annually, traditional milk markets supply over 80 percent of the milk sold. Compared to their commercial counterparts, small-scale dairy agents like Virginia and Hannah provide cheaper milk to consumers while paying better prices to producers. Despite this, public officials concerned about the possible health risks of consuming unpasteurized milk have in the past discouraged the country's indigenous milk markets. Today, Kenya's dairy development authorities urgently need more reliable information to make judicious pro-poor policies.

The Smallholder Dairy Project (SDP), led by the Ministry of Livestock and Fisheries Development in collaboration with the CGIAR and the Kenya Agricultural Research Institute (KARI), has undertaken a series of risk analyses needed to safeguard both public health and dairy livelihoods. The SDP is a partnership involving a number of Kenyan organizations including the Kenya Dairy Board, Nairobi and Egerton universities, Land O'Lakes, the Kenya Medical Research Institute, and the Kenya Ministry of Health. These institutions together provided the diverse partnership between researchers of different disciplines, policymakers, and regulators the project needed to analyze the risks to the poor posed by alternative dairy policies, and to test alternative policy options.

In national consultations in 2001, a wide spectrum of stakeholders supported the project's policy recommendations, thereby increasing the base of support for milk marketing by and for the poor. These recommendations provide more "carrots" (licensing, training) than "sticks" (policing) to small-scale operators. A new Dairy Development Policy and a revised Dairy Bill now explicitly recognize the predominance of the raw milk trade in Kenya, its importance to the poor, and the need for regulations and technologies to optimize the quality of raw milk. But while these changes are beginning at government level, the policies may take years to filter down to the Garissa road intersection where the milk hawkers work. They are still unlicensed and can still feel harassed by milk regulators.

"If they were licensed, they could sell the milk legally, without fear," says John Kutwa, a research technician with the CGIAR and the SDP. "Now, any time, they can be pushed off." And when you are making a run for it from the authorities, the plastic jerry cans John is trying to retire from service are a lot lighter than the new aluminum ones.

In a slight twist of circumstances Peter Karanja, a young milk hawker, reacted to these regulatory constraints by choosing instead an entrepreneurial path and opening a proper milk bar. His customers are assured of receiving hygienic milk and he also sells a yogurt-like, fermented milk product. But while he makes 500 shillings a day from his small store, his rent is 6,500 shillings a month with electricity and water. So more than 200 of those 500 shillings he earns each day go to overheads. "It's like I'm almost getting nothing," he says. "I earned more on the street." His story drives home the need for the new policy initiatives to be implemented in order for the poor to progress. The urban dairy market is still large and unregulated. The new policies could result in farmers being able to sell more milk for higher prices and achieve more stable livelihoods.

City vegetables

The Wakulima market, in the center of Nairobi, opens at five in the morning and is empty by noon. Nobody knows how much of the produce sold here is grown in and around the city. The mud and muck underfoot is at least 8 centimeters deep and smells of sewage. Behind the gates, bananas, potatoes, pineapples, sukuma wiki — a popular African leafy vegetable — tomatoes, lemons, and oranges are all for sale. It should be, but is not, an appetizing sight. Rather it is dirty and tumultuous, with hawkers yelling and pushcarts being cumbersomely shoved around. "About a third of these farmers use raw sewage for irrigation," says John. He knows where many of the vegetables come from.

As far as contamination from human waste is concerned, experts point out that the main health risk is to the farmers, unless consumers eat the vegetables uncooked or the fruits with the skins on. But there is far more risk from toxic contamination in towns. Industries, petrol stations, garages, and workshops discharge chemicals into the wastewater as well. Currently

the CGIAR is supporting a multi-stakeholder health impact analysis of urban agriculture in Kampala, Uganda. The results should help urban planners and farmers in many cities.

In Kahawa Soweto village in Kasarani, 21 kilometers west of Nairobi, there are around 5,000 inhabitants, with about half of the adult population involved in agriculture. Nearly a quarter of this agricultural production involves growing crops. Vegetable growing is preferred, as the market is good and the money better. Many sell direct to their neighbors in the slums. Crops are grown along the railway line that cuts through the slum, and by the River Kiuu, which is fed by more than four sewage drainage systems. Sewage water irrigation is carried out mainly around the three sewage-stabilizing ponds at the extreme south side of the village. Although a 2002 municipal council control program attempted to terminate the practice, vegetable growing is still the major form of crop farming in this "irrigated" agricultural system. Urban farmers in the area are able to farm because they have access to free land nearby, and on a recent visit, they were still irrigating their crops with sewage water diverted from an obviously hand-punctured sewer pipe. None would comment on where their water came from, but the crops visible from the high point in the slums were plentiful. The local farmers call this sewage-farming irrigation "night water".

On a brighter note, Soweto is cleaner than most slums in and around the city. There is an organized community-based waste management group called Soweto Youth in Action, which charges 20 shillings per household per bag of waste collected each week. On a free public piece of land in the village, the group sorts the household waste and composts the organic

component, adding manure to enrich it on the advice of KARI. Youth in Action has been giving this organic material free to local vegetable farmers, but now they hope to grow amaranth as a commercial crop with the enriched compost. With the help of the city council, some of the inorganic component is taken to another city dumpsite. The group's activities are boosted by a high literacy level among the members, the readiness of the members to provide manual labor, and the availability of tools like wheelbarrows which were bought using investor funds.

Soweto is also home to livestock farmers, who tend cattle, pigs, goats, sheep, ducks, chickens, and rabbits. Cattle are plentiful and much desired, as they produce manure useful in farming and milk for sale and for home consumption. Most of the livestock farmers practice zero-grazing in 6-meter-square enclosures that double as home and hearth to the farmers as well. The animals produce huge amounts of manure for composting, yet nearly two-thirds of the total manure produced in the village is dumped in public places — behind the village — and large heaps can be found piled around Soweto. Only 35 percent of the manure produced in the village is used for crop production. CGIAR input should help change this, as the reuse of nutrients in farming becomes more efficient and farmers can sell more easily — and safely.

These urban farmers will, within two decades, constitute the majority of farmers in Africa. Half the world's population now lives in towns or cities, and by 2020 this figure is expected to rise to 60 percent. The developing world will absorb most of the additional 1.5 billion urban dwellers. In Africa alone 50 percent of the population will move to cities. Already these trends are having severe effects on food security, poverty levels, and unemployment.

Hands from two generations that are sensitive to the health threat posed by vegetables grown in unhygienic conditions.

A need for more CGIAR research

There is a need for an integrated agricultural research response to this urban crisis. The growing importance of backyard crops and livestock farming for self-consumption among poor urban families calls for more research support. There are also increasing opportunities for research on small-scale commercial urban agriculture, as growth in the number of urban consumers boosts the demand for perishable, high-value agricultural products such as dairy produce, meat, and leafy vegetables. On the other hand, the potential contribution that urban agriculture can make to improving the urban environment (for example, through nutrient recycling of organic wastes) needs to be explored in more detail. The CGIAR's Systemwide initiative in urban and peri-urban agriculture — Urban Harvest — is making a concerted effort at the international level to directly address urban food and agriculture issues.

In and around Nairobi, Urban Harvest is working on improving the management of organic wastes and livestock manure to increase agricultural productivity. Urban Harvest scientists, in partnership with KARI and the NGO Greentowns, are working with slum dwellers like those in Soweto to identify opportunities to reduce the negative environmental impact of urban and peri-urban agriculture and accentuate its positive contributions, seeking to establish the perception of urban and peri-urban agriculture as a productive, essential component of sustainable cities.

Urban Harvest is working to help local governments and agricultural advisers formulate policies that protect against the health risks involved in dealing with urban waste — the nutrient recycling and sewer water use in growing crops in urban areas — so that the poor are able to sustain their livelihoods and the crops they sell pose fewer health risks. One very important aspect of the research being done is enabling farmers to understand and manage the health risks associated with reuse of wastewater, which will help ensure better quality products and more secure livelihoods.

As urban and peri-urban agriculture grows, so does the need for seed and seedlings. A drive along almost any major road in Nairobi reveals a high trade in roadside tree and plant nurseries. But CGIAR tree domestication specialists have found information exchange lacking between farmers in the nursery trade. Through a CGIAR-sponsored information exchange program, farmers are being encouraged to visit each other's nurseries and exchange information and ideas. In Nairobi's peri-urban area, a group called the Tree Nursery Operator's Self-Help Group has been holding exchange visits once a month. Concerned by the loss of forest cover in Kenya, the group, with 25 members from five districts, plans to visit and plant trees in these districts as a way of spreading the message to other farmers.

In the relative pastoral comfort of Kikuyu, a district less than 20 kilometers northwest of Nairobi, Geoffrey Njogu and his wife Minneh Wambui live with their three dairy cows in a more spacious landscape of 0.6 hectare, which is only occasionally thrown into chaos as the Nairobi-bound passenger train rattles through, shaking their small rooms and cattle shelter. Despite the relative space compared to Soweto, the cows are still zero-grazing. While the couple raise vegetables, and napier grass to feed their cows, they attribute their success to the animals, which provide milk and manure. The cows produce about 7 liters of milk a day: 1.5 liters are consumed by the household, and the rest is sold. Manure is removed from the pen every day, left to decompose, and then applied to the crops. The Njogus consider dairy the most profitable farm enterprise, the proceeds enabling them to buy a water tank and, over time, to build five small houses which rent for 800 shillings a month. The Njogus are illustrative of peri-urban agriculture when it works well.

Winneh Wambui is 53 and a large, gregarious woman with a smile that is contagious to all but the most resolute of strangers. She shovels, with her large hands, piles of charcoal, also produced on-farm for sale to her tenants. She smiles broadly as she does so, not minding the ash that covers her hands and dress, and brags that she has not had to worry about school fees for the last six years, thanks to her cows. "Cows are everything. But I don't like the ones I've got," she admits. "I hear they've got great cows in the United States. Maybe next time you visit, you'll bring me one!" she laughs. "Or better yet, I'll come get it myself!"

Feeding a cow tree fodder in a zero-grazing unit.

“I’m going to be a teacher one day.”
Selena Otieno, 13

KENYA

Harnessing biotechnology for food security

"Those who reject biotechnology do so on full stomachs."
Dr Romano M. Kiome, Director, Kenya Agricultural Research Institute (KARI)

"There is nothing worse than watching one of my animals die," says Akwala Solonka, a proud Maasai woman who has been caring for livestock as a pastoralist for most of her adult life. "You can tell when they are sick. If I have no money for medicines, I just have to watch a cow suffer and die. It hurts."

Demand for meat and milk in developing countries is expected to double in the next 20 years. Yet disease — usually vector-borne — threatens this predicted "Livestock Revolution". East Coast fever (ECF) kills 1.1 million animals a year in 11 countries of East, Central, and Southern Africa. Of the estimated 13.4 million head of cattle in Kenya, 76 percent are at risk from ECF. Rift Valley fever (RVF) and contagious caprine pleuropneumonia (CCPP), two other killers, come in wavelike epidemics, and while they claim far fewer victims than ECF, even a small outbreak is enough to shut down exports from a country. For subsistence food producers like Akwala Solonka, the death of just a single milking cow has large and sometimes tragic consequences.

Africa's crop production per unit area of land is the lowest in the world. Just as livestock are imperiled by disease, the staple food crops of Africa, such as maize, sweet potato, and banana, are similarly endangered by diseases, pests, and climate-related scourges such as droughts and floods. The average maize yield in Africa is about 1.7 tons per hectare, compared with a global average of 4 tons. With a burgeoning population threatening to double in the next 20 years, many believe Africa needs the kind of help agricultural research and biotechnology can provide.

Biotechnology to save livestock

Scientists from KARI and the CGIAR are employing biotechnology with great success in battling ECF, RVF, and CCPP. For two decades, the CGIAR and partner organizations have been studying the way a cow's immune system responds to the parasite that causes ECF. It took two years for the scientists of a CGIAR Center, along with partners from The Institute for Genomic Research (TIGR) in the United States, to decipher the entire genetic code of the parasite that transmits ECF, a remarkable scientific accomplishment in its own right. With this genetic blueprint, scientists were quickly able to identify the antigenic molecules of the parasite most likely to provoke the cow's immune system to attack the parasite.

The researchers are now working with a pharmaceutical company to test these high-potential vaccine candidate antigens in cattle. If successful, they will develop an improved "sub-unit" vaccine against ECF, which is built on parasite components rather than whole live (but weakened) parasites.

The immunization now used to control ECF is called the infection and treatment method (ITM). This method involves infecting cattle with the live ECF parasite and simultaneously treating the animals with a drug to stop development of the disease. The immunized animals are thereafter protected from disease caused by the same infecting organism. The ITM of ECF immunization is distributed in the form of parasite stabilate, which is stored in straws or tubes (usually containing 10–30 doses) of the vaccine diluent, and a dose of long-acting oxytetracycline (OTC). The stabilate must be maintained in very cold temperatures (for example in liquid nitrogen) for the parasite to remain viable, and the diluent stored at –20°C until immediately before use.

The cost of producing the live vaccine for the ITM has been estimated to be between US$ 0.50 and US$ 2.00 per dose. The largest component of the overall immunization cost is delivery of the vaccine. Current prices charged for ITM immunization in Kenya, Uganda, and Tanzania are already considered high, ranging from US$ 6 to US$ 20.

Country immunization records show that in Kenya, Malawi, Rwanda, Tanzania, Uganda, and Zambia an estimated 319,652 cattle have so far been immunized, compared to the current estimated population of 38 million cattle.

Ticks that feed on cattle carry the parasite that transmits ECF. A spray for killing ticks exists but it is expensive and its continual use can lead to tick resistance to the treatment. The spray can also leave toxic residues in milk and meat that are unhealthy for humans.

"There's great demand for the ITM," says Evans Taracha, a CGIAR scientist who heads the vaccine development project, "so adoption of a new cheaper sub-unit vaccine should be high." This vaccine, he says, "should have widespread impacts on reducing poverty in sub-Saharan Africa." Taracha says that the lessons learned in the cattle vaccine trials are likely to provide insights that will assist research on human scourges such as tuberculosis, malaria, and HIV/AIDS, which together kill 5 million people a year, most of them in poor countries.

Rift Valley fever is a disease of cattle, sheep, goats, camels, and other ruminants. It also affects humans. The mosquito-borne parasite is responsible for up to 100 percent of abortions in pregnant animals and 80 percent mortality in young stock. A vaccine in current use to control the disease causes both abortions and deformities of fetuses in vaccinated animals. No test for rapid diagnosis of the disease exists, but researchers at KARI's biotechnology laboratory, along with partners from Washington State University, have developed a technique, effective under confined laboratory trials, that enables rapid mass screening of animal blood and should make possible prompt diagnosis of the disease.

Research technician with a vial of well-fed ticks used to make a vaccine against livestock disease.

KARI is also working on diagnostic tools to detect CCPP more rapidly. The disease, which causes fever, coughing, and severe respiratory distress in goats, is caused by mycoplasma. Its morbidity rates are high. The disease is currently diagnosed by clinical signs and an assay, which is difficult to perform and requires highly trained technicians. The organism itself is difficult to isolate. KARI scientists have developed a rapid and effective diagnostic, called a latex agglutination test (LAT), which is undergoing field evaluation and validation and could be ready for commercial production within the year. The test will require only one drop of blood or serum from an affected animal to perform diagnosis and will take only a few minutes to perform. More importantly, diagnosis can be made before an animal is actually taken ill by the disease, leading to timely vaccination and early treatment and disease control.

Scientists know that by decoding the information stored in the genomes of tropical parasites of livestock, they are coming within an evolutionary hair's-breadth of finding new approaches to human disease. Popular expectation that the money invested in medical and veterinary research will lead to disease cures is justified, having been fulfilled historically time and time again. For people living in temperate climates, where there is good veterinary care and plenty of animal feed, it is difficult to appreciate the impact of livestock diseases and poor animal nutrition on the rural communities of the tropics. But with the human-animal disease interface growing ever larger, it may be possible to bring to world attention the animal disease work being done in the developing world.

New maize varieties to defeat the stem borer

In Kenya it is said "Without maize, there is no food." Kenyan smallholder farmers depend on the maize they produce to feed their families and earn a meager income. A host of factors threaten their harvest, including drought, low soil fertility, diseases, and pests, particularly the stem borer, which is capable of destroying entire maize fields when infestation is severe. Stem borers destroy more than 15 percent (estimated value US$ 72 million) of Kenya's maize crop annually. Several insecticides widely used against stem borers have been pulled off the market due to safety concerns.

The severity of the problem has been known for years, and in 1999 KARI and the CGIAR joined forces with the Syngenta Foundation for Sustainable Agriculture to form the Insect-Resistant Maize for Africa (IRMA) project. IRMA's goal is to deliver insect resistance for maize in a form familiar to farmers — the seed they plant.

As a young boy, IRMA researcher Stephen Mugo worked in his father's small maize plot on the southern slopes of Mount Kenya. He witnessed firsthand the damage stem borers could cause to an entire maize crop. "The stem borers would hit the crop around knee-high stage, inflicting damage that would mean very little yield. At harvest, we had to stoop to recover plants that had lodged on the ground, and the maize would often be rotten," he says. Thirty years on, Mugo is still fighting the stem borer. But now he has something to fight it with.

IRMA is basing its research on host plant resistance, both in the development of maize with conventional resistance and through the development of transgenic varieties with *Bacillus thuringiensis* (Bt) genes, which have proven effective against the Kenyan stem borer. Bt is a naturally occurring soil bacterium, which produces proteins that are lethal to many borers. There are no known negative effects on human or animal health, and organic farmers in many parts of the world use Bt in spray form. Synthetic versions of Bt genes have been inserted into tropical maize. The Kenya Biosafety Committee, having closely examined the technology, has approved the introduction of seeds of these new lines into Kenya, which opens the possibility of crossing them with local varieties to develop new resistant varieties suited to Kenyan conditions.

The new varieties have shown resistance to several types of stem borers found in Kenya. Because insect populations evolve to withstand both conventional and transgenic pesticides, measures must be taken to extend maize plant resistance. The IRMA approach is to "stack" or "pyramid" a number of Bt genes together with conventional resistance mechanisms to make it that much harder for stem borers to evolve an effective response. Considerable effort has also been directed toward examining insect and plant ecologies in maize cropping systems. This will help ensure that the technology will not be harmful to beneficial insects and the environment, and that appropriate refugia are available to counter the emergence of Bt-resistant stem borers. To further address potential environmental and consumer health concerns, scientists have developed gene constructs devoid of herbicide or antibiotic gene markers. Maize varieties produced by the IRMA project will carry only "clean" or "purified" Bt genes. While this approach costs more and takes longer, the researchers are committed to addressing all reasonable issues that emerge regarding this technology.

Tissue culture bananas create new markets and new lives

"When I used to plant traditional bananas it was a risky thing," says Paul Kariuki of Maragua District, near Thika. "It took two years to get the fruit after initial planting, and that only happened if the tree didn't fall down first. I never really got enough good bananas to sell."

Over the last two decades, banana production in Kenya and the rest of East Africa has been on the decline, in part due to the lack of clean planting material. Traditional methods of banana propagation perpetuated the problem of diseases and pests. Bananas became costly, and could no longer serve as a ready supply of highly nutritious food. As a cash crop, its

productivity was waning rapidly. Tissue culture, because it involves the production of fresh materials under sterile conditions in the laboratory, breaks the cycle of infestation, avoiding pests altogether and reducing the likelihood that diseases will be present. The use of juvenile tissues and the "hormonal kick" in the culture media are further sources of plant vigor. When improved varieties are propagated, the process of tissue culture combines the genetic benefits of these varieties with freedom from disease. The use of these plants can transform a smallholder's banana orchard from something that barely meets subsistence needs into a vital enterprise that increases incomes and provides livelihood opportunities.

KARI, along with Jomo Kenyatta University of Agriculture and Technology (JKUAT) and the International Service for the Acquisition of Agri-biotech Applications (ISAAA), has been involved in different stages of the tissue culture development. Commercial production of tissue culture banana with a capacity of up to 1 million seedlings per year has been established in addition to on-farm trials in orchard management. To date, commercial production is in progress and KARI has distributed more than 10,000 plantlets to self-help and women's groups. JKUAT, meanwhile, working with commercial distributors, has released between 500,000 and 600,000 plantlets.

"I can see us creating an international market for these bananas in the not-so-distant future," says Ben Chege, a research officer with KARI. "We are already seeing a liberation in the banana industry, with whole estates producing for market. For the smallholder, it means a whole new way to survive and make a profit." ISAAA also has a microcredit scheme for dissemination of tissue culture banana to smallholder farmers.

"My family used to go without. Without food. Without the things we needed to eat. Now, we have everything we need, including school fees. This tissue culture banana has meant everything to us," says Kariuki.

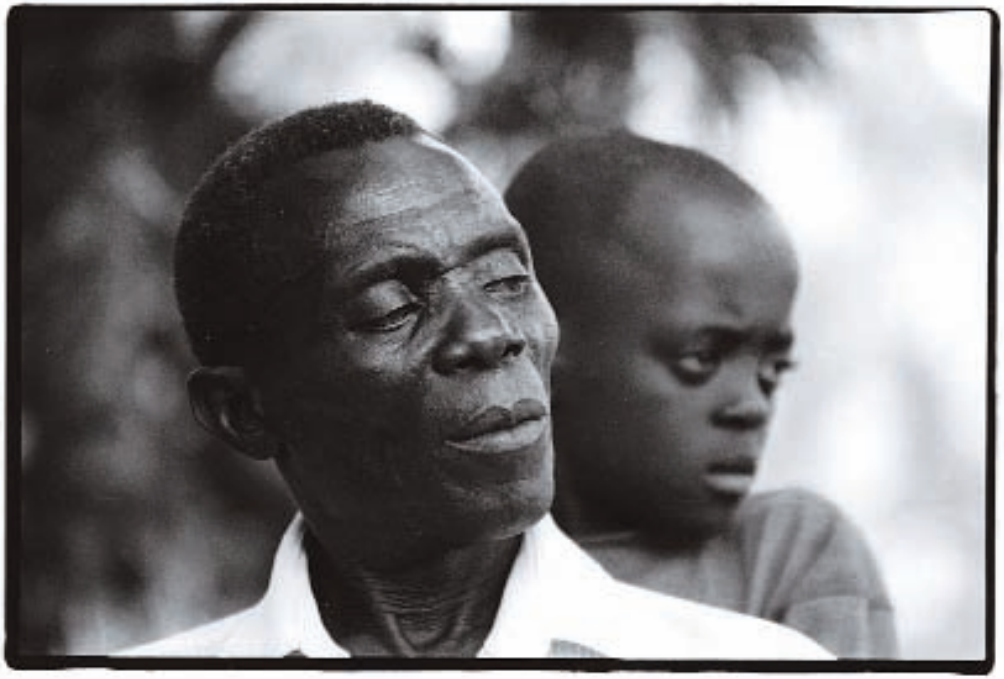
Sweet sweet potato

People in Africa rely on sweet potato as a staple food during good times, but they do so even more during bad times. Grown throughout sub-Saharan Africa, annual production in East and Central Africa has been marked at nearly 7 million tons. Although yield potential is thought to be in the order of 50 tons per hectare, the average yield in East Africa is only 4.17 tons per hectare, due to such factors such as poor soil fertility, virus diseases, and weevils.

Although viral diseases can often be responsible for up to 50 percent of sweet potato losses, weevils constitute the most important threat to productivity and sustainability of the crop — sometimes resulting in crop losses of from 60 to 100 percent. *Cylas formicarius, C. puncticollis,* and *C. brunneus* are the major weevil species widespread in sub-Saharan Africa.

The search for host resistance from sweet potato germplasm yielded no reliable result for either viral or weevil problem. Researchers from KARI and the CGIAR believe that the use of genetic transformation currently represents the most feasible means of achieving sustainable control under African farm conditions.

As with the maize stem borer, much of the search for resistance to the weevil is focusing on *Bacillus thuringiensis* (Bt), a bacterium widely used as a source of resistance to insects in many crops. Scientists are currently screening for a Bt strain effective against the weevil, and collaborative projects are under development to bring this work to Kenya and the region.



Looking to the future: Boaz Okwela has rejuvenated his farm with new techniques and crops and hopes his son Edwin will follow in his footsteps.

KARI and CGIAR scientists are also working together to find resistance in sweet potato to control sweet potato feathery mottle virus. The project has been collaboratively carried out with Monsanto and the Danforth Plant Science Center in the United States, the Agricultural Research Council and the Roodeplaat Vegetable and Ornamental Plant Institute of South Africa, the US Agency for International Development (USAID), the Mid-American Consortium, and ISAAA.

The protocol for transformation and regeneration of a sweet potato variety (CPT 560) was developed and refined at Monsanto, and mock trails were carried out alongside other local varieties in Kenya. The first round of restricted field trials was carried out in 2001 and 2002 at four KARI centers and involved 12 transgenic lines of sweet potato variety. The work is still at the experimental stage but there is great optimism for a biotechnological solution to sweet potato diseases and pests.

Monsanto research notwithstanding, the sweet potato has received relatively little attention from the private sector. The problem lies in the noncommercial value of the crop and the lack of funding for research in subsistence crops. That biotechnology generally has yet to make great strides with sweet potato underscores the need for developing-world public biotech research institutions to fund and conduct research on "orphan" crops of importance to poor populations in these countries.

Jeffrey Sachs, the director of Columbia University's Earth Institute and special adviser to United Nations Secretary-General Kofi A. Annan as Task Force Coordinator of the Millennium Development Goals on Poverty and Economic Development, puts it this way: "If it were true that the poor were just like the rich but with less money, the global situation would be vastly easier than it is. As it happens, the poor live in different ecological zones, face different health conditions, and must overcome agronomic limitations that are very different from those of rich countries."

"All the rich-country research on rich-country ailments, such as cardiovascular diseases and cancer, will not solve the problems of malaria," says Sachs. "Nor will the biotechnology advances for temperate zone crops easily transfer to the conditions of tropical agriculture. To address the special conditions of the developing world, we must first understand its unique problems, and then use our ingenuity and cooperative spirit to create new methods of overcoming them."

Farmers such as Jason Seko, who grows bananas (background), are benefiting from tissue-culture propagation of the crop.

"God made this land for farming.
What else am I going to do with it?"
Katuki Kilonzo

MACHAKOS

Harvesting water for survival

Machakos District, about 75 kilometers southeast of Nairobi, was supposed to be the capital of Kenya. "And then they built the railway line up here and found there was no water," says Chin Ong, CGIAR plant physiologist and hydrologist. "So those who wanted water stayed in Nairobi, and Machakos became populated by cattle ranchers." That led to high animal populations and land degradation. Eventually Machakos, with its low annual bimodal rainfall — sometimes as little as 600 millimeters a year — became a degraded desert. In the 1930s observers predicted that the increasing human and livestock pressures here would result in the land becoming degraded to an irretrievable extent. From 1932 to 1989 the human population increased nearly 5.8 times, while livestock population increased 1.6 times. Yet, the disaster predicted in the 1930s did not happen.

Population growth can be a driving force for disaster or recovery. In the case of Machakos, population pressure led to agricultural intensification. Although farm size has grown smaller, signs of erosion, visible in the 1930s, are harder to find. Now there are trees, terraces, and productive crop and grazing land. Tree density has increased and agricultural productivity has increased tenfold, mainly due to the adoption of horticultural practices, and with it cash crops.

Increasing water productivity in rain-fed agriculture

Machakos proved to be a challenging testing ground for innovative technologies in rain-fed farming because of its drought-prone environment. Long-term annual mean rainfall is 740 millimeters, divided approximately equally between the two rainy seasons. The main crops are maize, cowpea, beans, and pigeon pea. The soils are well drained, friable (crumbly), contain moderate levels of organic matter, and are susceptible to erosion.

In such environments, agriculture can be surprisingly ineffective at making productive use of rainfall; in the Machakos area, for example, only 10–30 percent of the annual rainfall is actually captured for crop production. In theory, there appear to be no hydrological limitations to doubling, or in many instances even quadrupling, yields of staple food crops. Moreover, appropriate technologies and methodologies are available that will enhance soil and water productivity. So why are so many farmers still reluctant to adopt them?

Farmers' investment decisions are strongly influenced by their perceptions of risk. The risk of lower returns — or no returns at all — on the investment of limited resources in rain-fed, semi-arid farming is directly related to unreliable rainfall distribution. As long as farmers "live at the mercy of rainfall" one should not be surprised at the extremely low level of investment in fertilizers, in improved crop varieties, and in water-harvesting technologies. But in recent years, encouraging innovations are coming from investments in small-scale water harvesting, made collectively by farmers' groups and motivated by the opportunity to produce off-season vegetables and improved mangoes for export. These advances are made possible by the opportunity to increase water productivity in rain-fed agriculture; the key is harvesting rainwater that would otherwise be lost to agriculture as runoff and evaporation.

Water harvesting means survival, and then some

The Machakos story shows that the wise use of water harvesting and soil conservation innovations, which have in some areas resulted in a tenfold increase in land productivity, can save communities that nay-sayers have long been inclined to write off. Through soil and water conservation, minimum tillage, improved crop varieties, and agroforestry, Machakos is still going strong. The adoption of these practices requires additional labor, capital, and farming skills. Access to markets and external resources can provide the impetus required to stimulate growth and development. Over the years, exposure to technology and socio-economic opportunities has helped boost the productivity of the available land. External assistance — in the form of investor aid, as well as effective government and NGO programs — has been a big part of the success in this area. But one persistent problem remains: Machakos still suffers from a dearth of water.

Stella Kyalo and
Sarah Mulee Matuku
of the Kitie Self-Help
Group in Machakos.

The environmental conditions in Machakos are typical of a large part of sub-Saharan Africa, where population pressure and land degradation are increasing. The risks associated with such a variable climate are a major constraint on adoption of new production technologies that are required to improve the lives and livelihoods of a rural population dependent on agriculture. But new CGIAR rain prediction technologies are increasing the capabilities of farmers to select appropriate management options that help to maximize production and minimize risks. In a recent study of rainfall in Machakos, improved and more reliable seasonal weather forecasts and system simulation models have helped scientists predict climatic changes in rainfall, helping farmers prepare for the bad years as well as the good. Seasonal climate forecasts, when interpreted and presented in a way that can be used by farmers in making their crop management decisions, have the potential to reduce risk and increase productivity and profitability.

The new Machakos rainfall data provides a basis for farmers to make more appropriate management decisions, such as which crops to grow and cropping systems to use, and whether to invest in expensive inputs like fertilizers. For example, farmers can use higher plant populations, apply recommended doses of fertilizers, and during wet years adopt intercropping options that entail lower risk of crop failure. Adjustments like these have produced a doubling of yields during wet years, resulting in an attractive overall annual return on investment of as much as 35 percent.

Although crop production has increased, the threat of famine still hangs over the local population in Machakos. While rainfall prediction is of great help in preparation for bad years, without the intervention of CGIAR-generated water-harvesting techniques Machakos farmers would not be able to survive the dry season.

Water for diversification

"Before water harvesting, farmers used ditches to retain water. The water would be there for just a few weeks," says Ong. But new water-harvesting technologies allow farmers to have nearly year-round water for irrigation — an additional three to four months of extra water. Another revolution here is that, instead of depending on maize alone, pigeon pea is coming back into the landscape and enabling farmers to earn more money. The introduction of fruit trees, a move advised by tree domestication specialists, has tipped the balance in favor of farmers with fruit cash crops, providing much-needed income.

With the advent of these technologies and soil conservation techniques, farmers are making investments in their land as never before. "It's counterintuitive," says Ong, "that in a dryland area like this, people are willing to invest. But in Machakos, we are witnessing the most sustained effort in reviving soil conservation and agriculture anywhere in Africa. You've got multiple cropping going on even though the rainfall is so low," he says. "But fruit trees are suited to dryland conditions, and there are fewer pests when it's dry. Whereas a crop will fail, there is fruit growing here all the time."

Farms in Machakos are usually small. Much of the population is supported by high-value products. Farms are generally productive despite the shortage of water. With water harvesting, farmers are in essence "drought proofing" their operations. They are no longer totally dependent on maize. The international Centers working in the Machakos area are also helping to connect farmers with markets. For instance, the area now exports pigeon pea to India, a distant market that local farmers would never have considered without CGIAR intervention.

Water for reclamation

Peter Katumba Kiio's father was a farmer but he died young, before he could teach Peter anything about farming. Peter abandoned the farm he inherited and went to Nairobi looking for a job. He didn't find one. "I gave up hope," he says. In desperation, he returned to his Machakos farm. He worked for another farmer for a while and began to learn his trade there.

Nduge Ndinda, 9, of Machakos, wants to be a doctor.

Shortly after he returned to his own farm he met up with representatives of the Regional Land Management Unit (RELMA). They helped Peter introduce water harvesting on his farm.

Before Peter began water harvesting, he grew only maize and beans. "I used to get only four bags of maize per season, fetching 700 shillings per bag, and one bag of beans fetching 1,500 a bag," he says. Now he gets 10 bags of maize and 4 bags of beans. He's still not getting enough to supply his family year round, but he sees improvement and this spurs him on. "The future is in mangoes," he says.

Peter has made good use of RELMA's water-harvesting technologies and proudly shows off his 70-cubic-meter, plastic-lined, underground reservoir, which cost him about 25,000 Kenyan shillings to construct four years ago. The water it contains can get Peter and his family through three to four months during the dry season. He also has two spherical tanks which hold 15,000 liters each. Now he has turned his efforts toward building a third structure, a waterhole to catch the rain runoff from the road that passes his small farm. It will hold 200 cubic meters of water. When this is done, he figures he will be able to make it through the year without having to buy or fetch water from the local dam.

"I'm using the water for my tomatoes, my nursery, and my pawpaw trees. When I can afford it, I can hire labor," says Peter. But water is still the biggest issue in his life. For domestic use — washing and cooking — he still has to send one of his sons to a dam 2 kilometers away. The boy makes three trips a day to fetch a total of nine drums, which he hauls by wheelbarrow.

Peter augments his horticultural farming — bananas, tomatoes, pawpaws, mangoes, and citrus — with pigeon pea and grevillea trees for wood products. He also plants tobacco as an additional cash crop. He recently bought two cows that are now giving milk, and uses the manure for his crops. By selling milk and some of his crops he can make between 6,000 and 7,000 shillings a month from his farm. The cows provide whatever fertilizer inputs the farm requires.

But like all farmers in this part of Machakos, Peter is obsessed with rain and water. "I need more water. If I had the money I'd make a closer dam." But Peter is ever hopeful. "I love farming. If you go around here," he says, pointing proudly to his small plot, "you will see how much I love it. But water, water is the problem. Water is life; it is the secret to success."

Water for success

Sammy Mulwa is a farmer who has attained great success in Machakos. Mulwa is a walking, smiling, example of what can be achieved by water harvesting and judicious selection of cash crops. As he wanders around his 12-hectare farm, which he bought in 1996, he speaks proudly about having started out growing maize and beans, but soon realizing that the climate and soils here were best suited to fruit trees. He has nearly a hundred mango trees now, and also grows pawpaws, oranges, and tangerines. He grows onions, beans, and tomatoes, and has three cows for milk. He makes more than 10,000 shillings a month from his farm, after paying for inputs.

He's been able to harvest water by building a small dam and has an excavated pan that can hold 400 cubic meters of water, mostly from road runoff during the rains. This is enough to last him approximately three months when there is no rain. There is also a shallow well that supplies water throughout the year. Runoff from the homestead is collected into a filtration ditch below the house. Terracing the whole farm has helped capture rainwater and controls erosion. He'd like to build a masonry dam below the farm to harvest more water.

"Water harvesting has made all the difference here," says Sammy, but adds: "One thing never changes." Even though he is prepared for it when it comes, "It seems I am always waiting for rain."

But water is not everything

Yet in any given year there will be famine somewhere in this region. Here, when you talk about food security, you're talking about money — money to buy food when the grain crops fail. And even for some who harvest water, crops still fail.

Katuki Kilonzo is 60. Her farm, despite its spherical water tank, is not very successful. She is supported by the off-farm employment of family members. She came to this 4-hectare farm in 1975. She tries to plant maize, beans, and pigeon pea. She lives with eight adults and four children. "I can't feed them all, not for the whole year. I can only get enough food from this farm for six months a year." Often, she has to resort to feeding the young ones once a day — maize meal and pigeon pea. When she can, she tries to make sure they get two meals, but that is not always possible.

"Life has been a struggle. If I don't have money I have to kill a chicken or a goat to make ends meet." Despite having built a spherical tank and a well which holds 20,000 liters of fresh water, this only meets her domestic needs — cooking and washing — but not her irrigation needs. In a good year she can sell her maize and pigeon pea. But good years are few and far between.

Mrs. Kilonzo's expression darkens as she speaks of her life in Machakos. She looks down at the weeds encroaching on her land. She worries how she will pay for labor to plant. And how she will ever get enough money to make the many repairs her farm and living quarters need. Before the storage tanks, she had to use saline water and had to send her children long distances to fetch drinking water. She would buy 20 liters for 2 shillings. She bought one drum a day — 200 liters. Her children would transport the drum by oxcart.

Whatever she has learned about farming, she has figured out by looking at other farms as she walks around her village on errands. "I worry about my future, farming this way. But I have no alternatives." Certainly she would like to move somewhere where the soil had more fertility and the rainfall was better. But that's just not an option. "God still made this land for farming. What else am I going to do with it? What else can anyone do with it?"

"We don't know which will go first, us or the land."
Naomi Nyangancha, Jennifer Ojwang, and their husband

LAKE VICTORIA BASIN

Managing soil and water resources

Naomi Nyangancha, Jennifer Ojwang, and their husband live in the surreal landscape of Katuk Odeyo, which bears the brunt of the soil erosion problems of Nyando District in Western Kenya. This former stretch of farmland is now randomly carved apart by a menacing web of gullies that run anywhere from 5 to 20 meters deep and some 10 meters wide. What was once a livestock farm of 1.2 hectares is now down to 0.8 hectare, and is eroding rapidly into the gullies that ominously surround the family, threatening to take their homestead. Scientists say the gullies may in fact do that within a few years.

"You are lucky! Today you could make your way here," says Naomi in greeting. The family has moved their front gate nearly a kilometer over the last few years to accommodate the ever-eroding access to their islandlike parcel of land.

All three residents are elderly, and Naomi laughs when she says "We don't know which will go first, us or the land." They have had livestock on their land for 46 years, but now they struggle just to hold on to what is left of it. They have had two neighbors die by falling into the gullies. Two cows and a sheep have died the same way. They used to have a walk of only several kilometers to the road. Now it is a 7-kilometer meander, winding through the gullies to the tarmac. "If someone gets sick, all we can do is pray," says Naomi.

Naomi hasn't been to market in over a year. Instead she sends her youngest grandchild, who navigates the gullies to and from school every day. In the rainy season it is a treacherous trip for a child. The Nyanganchas now listen to David Nyantika, a CGIAR research extension liaison officer in East and Central Africa, when he tells them they must stop cutting down their trees.

"All this has occurred only in the last decade. I have to work hard to convince this farmer to

keep his trees," says Nyantika. "He wants to cut the trees for sale before he loses his land. He doesn't see that the trees are what are forestalling the complete disintegration of his farm."

The threat to Lake Victoria

Katuk Odeyo is the most dramatically visible example of soil erosion in Kenya. The problem, of course, does not originate here, but 10 kilometers north in Kericho, also in Nyando District, where deforestation and soil degradation encourage rapid runoff, carving out the deep gullies that threaten families like the Nyanganchas. Thirteen to twenty million tons of sediment a year finds it way into the Nyando River system which feeds into eastern Lake Victoria, overloading the river channels and causing flooding downstream.

"The problems here are difficult," explains Nyantika. "They involve both overland flow and subsurface flow of water through land that cannot hold onto it." The interventions are also very different. Whereas you can manage subsurface flow through tree planting, managing overland flow, in most cases, requires dams and water catchment pools. According to CGIAR landscape ecologist Markus Walsh, the whole Nyando basin problem, which affects more than 200,000 residents, requires a large investment in hydrology research. "If you look up towards Kericho, you can't see the water flowing down. We need to understand the underlying hydrologic functions. How does the water really flow in this area? When we know that, we'll be able to make useful recommendations as to how to better manage it," says Walsh.

In the past, millions of shillings were spent on road and bridge repair, and on installing gabion boxes to reduce siltation; in many cases they were washed away almost as rapidly as they were installed. "If you don't manage the water flow, it doesn't matter what you build, the roads will still wash away," asserts Walsh. Even on a dry day the landscape is filled with the sound of running water, and the government is now thinking of relocating the farmers.

"We have to show that the problem begins upslope," says Nyantika. "That's where the soil erosion begins. If we do our interventions up there, and embark on a long-term tree-planting program down here, this land will be productive again. The weather here is excellent for

Naomi Nyangancha's small plot of land in Katuk Odeyo is gradually shrinking as gullies eat into it.

Naomi Nyangancha, Jennifer Ojwang, and their husband have lost two cows and a sheep to the gullies around their farm.

cropping. But the land is washing away. Each and every person in this area, the farmers upstream, midstream, and downstream, has a role to play. But the key challenge is how to link them in a unified effort."

The farmers in Kericho don't believe they are to blame for the runoff, which has now caused such silting in Lake Victoria that the fish are having trouble reproducing. "We try to tell them that all the problems we are seeing in the lake are emanating from upstream, but that's hard for them to believe," says Nyantika.

One way of convincing them may come from Walsh's extensive fieldwork on soil degradation in the Nyando River basin. Walsh is using reflectance spectrometry, a technology that is replacing traditional soil sampling with the measurement of patterns of reflectance from organic matter, clay particles, and iron in the soil. These patterns or spectral signatures can be easily measured with a portable spectrometer, giving researchers, in seconds, an overall picture of the chemical and biological composition of the soil, a process that used to take up to six months using traditional soil sampling analyses. The data collected by the spectrometer is then used to determine whether the soils tested are easily eroded or whether they can support crops like maize if soil-binding trees were to be removed from a given site. Walsh's spectrometry model proved to be a good or better predictor of yields than physical or chemical analysis.

The technology may also improve prospects for more accurate measurement of the carbon sequestration potential of soils on tropical farms — a subject of global environmental relevance.

Walsh is also linking the reflectance information with satellite images, enabling scientists to produce extensive maps indicating the precise pattern of soil attributes in a landscape. It was these methodologies that led Walsh and his team to discover a huge plume of siltation flowing from the five rivers of the Nyando basin into Lake Victoria.

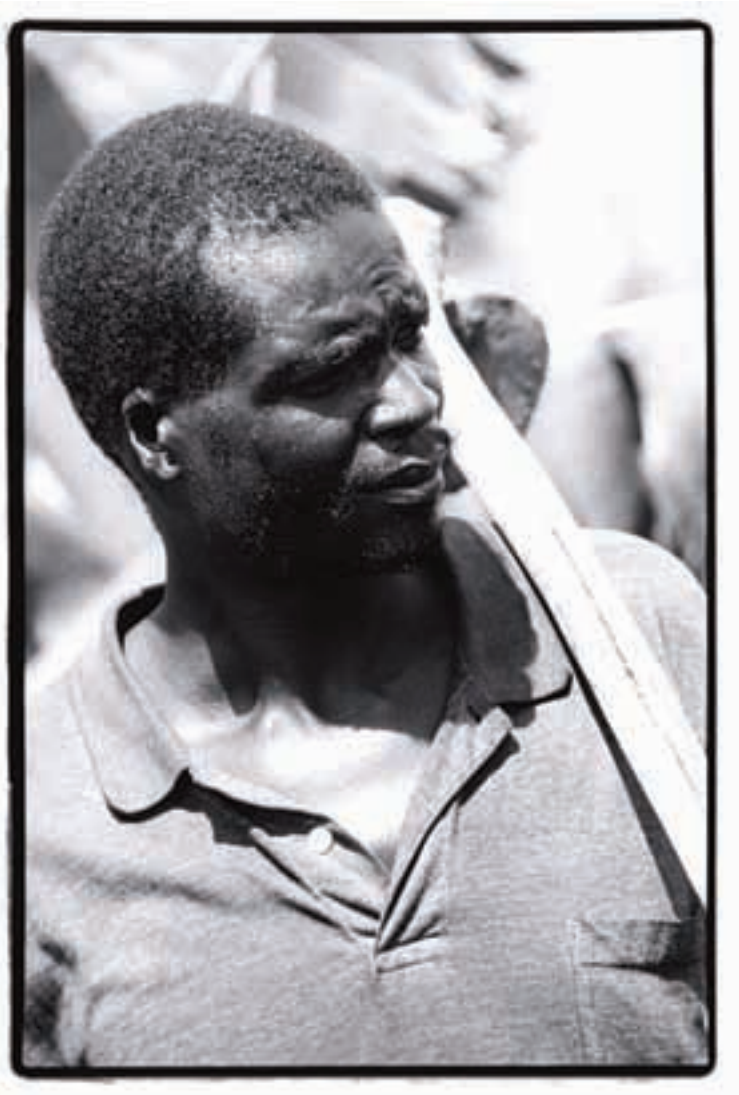
People and trees to save the land and the lake

"Long-term initiatives should be focusing on upstream control and reducing the sediment loads," says Nyantika. By forming and bringing together groups from all the affected regions a common understanding of the problems they are facing is emerging, and the hydrology theories of the CGIAR scientists working in Nyando are gaining gradual acceptance. "This area requires an investment of 3 to 5 million Kenyan shillings," he says. "Then we will see change in this area. Environmental economists look at long-term output from this area, and if you look at those numbers you won't invest here. But we're talking about people, their lives and livelihoods. If you look at indirect benefits, like the road not washing out and access to markets, it's not long before health comes to the surface. Old people and children are dying from malaria because they cannot access health care when the road is washed out."

Through the intervention of capacity-building programs initiated by the National Agricultural and Livestock Extension Programme (NALEP) — an extension program by the Kenya Ministry of Agriculture — and NGOs like Vi Agroforestry, farmers in Katuk Odeyo are beginning to reclaim their land. By building irrigation pools that catch the rainfall and road runoff, local farmers can now meet the domestic demands of more than 80 households in the area. Agroforestry ground cover initiatives are also taking hold.

"You need 60 percent tree cover to save these farms," says Nyantika. Local farmers are building tree boundaries around and within their farms. Fruit trees are bringing income to formerly barren farms, going a long way towards addressing land degradation, while providing cash crops and conserving the environment.

William Matinde, 21, has a small farm here, but his passion is his tree nursery. Trained by CGIAR tree domestication experts, William studied nursery management and was provided with the initial germplasm to start his now-thriving nursery. When he began, the demand for trees was negligible. "But when my neighbors began to see my farm saved by boundary planting and the value of trees in terms of income, they began to come to me demanding seedlings," explains William proudly.



Eddie Ouko is using agroforestry techniques to counteract the gully erosion of his land in Katuk Odeyo, near Lake Victoria.

William started his nursery with 2,000 seedlings. Now he has more than 15,000. Among them are eucalyptus, neem, mango, avocado, lemon, pawpaw, and passionfruit; and grevillea, leucaena, and casuarina. "I advise people to buy both fruit trees and forest trees. I tell them trees are important. Also the medicinal trees, like *Prunus africana*, which is said to cure prostate problems, and neem, which cures everything, even malaria!"

"I love what I'm doing!" says William. "It's my talent. I love helping my neighbors." While seven other nurseries are starting up in the area, William's is by far the largest and most successful. He makes about 75,000 shillings a year from his nursery, enough to support his wife and young child. "Trees are my future," says William proudly.

"I used to have 10 acres [4 hectares] doing nothing," says William Oburu, 42. "My land was covered in gravel. What can you grow on gravel?" Then he met Nyantika and other CGIAR researchers and the training he received changed his life.

"What has saved me are improved fallows," explains William. "Before I was introduced to improved fallows, I couldn't even grow maize here. Then I started using *Crotalaria paulina* [a nitrogen-fixing legume] and this upped my yields. Now I can get 180 kilograms of maize here. I barely got 4 kilograms before."

William has pawpaw trees now, and has been introduced to banana and mango tree production. He has introduced three varieties of sweet potatoes to the farm, and pineapple. "All this I learned from the outreach programs. I didn't know anything, not even how to manage water." Now he grows tephrosia and calliandra to improve his soil fertility and his farm is vibrantly alive. "My farm is always under improvement," says William.

William says his farm is now so productive he'd like to buy more land. "I've got four children and before, I could not feed them. I couldn't even stay here. I worked in town as a casual laborer. I was running away from reality."

"Now we have a resource person in William," says Nyantika. "We can call him a para-professional. He can train others." The CGIAR agroforestry capacity-building program has trained 700 western Kenyan farmers in crop production and another 600 in nursery management.

Fish out of water

From the headlands of Kericho, where the wind whispers strongly, you can see the silted waters of Lake Victoria, about 10 kilometers away as the crow flies. The lake is now affected so badly that the fish stock is seriously depleted.

At Dunga Beach on the lakefront, the weighing market is empty now. "It used to be you couldn't park here because the trucks from the fish-packaging factories took up all this space," says William Otuoma, chairman of the Dunga Beach Cooperative Society. Now the scales sway with the wind and the market echoes with the sounds of children playing on the beach. Otuoma sadly speaks of a time, when he was young, when there were fewer fishermen, and more fish. "Maybe we had twenty boats. Now we have over one hundred boats. The lake is still the same size, but the fish don't multiply like they used to. The more boats we have on the lake, the more dangerous it is. They have to go out farther and farther to catch fish. The fishermen are poor and don't have the expensive gear it takes to avoid catching fish that are too young, and they are cutting off the fish spawning cycle."

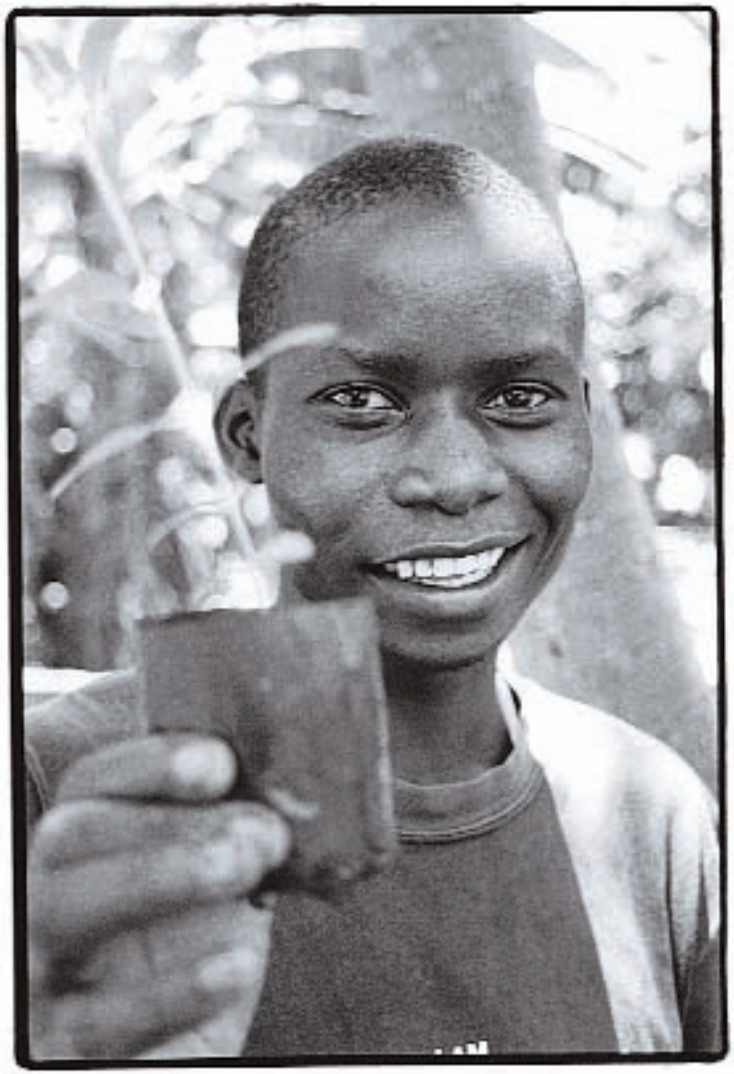
According to Otuoma, poverty here is so extensive many cannot afford to send their children to school.

During the El Niño rains of the late 1990s the lake became overrun with water hyacinth. "This was a blessing and a curse," says Otuoma. "The water hyacinth caused many people to suffer. They couldn't fish. But this meant the fish could multiply. When the water hyacinth left, people began overfishing and now the stocks are so low, they have to go farther and farther out in the lake, and get arrested fishing in the waters of other countries."

Raw sewage and industrial pollution pours directly from Kenya's rivers and factories into Lake Victoria. If stopped now, says Markus Walsh, the lake would take 75 years to recover. According to Walsh, 450 species endemic to Lake Victoria have disappeared in the last 50 years. "That's the greatest mass extinction since the Paleocene era!" exclaims Walsh. What few fish are left, like Nile perch, seem to be significantly reduced in numbers, though scientists have not yet determined the precise cause of the fish depletion. Fish have begun to migrate to the Ugandan side of the lake where the waters are deeper. So have the Kenyan fishermen.

"If something isn't done for us," says Otuoma, "we are going to die. I'm a fisherman. I used to go out and in six hours my boat was full. Now you catch nothing or maybe one kilogram of fish, that's worth 80 shillings. Our daily expenses are over 80 shillings. You are here now, and I am embarrassed that I cannot even give you a fish as a gift."

"If a man is born and bred in Dunga, he is a fisherman, and he must go to the lake," adds Otuoma, "even if it holds nothing for him."



William Matinde's tree nursery has become a valuable resource in the battle to rescue the lands of Katuk Odeyo from encroaching gullies.

"Striga brought hunger to my family.
It makes your crops grow down instead of up."
Consolata James

WESTERN KENYA

Children, the future of farming

Western Kenya is the most densely populated region in rural Africa. Despite being blessed with plentiful rainfall, decades of intensive agricultural production have seriously depleted soil fertility in the region, and soil erosion is a major problem. There is a crisis of low food production in the smallholder farms in this area, coupled with high levels of poverty and HIV/AIDS. While many agencies and development organizations have worked in the area for decades, there has been much duplication and fragmentation of effort.

Success stories in this part of Kenya are limited. But committed work by extension agents of the Ministry of Agriculture, backed by research products of Kenyan institutions and their CGIAR partners, are promising a vigorous battle will be waged to save this beleaguered and impoverished part of Kenya.

The devil's weed

Joshua Juma is barely into his twenties and already his life seems all but over. His small roadside plot of land, the only one he owns, is planted with maize and is decimated by *Striga*, a parasitic weed that destroys maize, millet, and sorghum. Made all the more aggravating by its beautiful purple flowers, striga is known as witchweed, or the devil's weed in western Kenya, because once it attacks your plants it is too late to do anything but count your losses. Striga exerts its toll on crops by inserting a sort of underground hypodermic needle into the roots of growing plants, siphoning off water and nutrients for its own growth. It drains photosynthate materials and water, and when it emerges from the soil, it has literally sucked the nutrients right out of the crops that farmers use to feed their families. Above ground the crops wither, and production is devastated.

By the time striga emerges from the ground with its lovely purple flowers, its seeds have been spread throughout the soil, and it is too late to do anything about it.

"My father used to tell me to burn the stuff," says Joshua, looking around at the lushly evil flower that permeates his property. "He said pull it up and burn it in a pit."

"That's exactly what not to do!" says Fred Kanampiu, a CGIAR agronomist. "You just spread the seeds like that," he tells Joshua. Once the seeds spread through the soil, it is much harder to get rid of striga. True striga control is coming, but it may not make it in time to save Joshua's land.

Controlling striga

In order for control to be effective striga must be stopped before crop yields are affected, and the striga seedbank must be depleted to control further yield losses. Methods that act before striga attachment will be the most effective in preventing the damaging effects of the weed. The CGIAR, along with the Weizmann Institute of Science in Israel, has developed a unique product for striga control in maize. It combines a low-dose herbicide seed coating applied to Imazapyr-resistant (IR) maize seed that leaves a field virtually clear of emerging striga blooms. Imazapyr (a systemic acetolactate synthase (ALS)-inhibiting herbicide applied in small quantities, as little as 30 grams per hectare) delivered in this manner acts before or at the time of striga attachment to the maize root, and prevents the phytotoxic effect of striga on the maize plant. Experiments in research stations and farmers' fields show that the low-dose herbicide seed coating on IR maize can increase yields up to fourfold, and because the maize seed is treated there is no need for spraying herbicide, putting the technology well in reach of resource-poor farmers.

The Kenya Agricultural Research Institute (KARI) and the International Centre of Insect Physiology and Ecology (ICIPE), a CGIAR sister institute based in Kenya, are leading another initiative, termed "push-pull", against striga and a maize pest called stem borer. Through dramatization groups farmers teach other farmers about the technique, which involves

The tiny seeds of the parasitic weed striga, which can devastate maize crops, are easily dispersed, highlighting the urgent need for improved control of the weed.

Boaz Okwela thinks his success story provides a lesson in life for his son Edwin (right) and his granddaughter.

intercropping maize with *Desmodium*, a nitrogen-fixing plant. Desmodium forms a canopy around the maize, inhibiting striga photosynthesis, and also contains chemicals that attach to the striga root so that it cannot attach to the host crop. It also inhibits stem borer. The farmer then surrounds the maize and desmodium intercropping with napier grass, which attracts the stem borer, luring it away from the maize and into the napier. The desmodium pushes away the striga, and the napier pulls the stem borer to it. Thus the appellation "push-pull".

In the local dramatizations in and around Ebukanga, Consolata James, a 50-year-old grandmother of five, plays Mama Striga, the evil witchweed. "Striga brought hunger to my life," says Consolata. "It makes your crops grow down instead of up. I hate striga, and it shows on my face when I am in the play." The plays are an effective method of extension and technology transfer in the area.

Another striga control technique recommended by CGIAR forestry researchers is the use of improved fallows. Over time this eliminates striga as growth substances released by the trees inhibit striga germination.

Growing up to be farmers

In this part of western Kenya a new generation of children is growing up watching farming falter. Pamela and Onyango Baridi greet visitors to their home by bringing out their best piece of furniture on which guests can sit — the springs from the front seat of an old truck. The farm is filled with children — their own, their neighbors', and kids from all around the neighborhood. They are all happy to see Peter Mbogo, a CGIAR field technician who has worked with Pamela and Onyango on improving crop yields through improved fallows and striga maintenance.

The farm is looking much better, according to Peter. But as the children mill about, the question is put amongst the ten or so that range in age from 2 to 13, what they would like to be when they grow up? "A driver!" scream two boys. "A pilot!" adds another. The girls seem mostly to want to be nurses or teachers. Only one boy, with his back to the visitors,

mumbles "farmer". The other children laugh. But Eric Otieno Onyango, aged 9, sticks to his guns. "I want to be a farmer, because farmers are rich men, because they always have food."

Always having food is the reason Boaz Okwela is teaching his son Edwin how to farm. When soil scientists first approached his 0.6-hectare farm, Boaz did not think he had a soil fertility problem. His yields were declining but he persisted. "I couldn't really stop farming, I'm not trained to do anything else," explains the 58-year-old. In two years I have gotten enough knowledge about inorganic fertilizers, about tephrosia, crotalaria, and manure from my cows, that now I'm getting 180 kilograms of maize a year!" he says proudly. He was down to getting only 2 kilograms before he learned about inorganic fertilizers. He controls soil erosion through terracing, plants napier grass and calliandra for his cows, and is thankful for the time he was able to spend learning all this with the help of KARI and the CGIAR's African Highlands Initiative. After his training, Boaz became chairman of the local farmer field school, a community initiative for farmer-to-farmer training.

Boaz is also planting new varieties of climbing and soya beans, which provide grain and improve soil fertility while fixing atmospheric nitrogen.

"I was going to leave this farm," admits Boaz. "I thought it was bewitched. But now I can teach my son and granddaughter not to give up in life. I'm very proud of this farm now. I could never sell it. And I know I'll be happy to be living here and happy to be buried here. I know I'll be leaving them a good plot of land."

On the borderline

While it is true that initiatives that help farmers improve soil fertility and livestock production can change lives, something else in western Kenya seems to be claiming lives with evil rapidity. The HIV/AIDS pandemic has hit this area hard. There are 600,000 AIDS orphans in Kenya. Three hundred thousand of them are in western Kenya. Growing up without parents, a full-time burden on mostly elderly grandparents, these children are the ones Fidelis Wainaina calls borderline children, the poorest of the poor.

"I used to see them on the streets of Kisumu. Some were begging. Some were sniffing glue. I used to wonder, where did all these children come from?" Feeling it was her duty to do something about the children Fidelis, a former schoolteacher, founded the Maseno Inter-Christian Self-Help Group (MICH) in the hope of strengthening the African family structure in western Kenya, preventing the children who would be predisposed to street life from moving in that direction.

MICH focuses on education and literacy for children. But it also has a strong community component aimed at improving food security at the household level. Most of the farmers Fidelis visits — often by trekking many kilometers even through the mud during the rainy season — no longer produce a lot of food on their farms. "They are living on less than a quarter of an acre [0.1 hectare]," she explains. "We try to get them to replace maize, if they are even growing that, with high-value crops. I realized that there is very little scientific farming going on among the farmers I visit — very little adoption of crop management. This is how we linked up with CGIAR research. Bringing to the farmers who cannot afford commercial fertilizers other options they can use to enhance their income."

Fidelis and others in MICH teach mostly women farmers and women's groups how to keep and breed chickens, how to graft mangoes, how to raise dairy goats, and how to plant agroforestry trees and other high-value crops to create enough income to keep the orphans they have inherited in school, or at least on the farm.

Sitting on the ground on a small farm in Vihiga District, four women are grafting mangoes. They listen to the radio and speak very little. Working at a rapid pace is Agneta Kavedza, who is 38. Besides her own five children, she has inherited four more from a brother-in-law who died of AIDS. Now that she's become, through MICH, an expert in grafting mangoes, she's teaching others at the community level. In addition she keeps and breeds chickens, which she also teaches others to do. With her new skills she is managing to support the nine children she never thought she'd have.

Lydia Awuor, a great-grandmother, never though she'd be tending children at her age either, although she declines to give her age. Her granddaughter Awino holds her son Okath, who is seven months old, and stares out at the driving afternoon rain wondering how much flooding there will be in her grandmother's modest home. There are four other grandchildren at home, ranging in age from 9 to 16. Lydia laughs as she remembers how her future husband used to watch her walk by this farm on her way to school and one day just kidnapped her to be his wife. Now, more than fifty years later, she admits that she never anticipated her current situation. But at church she heard about what Fidelis and MICH were doing, that there were outreach programs for children. "I certainly had some children that needed reaching out to," she laughs. She credits MICH with saving her grandsons Kevin, Edwin, and especially Richard, who is now very active in the church. "No, I never imagined all this," says Lydia as she looks out at the rain. "But when death comes, you have no alternative. You go on."

The children of Pamela and Onyango Baridi have wide-ranging ambitions, from pilot to farmer.

The importance of partnership

HIV/AIDS, declining soil fertility, and the bottoming out of farm productivity are threatening the very fabric of western Kenyan life. Many groups have tried to deal with the latter two problems over the last few decades. The success of their activities, however, has been limited. There is a need for organizations to forge strong partnerships and add value to each other's programs. There is also a need to partner with the private sector and link farmers with markets and rural development programs in order to enhance impact and ensure sustainability. These urgent needs engendered the Consortium for Scaling Up Options for Increased Farm Productivity (COSOFAP), which was initiated in January 2001. COSOFAP is currently liaising with over 70 partners, comprising research and development organizations, both local and international, including farmers who are key partners.

Since its establishment COSOFAP has conducted training in various fields, specifically soil fertility options, high-value trees/grafting, resource mobilization and developing winning proposals, strategic planning and governance (regional), and poultry- and bee-keeping (with assistance from Africa Now). It has also held field days and exchange visits; established interactive learning sites; distributed germplasm; organized professional training/workshops; developed extension materials and training notes for farmers; and provided training in collective action and conflict management.

In addition to the above activities, COSOFAP has enabled partners to forge more meaningful partnerships by creating a forum for agricultural development in the region and enhanced capacity for stakeholders.

COSOFAP plans linkages with other networks and consortia both in Kenya and in neighboring countries, and will be tying the consortium's vision and purpose to national initiatives such as the National Agricultural and Livestock Extension Programme (NALEP), the Kenya Rural Development Strategy (KRDS), and the poverty reduction strategy paper (PRSP). COSOFAP also intends to invite the CGIAR Centers represented in the region to join its technical advisory committee.

Through a relatively new program in western Kenya, the Folk Ecology project, CGIAR soils scientists aim to gather extensive data on indigenous knowledge about soil fertility with the intention of measuring how much farmers really understand about soil conservation, crop rotations, intercropping, and improved and natural fallows. Working in the footsteps of older CGIAR initiatives that taught the practices in towns like Emuhaya, the scientists hope to learn the best ways to make the technologies stick.

Making technology stick in western Kenya is definitely more than any one organization can handle. But through new partnerships and with great determination, this countryside, cursed by poor soils and the AIDS pandemic, and blessed with plentiful rain, could once again sustain its people.

"I am as happy as a salaried man!"
Nelson Maturi

CENTRAL HIGHLANDS

Of commerce and collaboration

The Central Highlands of Kenya, dominated by snow-capped Mount Kenya and the magnificent Aberdare range, are the agricultural breadbasket of the country. The home of the world-famous Arabica coffee, the area succeeds in agriculture for many reasons, not least of which are two plentiful rainy seasons, with an annual accumulation of over 1,200 millimeters a year. The climate is moderate and in some areas the soils are still fertile. Because of these conditions, and the absence of some diseases such as malaria, the highlands are densely populated, with between 500 and 1,000 people per square kilometer. Farms, therefore, are small, between 0.5 and 2.0 hectares, and they continue to shrink due to subdivision. Tenure security for households is, however, fairly strong, as land is acquired chiefly through inheritance and purchase and stays within families across generations.

The highlands are now home to agricultural diversification. Farmers often own land in a strip from a ridge, where houses and roads are located, down to a lower area. This permits them to significantly expand the range of their agricultural enterprises. Farmers in the Central Highlands may well have six or more different cropping enterprises, three different livestock enterprises, and five different tree production systems. Three important income-earning enterprises that have impacted significantly on smallholder farms are dairy, coffee, and tea.

Nationally, there are approximately 600,000 smallholder dairy farmers contributing approximately 80 percent of all marketed milk. Kenya has more high-grade cattle (between 3 and 4 million) than Tanzania, Uganda, Malawi, Mozambique, Zambia, Zimbabwe, and South Africa combined. There are approximately 500,000 smallholders growing coffee, accounting for 65 percent of coffee output (105,000 hectares), and nearly 300,000 smallholders farming 69,000 hectares of tea, which is about 70 percent of production in Kenya. Almost all of this production takes place in the highlands, with the Central Highlands leading the way. On

average, farmers in the Central Highlands are probably the most productive of all smallholders in rain-fed Africa.

One of the reasons the highlands are so successful agriculturally is the farmers themselves. They are dynamic in taking on new enterprises and experimenting with new agricultural methods and are innovative both individually and through collective action. They are commercially oriented and have embraced diversification of commercial enterprises as their strategy for success.

But the Central Highlands, despite their success, are facing hard times. The rising population, which sits on tinier and tinier plots, is now coping with a severely depressed world coffee market, a national glut of milk production, and a three-year stagnation of national food markets leading to reduced incentives to invest in inputs and maintain productive soils. Poverty looms and has hit smaller, less diversified farms particularly hard. Can the success of these intensive agricultural activities possibly be sustained?

Frank Place, a CGIAR agricultural economist who has worked in the highlands for nearly a decade, believes so. But the pathway to sustaining intensification will involve a continued embracing of diversification of agricultural and livestock activities to offset inevitable market shocks. CGIAR initiatives in the area have helped achieve significant progress towards sustainable natural resource management through diversification of agricultural activities (such as the introduction of higher-yielding crop varieties to increase the returns to land investments), through improved livestock health and feed strategies, and through systematic introduction of a variety of high-value trees (fruit, timber, fodder, medicinal, and ornamental) into the agricultural landscape. These innovations can directly improve natural resource management (e.g. trees and manure for soils) as well as increasing payoffs to farmers for improved investment. The use of high-quality manure, derived from contour hedgerow fodder-fed cattle, for improved crop production and income generation has been a key to sustainable natural resource management initiatives.

John Mark Gitari Munyi, leader of the Manyatta Dairy Goat Association, cradles some of the precious macadamia nuts that add diversity to his farm.

Edith Mukami-Njagi daily carries napier grass from the bottom of her steep, narrow plot to feed to her dairy cow.

Overcoming natural resource mismanagement to make sustainable gains in productivity while ensuring equity is the challenge being met through crop diversification, national policy initiatives, and broader access to markets, so that productive livelihoods can be sustained.

No choices

Edith Mukami-Njagi provides an example of how poverty can thrive within a relatively prosperous region. At 30, and with three children to support, she farms barely half a hectare in the Gaturu North section outside Embu. She's been here 10 years. Her plot is incredibly steep and narrow. She grows arrowroot, and napier grass for her three cows and three sheep. She buys maize and beans to feed her family, and grows some coffee. She gets almost nothing from her farm. The cows only produce 2 liters a day of milk, which she gives to her children. The cows also produce manure for farm use. She keeps the coffee, even though she's scarcely made any money from it, in the hope that one day the price will go up. She knows it probably won't. She's just started growing bananas, traditional and improved varieties. She says the markup is pretty good on bananas.

Edith only needs to work the farm two days a week. It's too small to take up much of her time, and she grows too little to work it any harder. The other three days she works as a casual laborer. "It's a very hard life, harder than I expected," she says, wiping the sweat from her forehead and cheeks. She is perspiring profusely despite the chill of the morning. "I start at five-thirty. I feed the kids breakfast, and then I milk the cows. Then I go cut them some napier." The cows eat four huge sack loads a day, which Edith hauls from the bottommost part of the farm. She puts the manure from the cows on her crops and then, if she has any bananas to sell, she heads into Embu town on foot, 7 kilometers away.

Edith and her family exist totally on off-farm income. She cannot usually afford school for her older children. Her son Eric, who is six, tries to reassure her about that. He doesn't want to work the farm when he grows up. He'd really like to be a driver. "I don't need school for that, Mama."

"She's just accepted that she's not going to get anything off this land," says Place. "Over generations, the farms just get narrower and narrower as they get subdivided." Usually the farmers of Embu try to send their children to school, because the farms just cannot sustain them. And many smallholders, like Edith, have no choice but to work off-farm. It is important to bear in mind, however, that the very existence of remunerative off-farm jobs in the region is strongly related to the productive agricultural sector that generates income to pay for such services.

So many choices

Hezekiah Kinyua Mairani and his wife Triza have a model farm. Hezekiah is a teacher, and like most teachers, he believes in continuing education. He prides himself on having taught himself how to farm. His salary as a teacher has allowed him this privilege. He bought his 2-hectare farm in 1985 and it is the very picture of diversification. The Mairanis grow a lot of tea, and they make the bulk of their money from it. But around their well-tended home they also grow maize, sugarcane, bananas, avocados, bananas, cabbages, napier grass, sukuma wiki, beans, Irish potatoes, sweet potatoes, and a variety of herbs filling the kitchen garden. The property is bordered to the point of being almost fenced in by agroforestry trees, such as grevillea and leucaena. The couple practice bench terracing and intercropping and use improved fallows. Triza shows off all the awards she has won for her farm management. Much of it she has learned from the CGIAR- and KARI-led initiatives in cropping and agroforestry, which have been incorporated into extension messages.

They also have a spotless poured-cement zero-grazing unit for their cow, complete with running water. "We've been helped by the Ministry of Agriculture quite a bit also," admits Hezekiah, who has two children in college and can afford to hire many casual laborers to tend to his tea. Above the door to his home is a sign that reads: To Fear Failure Is to Fear Success. "Personally, I don't fear hard work," says Hezekiah, "and I believe that the more success you have, the more courage you have to try something new." Judging from the success of his farm, one can only deduce Hezekiah to be a very brave man. But he says he is doing it all for his children, who, despite their extensive educations, will one day return to the farm. "I can claim it is my farm today, but the children grow up knowing that one day it will be their property," he says proudly.

The bountiful bleating of dairy goats

The Manyatta Dairy Goat Association is a thriving group in Embu. Led by 31-year-old John Mark Gitari Munyi, the association has 24 members spread out across several villages. The eldest is 74-year-old Nelson Maturi, who has 12 dairy goats and several cows. He feeds the goats maize leaves, which he dries in a shelter that he built himself. "You need the maize leaves because even with all the napier grass I grow, these goats will still eat as much as you put in front of them," he laughs. He feeds the cow and the goats calliandra as well; it makes for better manure, he says. The goats give him 25 liters of milk a day, all of which he sells. The milk sells so well because it is thought in the region to be healthier than cow's milk. Nelson sells the milk for 25 to 30 Kenyan shillings a liter. "Once a farmer starts with goat's milk, he's not going back to selling cow's milk," says Nelson. "A farmer can keep 12 goats for what it costs to keep a cow. I get one new goat calf a year." They reproduce nicely and often have twin kids. Also, whereas each cow requires about half a hectare, each goat only requires a tenth of that. Nevertheless, he is proud of his cow, and gladly unravels the cow's pedigree papers for any guest to peruse.

Nelson claims to make nearly 300,000 shillings a year from his farm, mostly from the dairy goats. "If I didn't have children to put through school, I'd have built a stone house by now," he brags. "I am as happy as a salaried man!"

Edith Mukami-Njagi (right) struggles to support her three children on her half-hectare plot in Embu.

As for John Mark, the success of the Manyatta Dairy Goat Association is in part due to his charisma and tenacity. John Mark was the first to pursue dairy goat farming with the help of KARI and its Agricultural Technology and Information Response Initiative (ATIRI) program. "Coffee is doing absolutely nothing in this area, but through collaborating with KARI and the CGIAR, we are making money from goats. People with goats have their children in school. The ones relying on coffee don't. They haven't been paid well for coffee for three years. The ones who have goats have clothes," he says.

The going rate for selling a goat is between 10 and 15,000 shillings. "At the end of the day we have to expand the milk selling," says John Mark. "The KARI-ATIRI project has helped us increase the number of animals we've got. For every member, in the beginning, they maybe had two animals. Then we hooked up with ATIRI, and now most members have between five and ten animals. This mzee" — he uses the respectful term for an older man as he points to Nelson — "has many more animals. Some never used to milk their goats, but now they have learned from other farmers and they have started milking the goats and getting good money." Place adds, "Farmers know the value of information in this area. And they will demand it and seek it out."

There are three hundred dairy goat associations throughout Kenya. "I spread the word around here, about what can be made from dairy goats," says John Mark. The association provides and rotates bucks to keep the goats healthy and to gather stud fees, which enable the association members to help one another in times of trouble.

"Pamoja" means "together": the critical role of collective action

"The role of collective action is very important here," says Place. "The CGIAR has studied the reasons people came together in this area. We looked at the types of activities that the local farmers get involved with, whether or not they tended to form new groups from these or build on social capital and take on new activities as groups. We looked at their performance. One of the questions local stakeholders had was whether group purpose, size, or diversity of members affected group success. To a large extent, the answer is no. Many different types of groups succeeded in the task of managing tree nurseries, in income-generating activities, and in assisting each other in times of need.

"Groups build on experiences and like to take on new activities. But they are also structurally dynamic. Actually it's interesting — with many of these groups, they pull in women to act as treasurers. For income generation they bring in men when marketing connections are required. So they are pretty savvy. And in central Kenya, there's a lot of groups contributing a lot of money — often as much as 1,000 shillings every month, and the farmers are getting a lot out of it. Farmers migrate toward income-generating activities in this area. So they could have started out as a self-help group, but now they are buying land, or building houses and renting them. They've got risk protection groups, funeral groups, marriage groups. Every single household we surveyed belonged to a group. It's the way of life here," says Place.

New cash crop challenges

It's groups like John Mark's that also promote new cash crops, such as the macadamia nut. John Mark is growing macadamia trees to keep his farm going. "There's money in macadamia," he says. "On a mature tree, you can get 140 kilograms of nuts which go for 24 shillings a kilo." It generally takes hybrid trees two years to give nuts. The trees offer potential in the highlands because their dense and deep rooting systems enable them to provide products even in drought conditions. There is a similar demand for mango trees.

"Coffee used to be the hub of life here," says George M. Karanja, national coordinator for ATIRI. "Now farmers must diversify to survive. New techniques, new varieties, new crops. Whatever it takes for the breadbasket to survive."

"Now I can afford to send my children
to school for the first time."
Akwala Solonka

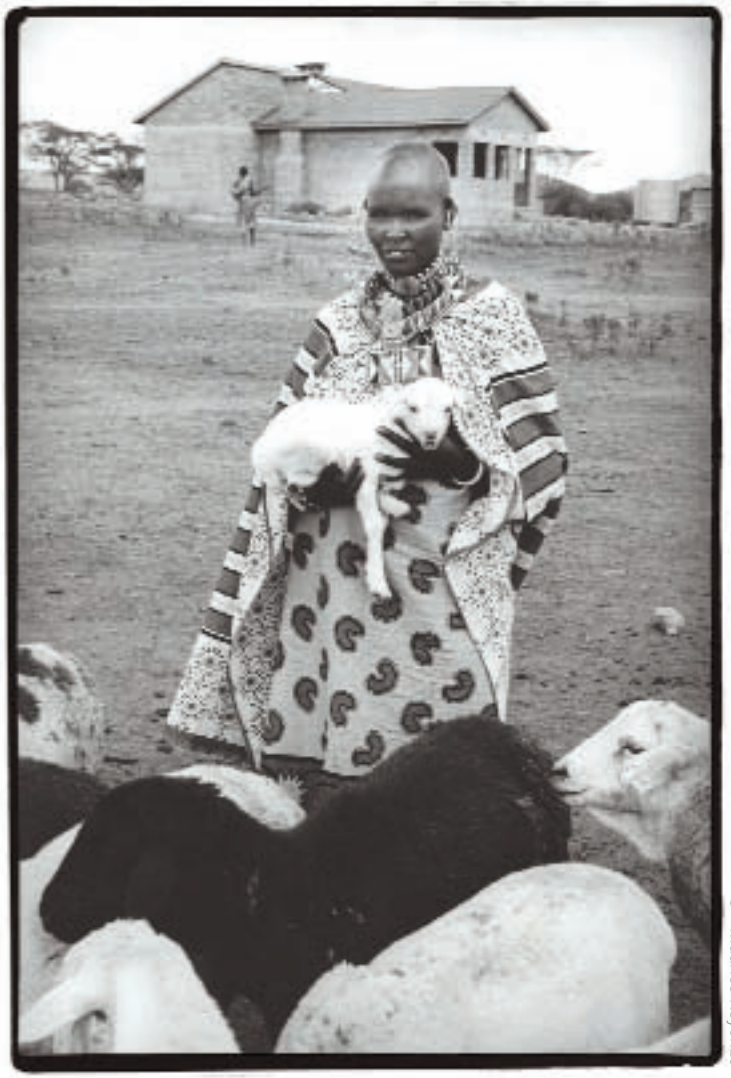
KITENGELA

Wildlife, livestock, and livelihoods

Akwala Solonka has a wind-worn face that bears the mark of the 20 or more years she has been tending her livestock. She owns 160 hectares where her 30 head of cattle graze. She also admits to having as many goats and sheep. But asking a Maasai how much livestock they actually have is like asking a stranger how much money they have in their savings account. It is rude.

For the Maasai, a person's entire self-worth is wrapped up in the livestock they own — cattle, goats, and sheep. "Livestock are just everything," explains David Nkedienye, a Maasai who also works as a community facilitator in charge of a Kitengela-CGIAR project working to conserve rangeland diversity. "They are a medium of exchange, it is how we pay for things; how we pay our debts. It is our prestige, our standing in society. If I want to take a bride, I must pay for her in cattle. We bond our friendships by giving sheep and goats. When we exchange gifts, we exchange livestock. And all the ceremonies in a Maasai's life focus around issues of cattle. The meat, the milk that the livestock provide, these are the things that sustain a family, that sustain our culture."

But the traditional pastoralist lifestyle of the Kitengela Maasai is under threat. The Maasai community nearest to Nairobi, Kitengela is feeling the encroachment of Nairobi's urban sprawl and pollution, and of a new, cash-driven society that is buying up pastoral lands and pressuring the Maasai in ways their forefathers could never have imagined. Unique to the Kitengela equation is Nairobi National Park, where ingress and egress for wildlife is becoming ever more constrained by urban sprawl. The wildlife using the corridor surrounding the park now increasingly moves through adjacent Kitengela. The lions follow and often find the Maasai livestock to be easy prey. Until recently, there seemed little hope of keeping the Maasai from retaliating.



In Kitengela, a Maasai woman cradles an important addition to her family's assets.

The Maasai have always been in conflict with lions and other large predators. "In the wet season, when the zebra and the wildebeest move out of the park, the lions try to follow and if they don't find the zebra, they will kill our cattle," says David. "Maasai always retaliated and killed the lion because our belief is that if you don't kill the lion, the lion gets habituated to killing the livestock. Domestic livestock is not wild, it's more docile. It's easier for the lion to kill."

Maasai culture has, in fact, been intricately linked to the killing of lions. There came a time in a young man's life when passage to manhood required that he team up with others to kill a lion. "In the last 10 or 15 years this practice has stopped in this area because of a growing emphasis on sending children to school. The more schooling young men receive, the less likely they are to follow the traditional path to manhood," explains David. But other encroachments on Maasai culture and society have not been ameliorated by more education.

Things in Kitengela started going wrong for the Maasai when the land they owned together was parceled out in an ill-conceived loan scheme during the mid-1980s. Once the land was broken up, parcels started disappearing. Some people sold off their land to quarrying, others leased to people who wanted to build nice homes on the outskirts of the city. Suddenly there wasn't much space for livestock to roam, and the Maasai found they could not protect their animals in times of drought.

"When you have more land, you can move from place to place when there is no rain," says David. With the kind of fences that went up, with the new presence of people less tolerant of the pastoral lifestyle, came more conflict. Maasai are very exposed to the vagaries of nature, like rainfall, and if in times of drought they cannot get to better pasture areas, they will lose livestock — the essence of their culture and very survival. When this happens, the repercussions can be dramatic.

The Maasai have an abiding respect for wildlife. Apart from retribution against lion, cheetah, and leopard that kill their livestock, they feel they are the original "proprietors" of wildlife. But the reduction of pasturage in the Kitengela area means that wild herbivores are increasingly

competing with livestock for limited forage. The Maasai blame some of this problem on the Kenya Wildlife Service, which, they feel, does not maintain the park well. "From records we know they used to manage the park very well," explains Godfrey Ntapayia, a young Maasai active in the Kitengela community. "But inside the park now, you find very tall, inedible grass. It hasn't been cut, so the herbivores will move out of the park to where the grass is much shorter, since it has been mown by our animals. The lions follow, and every time they come out, the lions kill cattle and are then killed by the Maasai. The conflict is still there."

"For the last four or five years there has been a debate whether to fence the park," says Godfrey. "There are people who want to fence it off, arguing that the animals will remain inside where the tourists will be able to see them more easily. But in reality, the park is part of a larger ecosystem, and was never meant to stand alone. If you fence the park, you lose an important chunk of that ecosystem, interfere with the natural movement of the animals, and, in fact, endanger their existence."

Community action at work

The answer for the Kitengela community has been to retie some of the knots undone in their pastoral society when they became landowners. Now the younger generation has organized community groups. And the groups are tackling issues that only two years ago seemed intractable. That was when the Kitengela Ilparakuo Landowners Association (KILA) was formed to give voice to a people who felt they were not being heard by the Kenyan government or the Kenya Wildlife Service. "People began to realize there was only so much they could do as individuals," says Ntapayia. "Many important issues facing the Maasai require a collective effort to succeed. This is a reorganization of a formerly organized community, people coming together and trying to have a single voice, where they can deal with common issues, issues that cut across from those of land to natural resources that are shared, to political issues, to having a political voice to lobby the government. And many of these issues pertain to wildlife."

But the younger Maasai also have an entrepreneurial eye on the county's greatest asset — wildlife ecotourism. They are meeting with potential developers to see what they can do to bring tourists to Kitengela by making eco-friendly havens for the wildlife. "Ecotourism is a way for us to give back to the community. People are already coming to Kitengela to see wildlife. So we should take on the challenge for tourists to see the wildlife here, and bring money to the local people. It has been an eyeopener for the community to see that they can make money from the wildlife by protecting it," says Nicholas Matiko, KILA's secretary.

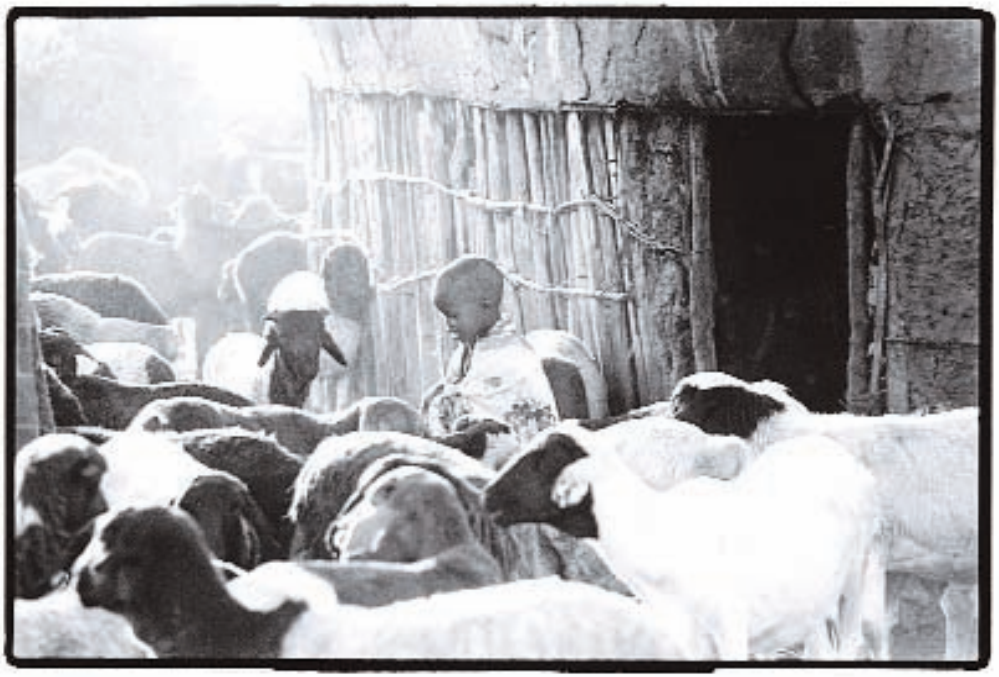
FONNAP, the local Friends of Nairobi National Park NGO, with the help of the Wildlife Foundation, a Kenyan NGO funded by the Wildlife Trust of the USA (based in California), has raised US$ 30,000 for a wildlife compensation scheme, which rewards Maasai communities that keep rangeland open for migrating wildlife. This has changed attitudes towards wildlife, which is no longer seen only as a "cost". Most of the Maasai are using these payments to pay school fees for their children and now there is even money to send girls to school, which traditionally the Maasai have not done. They understand that wildlife plays a part in their ability to educate their children. "We promote the coexistence of wildlife and livestock by paying the landowners in the Kitengela dispersal areas a little money in order to leave their lands open, so wildlife and livestock can live together," says Reagan Makui, a project officer working on the livestock lease program.

The role of CGIAR research

CGIAR economist Patti Kristjanson has had close contact with the Kitengela community for more than four years. "Game animals will be gone here in 10 years if we don't ensure that the benefits outweigh the costs for the pastoral people in this community. Since it is wealthy people that want to enjoy the wildlife their contributions, through programs such as the leasing scheme in Kitengela and shared tourism earnings, will conserve biodiversity and at the same time help alleviate poverty."

"Our research has revealed patterns in Kitengela that are consistent with some important global trends," says CGIAR ecologist Robin Reid, "such as the contraction of pastoral lands and an expansion of agriculture. There is cropping going on where cropping never was before; more and more pastoralists are settling down because of the availability of schools, health care, and so forth." This trend is associated with changes in land tenure, away from communal lands and towards private land ownership, and with a notable decrease in the number of livestock per person (livestock populations are more or less stagnant, but the number of people has been increasing rapidly). As these changes progress, the viability of livestock ownership as the sole means of survival is declining, pastoralists are becoming poorer, and their lifestyle is becoming much more tenuous. "This pattern is not unique to Kenya or East Africa, but is also being seen in other parts of Africa, in Australia, and in Central Asia," says Reid. "We now have ways to more accurately map these land use changes and better understand how agropastoral systems may change due to trends such as increasing population pressure, mounting pressures to diversify income sources, climate change, and other factors."

Why is CGIAR research on these issues needed? Why not leave this work exclusively to local and national institutions? Importantly, CGIAR research provides a bigger picture and can afford to be longer term and more strategic in nature; its national partners are closely involved in this work, but are often constrained by their national mandates to confine themselves to research within their own countries. CGIAR researchers contribute a cross-country, international perspective.



From an early age, the Maasai learn that livestock are an integral part of their domestic life and of the wider natural environment.

"Beyond that," says Kristjanson, "we can provide objective assessments of the options for pastoral livelihoods and for biodiversity and natural resource conservation, issues that often generate a lot of political heat at the national and local levels." Such assessments involve the following three primary activities.

Determining win-win livelihood strategies that reduce poverty and conserve resources
The first is measuring the returns to different land use options and potential livelihood strategies, involving socioeconomic surveys of households and communities. This research makes possible a comparison of financial returns (per unit of land or per person) to various activities, such as livestock production, cropping, quarrying, tourist-related uses (ecotourism), and so on. "Our studies in the Kitengela area clearly show that livestock isn't providing a sufficient return," says Kristjanson, "and cropping the land is an even less profitable venture. Right now, the 'wildlife leasing' option of US$ 4 per acre [0.4 hectare] open to Kitengela landowners essentially doubles the income earned from livestock for the poorest households." There is an important international public good aspect of this research: the development of innovative new income-generation strategies for pastoralists and new institutional arrangements that would make these strategies sustainable, not just for Kitengela, but also in other locations where wildlife-people-livestock conflicts are playing out.

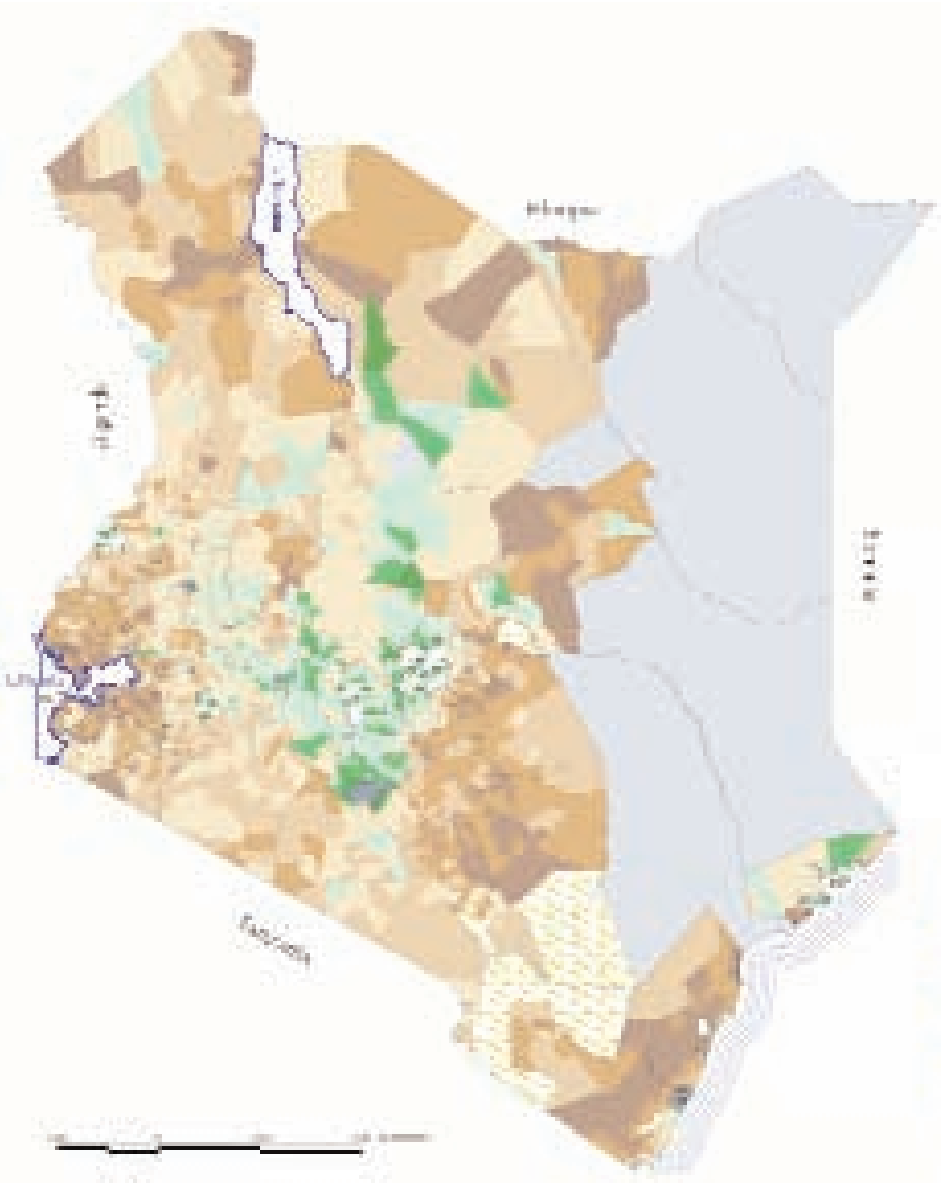
Assessing the impacts of changing pastoral livelihoods on wildlife resources
The second aspect of these assessments involves determining the consequences of various livelihood options for the health and sustainability of wildlife populations. "A good example," says Reid, "is the Mara wildlife count research effort, which mobilized a wide range of public and private sector stakeholders to assess the health of the Mara from a people, wildlife, and livestock perspective. The work uncovered some unexpected synergies between livestock and wildlife." In other words, traditional pastoral land management practices appear to be diversifying these landscapes rather than degrading them. Notes Reid, "Conventional wisdom says that the best way to conserve wildlife is to separate it from people, but in the East African context, this thinking may be seriously flawed."

Inspiring community action for sustaining pastoral livelihoods and ecosystems
The third assessment activity involves linking the research being done with community efforts to monitor their natural resources and livelihoods. The provision of more reliable information can lead to more informed decisionmaking. This approach encourages community interest in information about alternative livelihood options and/or ways to improve their livestock-based systems, such as with improved breeding and health management practices.

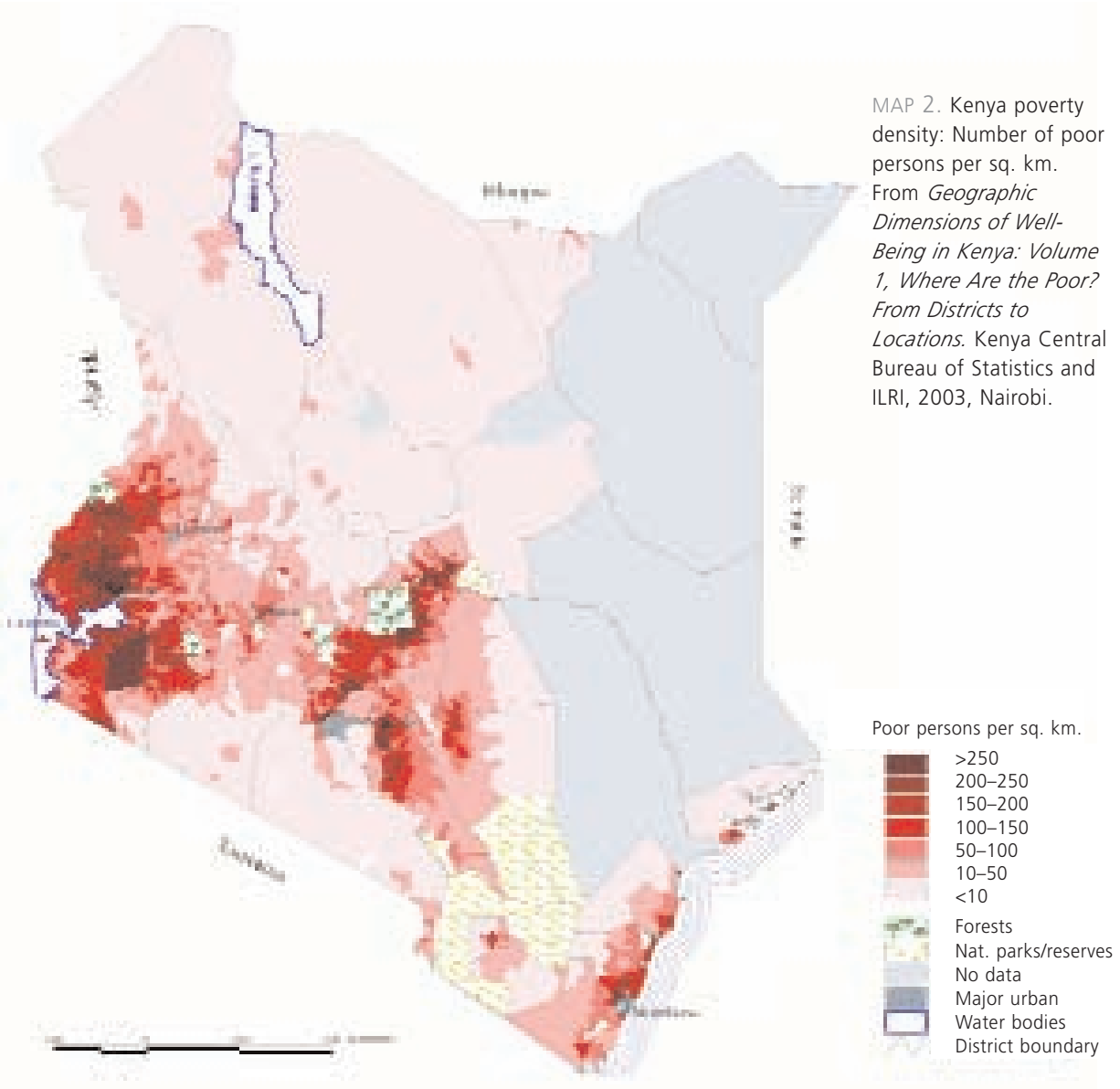
The Kitengela community remains in flux: the lions are still killing livestock and the pastoralists are still killing lions. Those who lose their livestock move to the nearby Athi River Industrial Park in search of work. So the Maasai are moving to town, and other tribes are moving into a traditionally Maasai area. "There is a lot of dynamic change going on in the area," says Kristjanson. "Our research is contributing to better policy options, and is helping to diversify income sources for the Maasai. We're working with many stakeholders to develop good sustainable options that won't wreck the environment, won't kill the livestock, and that broaden livelihood opportunities in the community."

Recent research impacts on saving Kitengela's wildlife-rich agroecosystem

The research collaboration between the Kitengela community and CGIAR research Centers and partners opened up a new dialogue between the numerous stakeholders involved in the area's wildlife-people-livestock conflicts and the new Kenyan government. The importance of this more informed dialogue was underscored this month when the Kenya Minister of the Environment announced that the government will not be fencing Nairobi National Park. This landmark Kenya government decision will allow the Maasai community to continue to benefit from wildlife and tourism. This is demonstrable evidence of the power of research to make a difference by steering policymakers towards win-win solutions that both conserve Kenya's wildlife heritage and reduce poverty among its pastoral peoples.



MAP 1. Kenya poverty incidence at the Location level: Percent of population living below the rural poverty line. From *Geographic Dimensions of Well-Being in Kenya: Volume 1, Where Are the Poor? From Districts to Locations.* Kenya Central Bureau of Statistics and ILRI, 2003, Nairobi.



MAP 2. Kenya poverty density: Number of poor persons per sq. km. From *Geographic Dimensions of Well-Being in Kenya: Volume 1, Where Are the Poor? From Districts to Locations.* Kenya Central Bureau of Statistics and ILRI, 2003, Nairobi.

THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

(CGIAR)

CGIAR is a strategic alliance of countries, international and regional organizations, and private foundations supporting 16 international agricultural research Centers that work with national agricultural research systems, the private sector, and civil society. The alliance mobilizes agricultural science to reduce poverty, foster human well-being, promote agricultural growth, and protect the environment.

Agriculture, the key to development

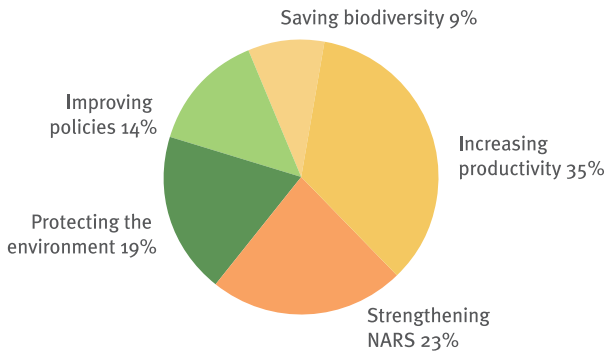
In a world where 75 percent of poor people depend on agriculture to survive, poverty cannot be reduced without investment in agriculture. Many of the countries with the strongest agricultural sectors have a record of sustained investment in agricultural science and technology. The evidence is clear — research for development generates agricultural growth and reduces poverty.

Agricultural research benefits people and the planet

Agricultural research for development has a record of delivering results. The science that made possible the Green Revolution of the 1960s and 1970s was largely the work of CGIAR Centers and their national agricultural research partners. The scientists' work not only increased incomes for small farmers, it enabled the preservation of millions of hectares of forest and grasslands, conserving biodiversity and reducing carbon releases into the atmosphere. CGIAR's research agenda is dynamic, flexible, and responsive to emerging development challenges. The research portfolio has evolved from the original focus on increasing productivity in individual critical food crops. Today's approach recognizes that biodiversity and environment research are also key components in the drive to enhance

sustainable agricultural productivity. Our belief in the fundamentals remains as strong as ever: agricultural growth and increased farm productivity in developing countries creates wealth, reduces poverty and hunger, and protects the environment.

CGIAR high-priority investments 2002



Agricultural research is delivering results

The CGIAR's more recent outstanding achievements include:

- Quality protein maize (QPM), a more nutritious type of maize bred for improved human health, is being planted on 1 million hectares in 20 countries.
- New rices for Africa (NERICAs) are transforming agriculture in the humid West Africa region. In 2002 NERICAs were planted on 14,000 hectares in Guinea and western Côte d'Ivoire, and their use is spreading across Africa. In Guinea alone, NERICAs have saved an estimated US$ 13 million in rice import bills.
- Afghanistan's agriculture is being rehabilitated. A major seed supply and distribution program has been implemented, and technical assistance is being provided to rebuild agriculture devastated by years of war, strife, and drought.

- Integrated aquaculture/agriculture techniques are resulting in increased rice and fish production in Asia. New strains of tilapia, which grow 60 percent faster, have been introduced.
- Over 75,000 developing country scientists and researchers have been or are being trained.
- Pesticide use in developing countries has been reduced by promoting integrated pest management and biological control methods.
- Zero or low-till farming practices are being introduced in Africa and Asia, minimizing soil erosion and boosting farm incomes and productivity.
- African producers are being enabled to exploit international pigeon pea markets.
- Agroforestry initiatives are being developed with community organizations in Asia and Africa.
- CGIAR researchers have won the World Food Prize for three years in a row.

These successes notwithstanding, future challenges are daunting. World population is expected to reach 9 billion by 2050. Food demand is expected to more than double over the same time period. Some 30 percent of irrigated lands are already degraded, and water use is expected to increase by 50 percent over the next 30 years. Science-based solutions for sustaining productivity increases while protecting ecosystems are key to addressing these challenges.

Increasing sustainable productivity, strengthening science-for-development partnerships, protecting the environment

The CGIAR was created in 1971. Today more than 8,500 CGIAR scientists and staff are working in over 100 countries. CGIAR research addresses every critical component of the agricultural sector, including agroforestry, biodiversity, food, forage and tree crops, pro-environment farming techniques, fisheries, forestry, livestock, food policies, and agricultural research services. Thirteen of 16 Centers are headquartered in developing countries. Africa continues to be a priority for CGIAR research. CGIAR research partnerships help achieve the Millennium Development Goals and support major international conventions (Biodiversity, Climate Change, and Desertification). The knowledge generated by the CGIAR is available to all.

The CGIAR has five areas of focus

- Increasing productivity (of crops, livestock, fisheries, forests, and the natural resource base)
- Strengthening national systems (through joint research, policy support, training. and knowledge sharing)
- Protecting the environment (by developing new technologies that make more prudent use of land, water, and nutrients, and help reduce agriculture's adverse impacts on ecosystems)
- Saving biodiversity (collecting, characterizing, and conserving genetic resources — the CGIAR holds in public trust one of the world's largest seed collections freely available to all)
- Improving policies (with a major impact on agriculture, food, health, the spread of new technologies, and the management and conservation of natural resources)

A twenty-first century alliance

Major reforms designed to strengthen science, extend the alliance, streamline governance, and maximize impact are yielding benefits. The innovative Challenge Program initiative is designed to address issues of critical importance, such as combating micronutrient deficiencies and improving water use efficiency in agriculture.

The CGIAR alliance is open to all countries and organizations sharing a commitment to a common research agenda and willing to invest financial support and human and technical resources. In 2002 four new Members joined the alliance and membership is growing.

CGIAR Members contributed US$ 346 million in 2002, the single largest public goods investment in mobilizing science for the benefit of poor farming communities worldwide.

CGIAR's evolving research agenda

A SNAPSHOT OF THE WORK OF THE CGIAR CENTERS IN KENYA

The Centers of the CGIAR, working with the strong network of public sector and civil society partners, have helped advance agricultural development in Kenya. Most of the CGIAR Centers operate research programs in the country.

International Center for Tropical Agriculture (CIAT)

New varieties of beans give higher yields

Farmers in western Kenya have adopted new varieties of beans that resist root rots and produce yields more than double those of the commonly grown local varieties susceptible to such diseases. In response to a root rot crisis, CIAT and the Kenya Agricultural Research Institute (KARI) worked with the extension service of the Ministry of Agriculture (MoA) to introduce 27 improved bean varieties. In a complementary participatory research project, local farmers selected 11 of those varieties as the best. Seed from the chosen germplasm was multiplied and distributed via women's groups, government extensionists, and an NGO. A recent impact study shows one of the new bush beans was being grown by 80 percent of farmers surveyed in one district and by 42 percent in another. Two other varieties had smaller adoption rates in both districts. The rate of adoption was highest in Vihiga District, which is one of Africa's most densely populated regions, with 850 persons per square kilometer.

Center for International Forestry Research (CIFOR)

Building forest-related research capacity

CIFOR has conducted three regional studies of forest-related research capacity in Africa. In 2001/02 CIFOR initiated a collaborative research initiative with the Kenya Forestry Research Institute (KEFRI). The FAO-supported study assessed the research capacity of 47 organizations in several East African countries, including Kenya. Country representatives from the region participated in a training workshop hosted by KEFRI in July 2001. Participants learned study methods from CIFOR scientists before returning home to apply them in assessing their national research systems. In January 2002 KEFRI and CIFOR organized the data analysis and writing workshop at Makerere University, Uganda, where findings were shared and the capacity information was analyzed. The final report is in press and, like earlier studies, is expected to influence investor funding for building research capacity in the region.

International Center for Wheat and Maize Improvement (CIMMYT)

Protecting maize from pests

"Without maize, there is no food." The Kenyan saying reflects the hard reality of life for the country's smallholder subsistence farmers. CIMMYT and KARI have collaborated to increase maize harvests through technologies that cut losses due to pests — specifically, stem borers and the parasitic weed striga. The Insect-Resistant Maize for Africa (IRMA) project brings KARI and CIMMYT researchers from diverse disciplines together to develop maize that is resistant to stem borers, which inflict yield losses of 15 percent annually (estimated value of losses US$ 72 million). Conventional breeding and genetic engineering are used to produce varieties that are better adapted to Kenya's diverse agroecological zones. The two institutes also teamed up with the Weizmann Institute to develop a novel, but simple, seed treatment method that protects maize from striga, which infests more than 75 percent of the farmland in western Kenya, causing an estimated US$ 1 billion in crop losses.

International Potato Center (CIP)

Developing a taste for sweet potatoes

Over the past seven years, over 70 partners have worked together under the umbrella of the Vitamin A for Africa (VITAA) initiative to fight vitamin A deficiency in Kenya. Among them, CIP, KARI, and the Rural Energy and Food Security Organization (REFSO), an NGO based near Lake Victoria, have teamed up to introduce orange-fleshed sweet potato in four Kenyan districts with the highest rates of vitamin A deficiency. CIP begins by breeding improved varieties of sweet potatoes to meet African consumer requirements while providing good levels of beta-carotene. The Center forwards these to KARI, whose Kakamega station provides a continuous supply of basic materials to REFSO. REFSO then organizes the production and distribution of vines and tips (sweet potato is planted using vine cuttings) to strategically placed farm families for testing and promotion. CIP works closely with KARI and REFSO to ensure quality control of the vine production. Over 3 million vine cuttings have been distributed to some 200 farm families, who in turn have passed the material on to their neighbors, promoting better nutrition for thousands of rural people.

International Center for Agricultural Research in the Dry Areas (ICARDA)

Improvements in crops and soil water use

Kenya cooperates with ICARDA in malting and forage barley improvement through its National Plant Breeding Research Center (NPBRC), based in Njoro. ICARDA recently supplied a special collection of 42 elite lines to NPBRC for use in the Kenyan barley improvement program, and eight barley nurseries were provided to select lines suitable for cultivation in Kenya. ICARDA has also been involved in the improvement of food and forage legumes (chickpea, dry pea, lathyrus, and vetch crops) for Kenyan agriculture. In cooperation with KARI, Moi University, and Kenya's National Dryland Farming Research Center, ICARDA has been undertaking crop improvement research and providing improved germplasm to Kenya.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Helping farmers meet market demand

ICRISAT is involved in an innovative system to ensure that farmers in semi-arid areas can benefit from market opportunities. Considering more than 70 percent of Kenya is semi-arid, this is without question a significant initiative. The focus is on grain legumes because of the strong domestic, regional, and international demand for these foods. To do this, ICRISAT works with a range of development partners: Catholic Relief Services (CRS), to organize farmers into production marketing groups; private sector partners such as the Kenya Agricultural Commodity Exchange (KACE), to provide market information and to facilitate trading; and TechnoServe, an organization with expertise in enterprise development, to develop a strong and vibrant private sector. On the science and technology front, ICRISAT works with KARI to ensure that farmers have the right varieties to meet market demand, and that they can increase productivity.

International Food Policy Research Institute (IFPRI)

Research projects to improve food security

Kenya is one of six countries participating in IFPRI's Network for East Africa, an innovative effort to reduce poverty and improve food security in the region using three main tools: collaborative research, strengthened capacity for food policy research and analysis, and improved communication of policy research. The network is guided by a regional advisory committee. Kenya has been an important focus of the network's research projects on rural services and agricultural markets, as well as its capacity-strengthening activities such as a competitive research grants program and proposal-writing workshops. The network's publications include a report on ways of improving delivery of animal health services for Kenyan farms. Kenya is also participating in an IFPRI-facilitated effort to design a collaborative masters program in agricultural and applied economics in East and Southern Africa.

International Institute of Tropical Agriculture (IITA)

Averting a crop disaster in western Kenya

When the devastating pandemic of the virulent Uganda variant of cassava mosaic disease (CMD) spread from Uganda to western Kenya, yield losses were so great that farmers started to abandon cassava cultivation. Six years ago IITA teamed up with KARI to tackle the problem. IITA, using its experience in fighting the pandemic in Uganda, provided diagnostic tools and CMD-resistant germplasm from its collection and was able to move the material quickly into western Kenya (working in conjunction with the Kenya Plant Health Inspectorate Service). As a result of the rapid multiplication and distribution of the new cassava, with the assistance of participating farmers and NGOs, production has returned to prepandemic levels and next year the harvest is expected to be even larger. The project is a fine example of the longstanding cooperation between IITA and Kenya's agricultural research system for achieving development impact.

International Livestock Research Institute (ILRI)

Smallholder dairy marketing for nourishment and income

ILRI was founded in Kenya in 1972. Among ILRI's closest Kenyan partners are KARI, MoA, and the Ministry of Livestock and Fisheries Development (MoLFD). Among their current collaborative projects are an award-winning Smallholder Dairy Project that is helping subsistence farmers market their products. Other Kenya-ILRI collaborative projects are helping highland farmers integrate livestock and crops for higher yields and better soils, determining the severity of droughts in the Horn of Africa, developing new diagnostics and vaccines against East Coast fever and trypanosomosis, and assessing development trade-offs in Kenya's wildlife-rich rangelands. Fifteen years of research by KARI, MoA, MoLFD, the Kenya Dairy Board, and ILRI has supported the ongoing boom in Kenya's smallholder dairy production, which — contributing up to 80 percent of the milk marketed in Kenya — has proved one of the most effective ways for poor Kenyans to nourish their children while generating incomes and jobs.

International Plant Genetic Resources Institute (IPGRI)

Strengthening the vegetable genebank

African leafy vegetables are important for food security, nutrition, and poverty alleviation throughout sub-Saharan Africa. They are adapted to local conditions and add to the genetic richness of home gardens. IPGRI's regional office in Nairobi has worked with local partners, including KARI, through the National Genebank of Kenya (NGBK) to increase understanding of the role of African leafy vegetables in production systems. IPGRI and NGBK have conducted surveys of 14 priority species. More than 1,000 accessions are currently documented and conserved in the genebank. Together with farmers, NGBK is characterizing six key species, which will be followed by participatory varietal selection and bulking of seed. A major outcome has been the discovery of two new species within the *Solanum nigrum* complex. One of these has exceptional characteristics — it is not bitter and therefore has great market potential.

International Water Management Institute (IWMI)

Controlling malaria in Kenya

As part of the Systemwide Initiative on Malaria and Agriculture (SIMA), collaborative research by IWMI and the International Centre of Insect Physiology and Ecology (ICIPE) in the Mwea irrigation scheme in Kenya has helped identify opportunities for improving the health and economic well-being of communities in rice irrigation schemes. Water management practices were researched for their potential to reduce malaria and other health risks — in particular the wet/dry irrigation method that involves the intermittent drying of rice fields. This method is effective as a means of saving water and killing off mosquito larvae. Farmer cooperatives have expressed interest in this method of boosting rice production under conditions of increasing water scarcity. Because malnutrition lowers people's immunity to disease, researchers also assessed the mixed crop and livestock production systems of the Mwea scheme to help improve household nutrition and income generation.

World Agroforestry Centre (ICRAF)

Agroforestry and conservation go hand in hand

The World Agroforestry Centre was founded in Kenya 25 years ago as ICRAF (International Centre for Research in Agroforestry). Close partnerships with Kenya's two principal national agricultural research institutions — KARI and KEFRI — have been vital to the success of its work and the impact it has had on Kenyan farmers. The foundations for the science of agroforestry were laid in Kenya and expanded through the Machakos field station set up in 1981. From there were developed improved fallows of leguminous trees to restore the fertility of degraded soils and increase crop yields and the incomes of small holders. These practices are now being used by tens of thousands of Kenyan farmers. In partnership with national and international institutions, the Center also introduced the use of fodder shrubs as low-cost dairy feed options. Mixed agroforestry systems developed around the periphery of the Mount Kenya World Heritage Site are providing poor people with alternative sources of timber and income. Agroforestry is also helping to restore the health of the Lake Victoria watershed.

WorldFish Center

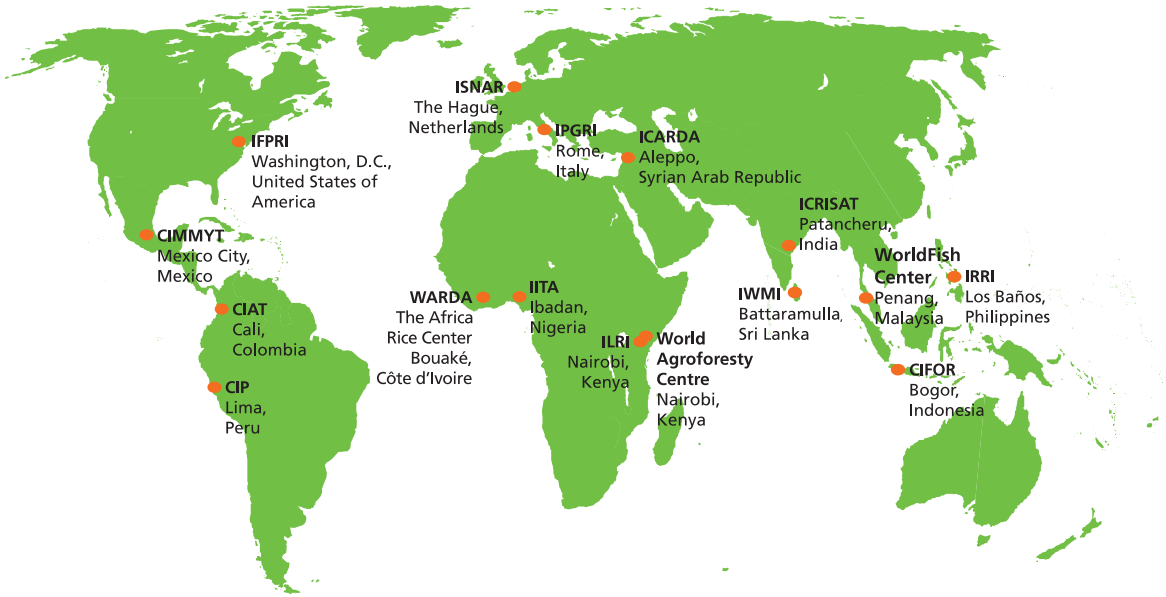
Fostering the development of aquaculture in Africa

In 2002 Kenya hosted a groundbreaking meeting on the impacts of using genetically improved and alien species in aquaculture in Africa. Convened in Nairobi with the support of the WorldFish Center, the Technical Center for Agricultural and Rural Cooperation (CTA), the World Conservation Union, FAO, UNEP, and the Convention on Biological Diversity (CBD), the workshop brought together over 40 aquaculturists, geneticists, and conservation specialists to develop guidelines that will foster the development of aquaculture in Africa while maintaining the continent's aquatic biodiversity. The meeting issued the Nairobi Declaration on Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species for Aquaculture in Africa (http://www.worldfishcenter.org/news/news_9.htm). This landmark document is being widely used across the continent to guide policies and research on these issues.

ABBREVIATIONS AND ACRONYMS

AGGDP	agricultural gross domestic product
AIDS	acquired immunodeficiency syndrome
ALS	acetolactate synthase
ATIRI	Agricultural Technology and Information Response Initiative
Bt	*Bacillus thuringiensis*
CBD	Convention on Biological Diversity
CCPP	contagious caprine pleuropneumonia
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical)
CIFOR	Center for International Forestry Research
CIMMYT	International Center for Wheat and Maize Improvement (Centro Internacional de Mejoramiento de Maíz y Trigo)
CIP	International Potato Center (Centro Internacional de la Papa)
CMD	cassava mosaic disease
COSOFAP	Consortium for Scaling Up Options for Increased Farm Productivity
CRS	Catholic Relief Services
CTA	Technical Center for Agricultural and Rural Cooperation
EAAFRO	East African Agriculture and Forestry Research Organization
EAVRO	East African Veterinary Research Organization
ECF	East Coast fever
FAO	Food and Agriculture Organization of the United Nations
FONNAP	Friends of Nairobi National Park
FTE	full-time equivalent
HIV	human immunodeficiency virus
ICARDA	International Center for Agricultural Research in the Dry Areas
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	World Agroforestry Centre (formerly International Centre for Research in Agroforestry)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture

IPGRI	International Plant Genetic Resources Institute
IR	Imazapyr-resistant
IRMA	Insect-Resistant Maize for Africa
ISAAA	International Service for the Acquisition of Agri-biotech Applications
ITM	infection and treatment method
IWMI	International Water Management Institute
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KACE	Kenya Agricultural Commodity Exchange
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
KEMFRI	Kenya Marine and Fisheries Research Institute
KETRI	Kenya Trypanosomiasis Research Institute
KILA	Kitengela Ilparakuo Landowners Association
KIRDI	Kenya Industrial Research and Development Institute
KRDS	Kenya Rural Development Strategy
LAT	latex agglutination test
MICH	Maseno Inter-Christian Self-Help Group
MoA	Ministry of Agriculture
MoLFD	Ministry of Livestock and Fisheries Development
NALEP	National Agricultural and Livestock Extension Programme
NERICA	new rice for Africa
NGBK	National Genebank of Kenya
NGO	nongovernmental organization
NPBRC	National Plant Breeding Research Center
OTC	oxytetracycline
PRSP	poverty reduction strategy paper
QPM	quality protein maize
R&D	research and development
REFSO	Rural Energy and Food Security Organization
RELMA	Regional Land Management Unit
RVF	Rift Valley fever
SDP	Smallholder Dairy Project
SIMA	Systemwide Initiative on Malaria and Agriculture
TIGR	The Institute for Genomic Research
TRIEA	Tea Research Institute of East Africa
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VITAA	Vitamin A for Africa



CGIAR-supported Centers

International Center for Tropical Agriculture (CIAT)
www.ciat.cgiar.org

Center for International Forestry Research (CIFOR)
www.cifor.org

International Maize and Wheat Improvement Center (CIMMYT)
www.cimmyt.org

International Potato Center (CIP)
www.cipotato.org

International Center for Agricultural Research in the Dry Areas (ICARDA)
www.icarda.org

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
www.icrisat.org

International Food Policy Research Institute (IFPRI)
www.ifpri.org

International Institute of Tropical Agriculture (IITA)
www.iita.org

International Livestock Research Institute (ILRI)
www.ilri.org

International Plant Genetic Resources Institute (IPGRI)
www.ipgri.org

International Rice Research Institute (IRRI)
www.irri.org

International Service for National Agricultural Research (ISNAR)
www.isnar.cgiar.org

International Water Management Institute (IWMI)
www.iwmi.cgiar.org

West Africa Rice Development Association – The Africa Rice Center (WARDA)
www.warda.org

World Agroforestry Centre (ICRAF)
www.worldagroforestrycentre.org

WorldFish Center
www.worldfishcenter.org

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