WATER MANAGEMENT TECHNOLOGIES FOR SUSTAINABLE AGRICULTURE IN KENYA

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ABSTRACT

Improving food production in Kenya, as well as elsewhere in sub-Saharan Africa (SSA), is a daunting problem. Agricultural production is generally low, averaging less than one ton per hectare, which translates to a continuing cycle of poverty for millions of smallholder farmers. Improved utilization of water resources for agricultural production is an important prerequisite for increasing food production and incomes. This paper reports on experiences with a number of water management technologies and approaches in Kenya that are leading to sustainable increases in agricultural production and increased employment and incomes for smallholder farmers. Among these improvements are rainwater harvesting, improved performance of smallholder irrigation schemes, micro-irrigation technologies, and the participation of smallholders in export-oriented vegetable and other high-value crops production. Farmers who have access to seasonal water runoff can improve production with rainwater harvesting technologies. Modest investments and technical support have measurably improved the performance of existing smallholder schemes in Kenya. Micro-irrigation technologies, such as treadle pumps and low head drip kits, have provided farmers with low-cost methods of improving water management and agricultural production. Smallholder farmers throughout Kenya are participating as outgrowers in the production of export-oriented crops, meeting international quality and safety standards and substantially increasing incomes. The paper discusses these promising technologies and highlights recent research and interventions.

INTRODUCTION

Agricultural production in Kenya, as in most of sub-Saharan Africa (SSA), has long been stagnant with per capita production decreasing 33% between 1980 and 2000 (Earthtrends, 2006). The generally accepted wisdom is that the green revolution, which boosted Asian countries' production, bypassed African countries. A number of reasons are given for this missed opportunity: lack of transportation and marketing infrastructure, poor adoption rates of new varieties, lack of reasonably priced fertilizer, poor governance in the countries involved, poor water resource availability, and lack of investment in irrigation. Kenya's agriculture, like many other countries in the region, is highly susceptible to drought. Despite this grim picture, Kenya's economy (GDP) grew at the rate of 5.5% in 2005 (CIA, 2007). While irrigated agriculture comprises only 1.5% of total land under agricultural production, it contributes 18% of the value of all agricultural produce (Mwarasomba, 2006). This paper updates some of the technologies and approaches described in a more detailed earlier publication (Blank et al. 2002). One of the

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greatest niche opportunities is to supply fresh horticulture and floriculture crops to the European market during the winter months. Private investors in a number of SSA countries have seized on this opportunity. For example in Kenya, one company weekly exports 500 tons of cut flowers and vegetables to Great Britain via a dedicated fleet of large jet aircraft (Flamingo Holdings, 2007).

Agriculture is the major economic activity for 75 to 85% of the populations of the SSA countries (Ngigi, 2003). The vast majority of this activity is subsistence farms, reliant on rainfall and subject to drought. A major assistance to these subsistence farmers would be affordable rainwater storage for supplemental irrigation and adoption of drought resistant crops—the first of the approaches discussed in this paper.

RAINWATER HARVESTING

One of the promising solutions to increase agricultural productivity in SSA is upgrading rainfed agriculture through rainwater harvesting and management (RHM) systems. RHM systems are diverse and range from in-situ moisture conservation to large runoff storage systems and flood diversion and spreading (spate irrigation).

Rainwater Harvesting Research

Ngigi (2006a) conducted research on rainwater harvesting in Kenya and other countries in SSA as part of his PhD dissertation. The results of his study revealed that there a number of viable RHM systems that can improve agricultural production in semi-arid environments, although their effectiveness is limited by high water losses, inadequate storage capacity, poor water management, high occurrence of dry spells and drought, farmers' risk aversion, and financial constraints to invest in new farming systems.

On-farm storage systems for supplemental irrigation were found to be an economically viable alternative for smallholder farmers. A simulation of seasonal runoff using 16 years of rainfall records was carried out for a typical semi-arid environment in Matanya, Kenya (Figure 1 locates geographic placenames discussed in this paper) with average rainfall of 787 mm yr^{-1}. Rainfall was concentrated in two seasons per year, with average rainfall of 209 mm and 295 mm respectively. The simulation determined the reliability of a RHM system with a catchment size of 0.5 ha and a cropped area of 0.2 ha in meeting supplemental irrigation requirements. Despite relatively small landholdings, the availability of catchments to generate adequate runoff was not a limiting factor. The study found that grazing land generated adequate runoff for filling 50 m^3 farm ponds. Other opportunities include diversion of runoff concentrated by roads, footpaths and cattle tracks.

Optimal design parameters for sizing storage ponds were developed at the 80% reliability level. Optimal designs would improve overall system reliability, and reduce hydrological risks and crop failures. A benefit-cost analysis of a 50 m^3 pond and low-head drip irrigation system with total investment cost of $650 showed a net increase in income of $150 per season for an improved RHM system versus the conventional dryland system, with a payback period of about four seasons, or two years.

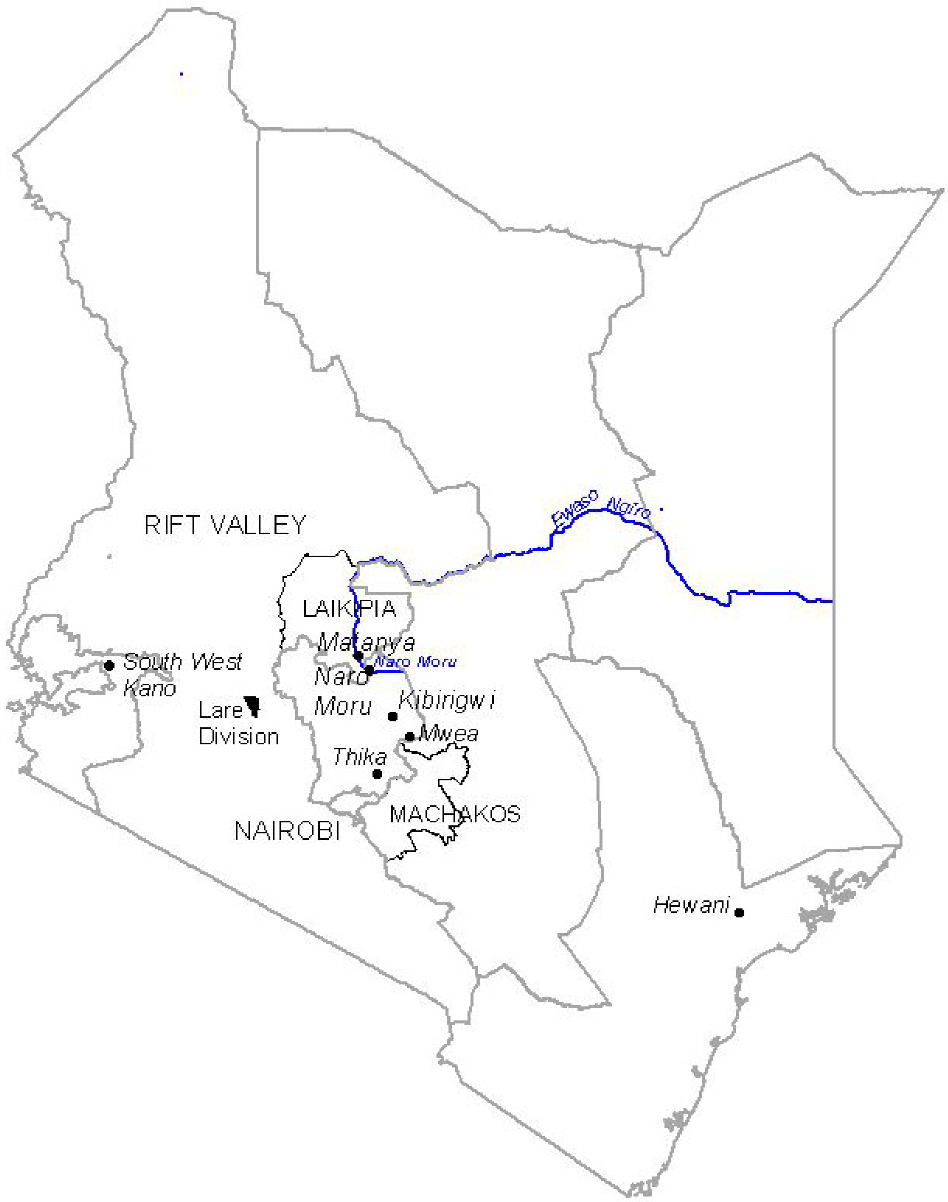

Figure 1. Location map of irrigation sites in Kenya

A study of on-farm ponds was carried out in the semiarid Laikipia area of Kenya with average rainfall ranging from 500 to 900 mm yr^{-1} (Ngigi, 2003). One of the survival strategies adopted by recently settled farmers was to construct on-farm ponds. The pond sizes ranged from 50 to 1500 m^3, with the storage potential varying by pond size and water losses due to seepage and evaporation. Most ponds were able to store water for 4 to 16 weeks after the cessation of rain, thus allowing for production using the stored water as supplemental irrigation. This technology is adaptable to a large part of the district.

Although RHM systems reduce the impacts of drought, their adoption is affected by high investment costs, the relatively low economic status of farmers, farmers' risk aversion, inadequate design, and poor water management. Although promising, RHMs alone cannot assure sustainable production. The need for improved agronomic practices, such as timely planting to take advantage of expected rainfall, cannot be over-emphasized. The challenge is to convince poor and risk-averse smallholder farmers that they can benefit by improving their agricultural production systems. An integrated approach is a prerequisite for achieving sustainable solutions.

The Lare Experience

While in general Kenyan farmers have not adopted rainwater harvesting, farmers in certain areas have adopted these techniques to an impressive degree. One such area is the Lare Division of Nakuru District. This agricultural area has a bi-modal precipitation pattern ranging from 600 to 1000 mm yr^{-1} with little access to ground water or perennial streams (Mati and de Vries, 2005). In a project conducted between 1998 and 1999, farmers were trained in various rainwater harvesting technologies. This project was a collaboration between Kenya Agricultural Research Institute (KARI), Egerton University, local NGOs, Ministry of Agriculture (MoA) and the United Nations Development Program. Training modules were developed to empower farmers to be able to do their own site selection, calculate water-storage capacity, construct and maintain water pans, and use the water for irrigation of crops suitable to local conditions. Treadle pumps were introduced to draw water from the pans to the cultivated fields. Since the project ended, the adoption rate for rainwater harvesting has continued to grow. In 1998, about 409 households had runoff harvesting systems, these increased to about 1,030 households by the end of 1999, and to 2,000 by August, 2004. Recently, using satellite imagery, Malesu and others (2006) found nine farm ponds per square kilometer in the Lare area, with most households possessing ponds. In addition to farm ponds, researchers found that farmers use other rainwater harvesting techniques as well, including roof catchments and in-situ soil moisture conservation such as pits and runoff farming.

Farmers have identified several problems which affect adoption: lack of information on proper sizing and other design information, and high infiltration rates experienced with some types of soils. These factors limit adoption to a wider group of farmers. Economically, farm ponds appear to make good economic sense. In Lare, farmers are less prone to drought and report increased production throughout the year. Milk production has increased through increased fodder production and better livestock water availability, and farmers report savings in labor costs that were previously expended to obtain water from distant sources.

Environmental Effects

In general, the negative environmental impacts of RHM systems are minimal. Ground catchment systems for community use and individual farm pond systems in Lare had positive environmental impacts by reducing storm runoff and erosion, and stimulating tree planting. Questions about ground water recharge remain, although it is clear that seepage and deep percolation from ponds contributes to ground water recharge. Ngigi (2003) found that adoption of RHM systems in Machakos District led to rejuvenation of springs downstream that had ceased to flow. There is concern that RHM systems may intercept runoff in the upstream part of the catchment, thus depriving potential downstream users of their share of the resource.

The Ewaso Ng'iro River basin has been studied by numerous researchers (Gichuki, 2003). Excessive water extraction by upstream irrigators has resulted in diminished river flows. Irrigators compete with downstream pastoralists who need water for livestock and with the needs of wildlife and the tourism industry. For example, in the Naro Moru sub-basin, only 25 of 100 irrigators have permits, and only half of the permits have been authenticated by the Ministry of Water and Irrigation. While it has been proposed that water users associations would improve water resources management in the Ewaso Ng'iro basin, reality dictates that a suitable solution would be to develop more upstream storage.

RHM systems in the Ewaso Ng'iro basin can provide an alternative water source that could reduce the demand on river flows and over-extraction during dry seasons (Ngigi, 2006a). RHM systems can be small to medium on-farm storage structures, such as are common in Lare, or can be off-stream storage reservoirs for larger communities. These structures would provide storage for excess runoff and flood flows that would be stored for use during low flow periods. By storing excess rainy season runoff and reducing dry season abstractions, flows would be more evenly distributed and available to downstream users throughout the year. The Government of Kenya (GOK) Water Act requires applicants for water permits to have facilities for 90-day storage. Unfortunately, stricter compliance of this condition is needed.

An evaluation of RHM systems in Ethiopia, Uganda, Kenya, and Tanzania identified some environmental issues that need to be addressed (Ngigi, 2003). These issues include increased mosquito and snail populations in open ponds, soil erosion along inlet channels, poor water quality, and risk of drowning in deep ponds. On the other hand, RHM technologies such as terracing generally reduce soil erosion by capturing sediment. Rainwater harvesting from rooftops for domestic use generally provides good quality water if minimal precautions are taken. Inadequately designed or constructed dams, spillways and canals also are environmental hazards. The study noted that expansion of RHM systems in upstream areas would not significantly deprive downstream water users of the resource.

A study of rainwater harvesting in Syria, Pakistan and Egypt looked at the impacts of the technologies at different spatial scales (Ali et al., 2007). At the micro-catchment scale (25-50m^2) in Syria, the researchers found insignificant localized effects downstream. At larger spatial scales, the study found greater effects. At the farm-scale in Pakistan under low rainfall conditions, the study found conflict among farmers who were competing for the limited water resource. At the larger watershed scale (i.e. between villages) in Egypt, the study found the potential for larger upstream-downstream impacts. For example, farmers often construct bunds across dry wadi beds to capture runoff. During high rainfall events, these bunds may break and can cause chain breaching and heavy soil erosion, destruction of property, and even loss of human life downstream. Nevertheless, despite some of the identified issues, the positive socio-economic and environmental impacts of RHM systems outweigh the negative impacts in the Kenya cases.

IMPROVING SMALLHOLDER IRRIGATION SCHEMES

The Improving the Performance of Irrigation in Africa (IPIA) project in Kenya, funded by the French government, attempted to increase performance of irrigation schemes through relatively low cost interventions. The aim was to develop irrigation as a profitable enterprise through development and dissemination of appropriate technologies, irrigation capacity building for farmers, support for water users associations (IWUAs) and extension staff, production improvement through enhanced water productivity, use of appropriate agronomic practices, improved enterprise profitability, and establishment of an interactive database for information sharing and networking among stakeholders. Manuals were produced based on a methodology of participatory rapid diagnosis and planning (van der Schans and Lemperiere, 2006). Ten pilot schemes were identified and project activities were carried out between 2003 and 2006. Project funding was extremely limited, with IPIA funding averaging less than $3,000 per site, while GOK and local contributions were estimated at up to $90,000 per site.

The project resulted in significant yields increases through most of the schemes, particularly at Mwea, Kibirigwi, Naro Moru, and Hewani. Secondary data from Hewani indicated a three-fold increase in yield, while yield more than doubled in a Kibirigwi scheme with improved water application. In Mwea where there had been no IWUA, a well-trained management committee was established after several sensitization meetings were held. The National Irrigation Board (NIB), which had previously been rejected by the farmers due to its top-down approach, has now been accepted as the water service provider. Farmers now benefit from the services the government and other stakeholders are able to offer. Infrastructure improvements have been undertaken resulting in more equitable distribution of water, among other benefits. While some farmers have enjoyed an increase of 750 to 1,250 kg/ha due to proper use of fertilizer and other crop husbandry techniques, in previously-contentious Block W3, the increase is more than 100%. Some farmers who harvested less than 25 bags/ha reported yields of more than 62.5 bags/ha due to assured provision of water brought about by their IWUA. Farmers now receive water in a one- to two-week rotation to avoid crop losses.

Another improvement was growing of more than one crop per year, especially in the Mwea scheme where one rice crop was traditionally grown and the land left fallow the rest of the year. Farmers are now able to grow other crops immediately after harvesting the rice crop; these include soya beans, green gram (a leguminous plant also known as mung bean), and short-season corn. Other crops grown in the scheme are sunflower, French beans, passion fruit, tomatoes, and other leguminous and horticultural crops. The same trend was found in Naro Moru and Kibirigwi schemes where new crops were introduced to increase farm profitability through improved plot use.

In Southwest Kano, the IPIA initiative was timely because it coincided with the planned revival of the scheme after five years of abandonment. The project has contributed to reduced canal siltation and unauthorized water diversions through training farmers and extension staff on water management. The training included land leveling to improve on-plot water use efficiency. While other stakeholders contributed to improved plot use through training on agronomic practices, IPIA facilitated the formation of an operational water users association in the scheme.

The results of this modest project have been surprisingly good. After being a relatively neglected sector in Kenya for many years, irrigation is now picking up. Farmers are receptive to the assistance when their voices are heard, as has been the approach of the IPIA project. Farmers are open to new markets and realize that cooperation over water allocation is essential for sustainable improvements in income.

MICRO-IRRIGATION TECHNOLOGIES

Treadle Pumps

KickStart, formerly known as ApproTEC, is a non-profit social enterprise, which for the past 15 years has produced a manual irrigation pump and other products that have been marketed to smallholders in Kenya and other SSA countries. The design of the pump has been continuously upgraded. A very efficient pressure pump has been developed: it allows two people working eight hours per day to irrigate nearly one hectare from a shallow water source. The maximum suction lift of the pump is 7 m and the maximum total pumping head is 14 m. As of 2006, KickStart had sold over 66,000 of its MoneyMaker line of pumps and created over 44,000 successful family enterprises generating over $47 million in annual profits. This novel approach to irrigation now accounts for over 0.5% of Kenya's gross national product.

This success story has been closely followed by the international community, as well as other non-profit organizations. The key to the success in Kenya appears to be the marketing and the national distribution network. The pumps are widely advertised in local media, and a substantial amount of the KickStart budget goes to advertising. The pumps are widely available through a network of hardware stores throughout the country. KickStart has been firm in its conviction that serious farmers can find the resources to purchase the $95 pump, another key to the success. Giving away free pumps, as has been tried by various aid agencies, is not a successful approach because it does not discriminate the serious farmers prepared to produce crops for the market.

KickStart has recently introduced a Chinese-manufactured version of the treadle pump, produced at considerable cost savings compared to the locally produced version, with a strategy of covering more of the promotion costs from sales revenues. It has also introduced the MoneyMaker hip pump which is sold at $35 and is capable of irrigating about one-third ha.

Over the next three years, KickStart plans to expand into three more countries from their current operations in Kenya, Tanzania, and Mali. They expect to sell more than 125,000 pumps and create over 80,000 new irrigation businesses. They plan to introduce new and lower cost technologies, extend their marketing reach, and introduce a financing program to help farmers buy pumps. They are expanding their sales to other non-profit organizations, and continue to encourage the non-profits to adopt the proven KickStart model.

Low-Head Drip Irrigation Kits

Low-head drip irrigation systems were introduced in Kenya in the late 1980s. The earliest were supplied by missionaries but had limited impact (Sijali and Okumu, 2003). In 1996, the Kenya

Agricultural Research Institute (KARI) linked with Chapin, a U.S. manufacturer of drip irrigation equipment. Chapin supplied the kits, which were assembled and distributed locally through KARI. The kits are of various sizes. The smallest is the bucket kit consisting of a 20-liter bucket, an inline screen filter, PVC connector and header pipes, and four or more rows of conventional drip irrigation lines. The innovation of low head and good uniformity created a kit that was affordable and attractive to users, particularly for kitchen gardens. Tests of emission uniformity (EU) for 0% slope, 1.0 m head and 15 m lateral length have shown EU up to 90% depending on type of drip tape (Ngigi, 2006b). Larger kits, with storage ranging from 200 to 2,500 liters or more and drip lines covering 75-1,000 m^2 moved the farmer to a commercial producer. Various crops are successfully grown with the kits, including traditional vegetable crops such as green beans, tomatoes, cabbage as well as irrigated maize and baby corn.

The early approach was to import the equipment in container lots with the kits assembled and distributed by KARI. The bucket kits were marketed at $10-15. Demonstration farms with knowledgeable staff trained and sold kits to interested farmers. Demonstrations also were conducted at agricultural fairs around Kenya with some media coverage. Over the first ten years, KARI sold 15,000 units despite the lack of a mass marketing approach, national dealer network, or technical support program. KARI is in the process of transferring distribution to the private sector.

Stephen Ngigi recognized the opportunity to put together drip kits made from locally available parts, including drip tubing manufactured in Kenya. This was marketed as the Dream Kit, available in three sizes. Between 2002 and 2005, more than 200 drum/mini-tank (200 liter) kits, 500 jerrican (40-100 liter) kits, and 800 bucket (20 liter) kits were sold without a mass marketing campaign or a national distribution network (Ngigi, 2006b).

Little work has been done to measure the impact of drip kits. A stakeholders' workshop was conducted in 2000, which obtained feedback from users of the kits (Winrock, 2000). This workshop identified minor problems with clogging and similar problems. It was reported that many kits distributed freely by intermediaries were abandoned. Where users have been convinced of the utility of the kits and purchased them themselves, the utilization rate is much higher. One study showed that gross margins realized from the sale of tomatoes and other high-value vegetables amounted to $60, $380 and $1090 from the 20 liter bucket kit, the 200 liter drum kit and a 1000 liter kit serving 500 m^2, respectively (Nyakwara et al., undated).

In follow-up evaluations by KARI in the Northern Rift Valley and in Eastern Kenya (KARI, 2003), it was found that the performance of the kits was good when used to grow both food and income generating crops for the market. In drier areas where boreholes have been developed for women's groups, the most suitable technology was the larger kit covering 2,500 m^2. At one site women hand watered outside the area of the drip kit in order to extend production. A drawback of the drip technology was the limited availability. The study found that drip irrigation technology needs to be extended together with rainwater harvesting and pumping technologies. Utilization of the drip irrigation kits in conjunction with treadle pumps and/or rainwater harvesting ponds is an attractive option for farmers, although the pressure treadle pump is usually used to irrigate crops directly.

SMALLHOLDER FARMERS OUTGROWERS PROGRAM

Homegrown, a group company of Flamingo Holdings, is a Kenyan company that produces cut flowers and vegetables for the European market. They have an outgrower program that works with over 600 outgrowers producing green beans and other crops in 11 regions around the country, including Naro Moro, Thika, and Machakos.

In Machakos, Homegrown works with 16 farmer groups, with 10-15 farmers per group. They produce fine and extra fine green beans, courgettes (zucchini), and sugar snap peas. The farmers are paid Ksh. 45 per kg ($0.65 per kg) for fine grade beans. The fine quality must be less than 8 mm diameter, and extra fine less than 6 mm. Crops are harvested in the morning, cooled at the collection sites, transported in the evening, and placed on supermarket shelves within 48 hours of picking.

Crops are produced for four or five supermarket chains in the United Kingdom (UK) which require the outgrowers to meet international quality and farm worker safety standards. Farmers are provided spraying equipment and training in safety procedures and are required to rotate crops and fallow bean fields for 6 months. Farmers are required not to spray during the period prior to harvest, with strict no-spray periods ranging between one and seven or more days depending on the type of pesticide used. Homegrown has a tracking system that can track shipments back to the individual farmer or at least to the farmer group. Also, farmers are provided with seeds according to what they can produce based on water availability and demand. One of the standards is that the farmers must have a permit for irrigation water.

Homegrown's strategy is to grow in various climatic zones so that crops are planted every week and harvested throughout the demand period. Diversifying the supply of produce from different regions minimizes the risk that Homegrown will be unable to provide the UK markets with their expected needs. This is important as water availability (and crop production) varies across the regions according to time of year. Demand by the supermarkets is particularly high in the winter months when European farmers are not producing. Homegrown has negotiated with the UK markets to purchase the crops grown in Kenya year-round, ensuring a more regular income for growers during the European summer months. This is an incentive to keep farmers supplying to Homegrown even when demand is high and “suitcase exporters” offer higher prices. Those farmers who sell outside the Homegrown network and reduce the agreed upon supply to UK markets, can be penalized (through reductions in purchases) when demand is generally low but when Homegrown is able to by produce due to their guaranteed market.

Some of the outgrowers use drip or sprinklers while others use furrow irrigation, diverting from spring fed streams and applying water from furrows to individual plants with hose pipes or buckets. Most farmers are in a water short situation, and may have a rotation system, each farmer getting water two days a week or less. Low-head drip has the following advantages for these farmers:

- Time and water saving in irrigating.
- Evenly spaced plants resulting in higher plant population per unit area.

- Improved uniformity of plants resulting in higher quality product.
- Option to fertilize through irrigation lines.
- Drip systems can be removed during fallow periods and used in other fields.

While air freight limits the number of crops, other crops suited to smallholders, such as mangoes and avocados, have started to be exported to Europe via ship. The potential advantages to farmers in terms of increased income are huge, especially in comparison to producing for the local market.

CONCLUSIONS

Farmers who have access to seasonal water runoff can improve production with rainwater harvesting technologies. In some areas of Kenya, farmers have shown high adoption rates of farm ponds and other rainwater harvesting technologies. Rainwater harvesting provides an increased level of drought protection, and it allows more flexibility in market timing for those farmers producing market crops.

Public sector investment in irrigation development has been minimal in Kenya since at least the 1980s. Many existing schemes have languished without technical and other assistance from government and other sources. The IPIA project approach has shown that in many cases modest investments and technical support can measurably improve the performance of these schemes. Efforts to encourage farmers to diagnose constraints affecting their irrigation schemes, plan and carry out improvements, strengthen farmer organizations to collect operation and maintenance (O&M) funds, improve water distribution, and market produce have been shown to be readily accepted by farmers.

Micro-irrigation technologies, such as treadle pumps and low-head drip kits, provide farmers with low cost methods of improving water management. Farmers who previously lifted water with buckets and irrigated with water cans respond readily to these labor saving technologies. Farmers who have no previous experience with irrigation or who have no experience with producing and marketing high-value crops may not respond so readily. The establishment of training and demonstration centers would assist farmers to make the transition from subsistence to commercial producer.

Farmers are expanding production for the local market and participating in export opportunities. Labor intensive crops such as green beans, are excellent crops for smallholders. In order to meet quality standards, exporters have established systems and trained smallholders in pest management, pesticide handling and safety, and improved agronomic practices. The grail for smallholders—the export of high-valued crops—remains elusive except to a small number of farmers, but valuable experience about producing for the European market is being gained. In order to expand the pool of qualified farmers, programs need to be developed to train and organize groups of farmers so that they can successfully work with exporters.

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