Relevance of Kenyan Irrigation Experience to Eastern and Southern Africa

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Introduction

Why Irrigation?

Most documents about agriculture in sub-Saharan Africa will normally have at least a sentence complaining that there is very little irrigation and that only about 5 percent of the irrigation potential is being exploited. However, despite its high profile, irrigation is only one method of managing the water available to plants. Consequently, the issue should not be how many hectares are under irrigation, but how many hectares get optimal amounts of water to meet crop needs throughout the growing season. The water can be supplied directly by rain or through irrigation. Planning for irrigation by a given farmer in a basin or a country should, therefore, be preceded by efforts to maximize and optimize the use of direct rainfall. This is especially important in cereal production systems in sub-Saharan Africa, for which irrigation often gives low returns and low profitability (FAO 1986, 48).

The point being emphasized here is that major improvements in cereal production in sub-Saharan Africa can be achieved by increasing the amount of biomass produced per unit of water used, under both rain-fed and irrigated farming. Further, irrigation should be designed for the purpose of enhancing water available for crop production only after direct rainfall has been used effectively. This point has been made before. For example, the FAO (1995a, 1) stated that adoption of the improved water-conservation technology in the Central Great Plains of the USA made the largest single contribution (45%) to the increase in average wheat yields from 750 kg/ha to 1,800 kg/ha from 1936 to 1977. This was ahead of improved varieties (30%), equipment (20%) and fertilizer practice (5%).

The concept of increasing the effectiveness of water use is also a major concern in irrigation. For example, Scheltema (2000) refers to the concept of tail-to-mouth approaches to rehabilitation of irrigation schemes. The basic principle of this approach is that farmers have to improve the efficiency of using the little water they have before efforts are made to increase the amount of water reaching the field. This emphasizes that, to be effective and profitable, irrigation should not do what can be achieved with direct rainfall but should rather supplement/complement and extend the productivity of rainfall. A field that cannot use rainwater effectively will rarely use irrigation water efficiently. In many farming systems, more than 70 percent of the direct rain falling on a crop field is "lost" as nonproductive evaporation or flows into saline sinks. In extreme cases, only 4–9% of rainwater is used for crop transpiration (Rockström et al. 1998).

Irrigation is one of the management tools available to farmers when combined with other tools and inputs enabling them to maximize productivity and profit. One vital role of supplementary irrigation, for example, is to even out the poor distribution (both spatial and temporal) of rainfall that often makes rain-fed farming a high-risk business. With irrigation to reduce the risk, a farmer can afford to invest in other inputs (e.g., fertilizer, improved seeds, etc.) for intensive production, but such inputs are also costly. Using these inputs without improved water management exposes the farmer to a big loss in case of drought at a critical crop-growth stage.

Since most of the countries in the region are adopting free-market economic systems, the extent and choice of irrigation should be demand-driven. This means that commercial requirements should guide farmers, communities and even countries to choose the type and extent of irrigation that is most suitable for their circumstances and businesses. This is a radical step given the recent history of irrigation development in sub-Saharan Africa, where governments have used irrigation as a tool for achieving social goals with very little economic considerations. Reasons for irrigation development have included attempts to achieve food self-sufficiency and security, creation of employment, establishment of settlements and boosting of foreign-exchange earnings. The governments have enacted policies that stipulate by how much, and by what means, irrigation will be developed in a country. Irrigation was supply-driven rather than demand-driven, and failures, such as that represented by the Bura irrigation scheme in Kenya (see under *Private investment,* 316) are consequences of this policy.

At this point, it is important to emphasize that the large public-irrigation schemes, which made news by failing miserably, are not the whole story of irrigation in the region. There are examples in all the countries reviewed in this paper of very successful large and small commercial irrigation schemes. Therefore, the review of the changing face of irrigation in the region, with special focus on Kenya, has come at the right time. It will provide an opportunity to learn from both failures and successes so as to properly guide the ongoing privatization and commercialization of the irrigation subsector in the region.

Status of Irrigation in the Case Study Countries

Examples from five countries in the region were selected to compare and assess the relevance of the Kenyan irrigation experience to eastern and southern Africa. The five countries, Sudan, Ethiopia, Zimbabwe, Mozambique and Tanzania, provide different frameworks on which to extrapolate the experience from Kenya. The region also provides an attractive possibility of developing irrigation to meet regional needs rather than local food self-sufficiency. If countries, basins or households can be freed from the need for food self-sufficiency, then water resources and irrigation can be directed to areas of best economic use and comparative advantage.

The selection of Sudan was based on the fact that it has the largest irrigated agriculture and perhaps the longest experience, in the region. Irrigation has been practiced in Sudan since ancient times. Over 25 percent (1.75 million hectares [M ha]) of the cultivated land (7.6 M ha) is irrigated using free-flow open channel systems. Most of the water is obtained from the Nile but in the north of the country, irrigation depends on groundwater in about 12 basins. Although small private irrigation schemes exist especially for the production of horticulture, large-scale schemes with tenant farmers are still the main approach to irrigated agriculture in Sudan (USAID 1982, 5). Therefore, it can be said that irrigation in Sudan is dominated by a few with very large irrigation schemes. These are the Gezira (468,00 ha), Managil (379,000 ha), Khashm Al-Girba (164,000 ha), Rahad (126,000 ha), Essuki (37,500 ha), Guneid (35,700 ha) and Kenana (33,000 ha) (FAO 1986, table 15). Several studies have shown that returns from irrigation in Sudan have been far below the potential (World Bank 1990). Examples from Sudan are based on a desk review of literature prior to 1990. Unfortunately, we do not have current information on the status of irrigation in Sudan.

Ethiopia was chosen because of its unique location at the upstream end of the Nile basin. It is estimated that about 90 percent of the annual runoff in Ethiopia flows into neighboring countries through 11 rivers. Therefore, development of irrigation in Ethiopia would have international implications of a large magnitude when compared to Kenya where the major rivers flow into the ocean. However, irrigation is very limited in Ethiopia and it is estimated that only 2 percent of the cultivated land is irrigated (Baecher et al. 2000).

Zimbabwe can be compared to Ethiopia in terms of its location in the Zambezi river-basin system, but also more closely with Kenya, in terms of the characteristics of the agriculture sector. Zimbabwe's irrigation is however more developed and capital-intensive than in the other two countries. The most interesting aspect of irrigation in Zimbabwe is the dominance of private, large-scale commercial farms. Out of the 150,000 hectares estimated to be under irrigation, 126,000 are said to be large-scale commercial farms (Mazungu and der Zaag 1996, 1). Another interesting aspect is the extent of investment in water-storage reservoirs for irrigation. It is estimated that there are over 6,500 reservoirs of various sizes in use in the country (ICID, Website).

Mozambique has been included because of its downstream location to several international river systems, including the Ruvuma, Zambezi and Limpopo. Only 50 percent of the surface water is generated internally. One of the most interesting aspects of irrigation in Mozambique is the low utilization of water for irrigation from existing large dams. The country has more than 10 large dams with a total storage capacity of over 50 billion m^3. Only 9 percent of the stored water is utilized for irrigation.

Tanzania was selected because it has a large number of irrigation schemes (estimated to be more than 600) of various sizes. Official statistics show that the irrigated area in Tanzania is about 150,000 hectares of which 120,000 hectares are made up of approximately 100,000 smallholdings, each less than 5 hectares. About 25,000 hectares are large, centrally managed irrigation schemes (MoFA and DANIDA 1997, 1). An interesting aspect of irrigation in Tanzania is that major schemes are located upstream of hydropower plants in the Pangani and Rufiji basins.

Purpose of the Paper

The aim of this paper is to synthesize the findings from the Kenyan case studies in the context of eastern and southern Africa. The paper summarizes key issues related to irrigation transformation as identified in the Kenyan case studies. This is followed with an evaluation of the relevance of these issues to the case-study countries. Finally, the paper attempts to identify key lessons and research areas for consideration in the ongoing restructuring of the irrigation sector in the region.

Methodology

The approach consisted of a review of all the Kenyan case-study papers and identification of key issues in the process. The next step was the collecting and reviewing of relevant documents on irrigation in the selected case-study countries. A substantial amount of information was obtained through the Internet. In the case of Tanzania, in addition to a review of literature on irrigation development of the country, limited firsthand information was collected from several schemes. This included field visits to the Lower Moshi irrigation complex, which is in the foothills of Mt. Kilimanjaro. There are two main irrigation schemes in the complex. The next area investigated was the Usangu complex on the upper end of the Rufiji basin. There are three major irrigation schemes in the Usangu complex. These are Kapunga, Madibira and Mbarali irrigation schemes. The third area was in the Morogoro region where it is estimated that 50 percent of the irrigation potential (23,350 ha) has been exploited. Several irrigation schemes including the Dakawa rice farm were assessed for this review.

Results and Issues

Database on Irrigation

Two issues on irrigation databases clearly emerge from the Kenyan papers. First, data are available only in a small amount and is of low quality. Second, improvement of the quantity and quality of the available data and their effective utilization are constrained by technology and low priority accorded to the building of databases. This situation is not unique to Kenya but is common in all the countries reviewed in this paper. One example of the poor quality of data is given by the variation in published data on irrigation potential of different countries (table 1). The development of a meaningful database requires an agreement on definitions of the most important aspects. The example given in table 1 is a result not only of the poor data collection but also of the lack of common definitions of what irrigation is and what determines irrigation potential in a given area. Data on actual irrigated area are also poor because there is no common understanding of irrigation scales or differentiation between supplementary and dry-season irrigation.

Lack of common definitions

Irrigation is generally defined as artificial application of water to land to sustain plant growth (Withers and Vipond 1974). Others define irrigation as the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset drought in semiarid regions (FAO 1997). Stern (1980) defined irrigation as any process, other than natural

Table 1. Differences in the estimation of irrigation potential ('000 ha) of a country by different organizations.

Source Country	National Ministry	Other National Agencies		FAO	IFAD	WB	AQUASTAT
Ethiopia	2,300	2,700	3,500	670	2,800	1,500	3,637
Kenya	540	390		350		245	
Mozambique				2,400			3,300
Sudan				3,300			4,842
Tanzania				2,300			829
Zimbabwe				280	150		

precipitation, which supplies water to crops, orchards, etc. However, given the role of new technologies and environmental concerns, these definitions are not comprehensive enough. Therefore, irrigation should be defined as any process other than direct rainfall, which adds water in a cost-effective way to the soil to maintain optimum Plant Available Water (PAW) and aeration in the root zone of a given crop, without degrading the soil in the long run.

The issue of scale

In reference to size of irrigation schemes, the terms "large scale," "medium scale" and "small scale" are used without any agreement on what makes an irrigation scheme or activity large or small. Table 2 shows how the reviewed countries differ in their definition of different scales of irrigation. This is an example of the difficulties of using the concept of size at global level. What is large in one region may be micro-scale in another. This is an important issue when international organizations attempt to develop programs and guidelines for a certain scale of irrigation, often small-scale.

There is some confusion regarding the size of a scheme and the size of a plot under a single irrigator. The tendency has been to consider schemes with many irrigators as small scale. For this reason many large-scale irrigation projects have been called small scale on the basis of the size of plots per farmer. Consequently, until recently, truly smallholder irrigation has not been recognized, and is often missing from irrigation statistics. Irrigation officials in different countries are now calling the truly small-scale irrigation schemes, traditional irrigation (Mrema

Table 2. Differences between countries and international organization in determining the scale of irrigation.

Country Scale	Ethiopia	Tanzania	Mozambique	FAO
Large (ha)	>3,000	>2,000	>200	> 500
Medium (ha)	200–3,000	400–2,000	30 –200	50–500
Small (ha)	<200	<200	<30	< 50

1984, 309–310). In Zimbabwe, small-scale irrigation has been called “informal irrigation” (Mazungu and der Zaag 1996). There is another scale, which is too small to qualify as small scale, which is that given in the paper by Sijali and Okumu (2000, 2). Many of the individually operated irrigation systems, most of which predate the so-called “formal” irrigation, are designed to irrigate less than 1 hectare of land. Similar to what has already been explained regarding small scale, the micro-scale systems have been largely neglected in official statistics and have received only a minimum of inputs in terms of investment, research and extension.

Supplementary v dry-season irrigation

Supplementary irrigation is defined as the application of an extra amount water during the rainy season over and above that supplied by direct rainfall in order to optimize water available for plant growth (Oweis et al. 1999). Dry-season irrigation is a system of irrigation designed to provide enough water to raise a crop even when there is no direct rain. Supplementary irrigation is often designed to capture water directly from a river or flood-flow, with a limited control of the water availability in both quantity and timing. Therefore, there are seasons when the water is inadequate and only part of the command area gets water for irrigation while in other years, the water may be in excess, and drainage becomes important.

Nearly 80 percent of irrigation in Tanzania is supplementary (MoAC 1999) where there are no water-storage systems. Even Sudan, with a high level of water management in irrigation schemes, has over 100,000 hectares under supplementary irrigation in the Gash and Tohar deltas. On the other hand, in Zimbabwe nearly all the major irrigation schemes have reservoirs for water storage as part of the system (ICID, Website)

Public v private irrigation

Another area of definition that will soon be causing confusion in the interpretation of data is the differentiation between public and private irrigation schemes and projects. It is most likely that the privatization process will lead to a situation where both public and private interests are involved in an irrigation scheme. There is, therefore, a need to develop a common definition and demarcation between public and private schemes. The FAO Investment Centre (1995) proposes the following definitions: a) Public irrigation is where the government, directly or through agencies, has the dominant financial interest or management/control. b) Private irrigation is where private individuals (e.g., farmers) or groups (e.g., companies) have a dominant financial interest and carry the risks.

Accuracy of data

Current data on irrigation in most countries are basically guesswork. There is an urgent need for an agreed common approach for assessing irrigation potential, so as to facilitate a reliable review of the data currently being quoted. In many cases, land suitability is the only criteria used (FAO 1986, 14). However, in reality, water availability and soil resources would be better measures of irrigation potential (FAO 1995b, 325). The question is how this can be done. Further, the final determinant should be technology and socioeconomic infrastructure available to support irrigation. As more efficient technologies are adopted, some land constraints could be overcome thus making efficient technologies the determinant of maximum irrigation potential (FAO Website).

Data on actual irrigated area in the reviewed countries are also doubtful. This is because, as shown in this section, it is not clear what type (supplementary or dry-season) and which scales are counted. Similarly, most of the micro-scale and some of the small-scale (traditional or informal) schemes are not counted [box 1]. In general, data on irrigation in most of the countries require major and urgent revision.

Resources, Adequacy and Tenure

From the Kenya case study papers, many issues related to resources, adequacy and tenure have arisen. These include the following:

- skewness in spatial and temporal distribution of rainfall

Box 1. "Traditional irrigation" in Tanzania.

It is estimated that furrow irrigation on the highlands of Tanzania dates back to more than 2,000 years. A survey conducted in 1987 showed that vegetables supplied to major cities and towns in Tanzania came from land irrigated by these ancient furrow irrigation systems. Most of this irrigation does not show up in official statistics. The most prominent highland districts in Tanzania with hillside irrigation include:

- Lushoto
- Same
- Mwanga
- Arumeru
- Iringa
- Kilosa
- Bukoba

It is not known how many hectares are under furrow irrigation in these districts.

- shortage of water available for effective use
- unclear ownership and access to water
- poor definition of landownership
- obsolescence of the tenancy system
- poor land management

Skewness in spatial and temporal distribution of rainfall

Given that rainfall is the ultimate source of water, the skewness of rainfall is a major problem facing irrigation development across the region. This problem is of regional scale in that the southern subregion including countries such as Zimbabwe, Mozambique, Republic of South Africa and Namibia have low rainfall compared to the eastern subregion (Malawi, Zambia, Democratic Republic of Congo, Rwanda and Burundi). The amount of rainfall also decreases rapidly northwards as one crosses the equator, Ethiopia being the exception.

There are two important implications of skewness in the availability of the water resources. The first is the need for long-distance transfers of water from points of source to the points of use. This becomes complicated where the two points are in different countries. The second is the need for large storage facilities, so as to reserve rainwater, which is available during a short time of the year, for use during periods of unavailability. Both approaches require high investments in capital. Often, payback from irrigation is considered inadequate to justify the high capital investment. Hence, many storage dams in the region have been constructed mainly for the generation of electrical power. Generally, major water transfer schemes are constructed to supply water for domestic and industrial uses although Sudan is an exception.

Ineffective use of available water

Recent writings on water as well as several of the Kenyan papers (Mati 2000; Ngigi 2000a, b; Huggins 2000; Gichuki 2000) present a view that there is scarcity of water in general and for irrigation in particular (Seckler et al. 1999, 1; Barker and Van Koppen 1999, 1). But when viewed from the point of view of quantity of rainfall at country or regional level, there is plenty of water. Seckler et al. (1999, 8) state that at global level, water is the ultimate renewable resource. One uses all of one year’s supply and then, on average, the same amount is available for use the next year. The problem is that the water is available only for a short duration and sometimes only in a few areas. So what is scarce is rather not water but technologies for overcoming poor spatial and temporal distribution.

Inadequate conservation of rainwater is a result not only of shortage of storage infrastructure but also of degradation of soil, which is a natural storage medium. Poor land use is rapidly reducing the capacity of soil to store water in readily available form, so that rainwater rapidly evaporates back to the atmosphere or quickly flows to saline sinks before it is put to beneficial use. Another consequence of destroying the capacity of soil to store water is that groundwater is often depleted due to inadequate recharge.

Supplementary irrigation can be designed to exploit water that floods plains during the rainy season. An example of this approach is the irrigation schemes in the Usangu plains of Tanzania. It is estimated that most of these schemes are utilizing water that, in the past, flooded the plains and was lost by evaporation. Preliminary data show that, during the growing season, these schemes take very little water away from downstream users (MoW 2000, 66).

Ownership and access to land and water

The concept of water as a public good and free access to water as a human right is the cornerstone of water resources policy and management strategies all over the world. Although it is difficult to see a viable alternative to this approach, this concept is a source of many problems associated with ownership and accessibility to water. In all countries in the region, water essentially belongs to the state with specific water rights/permits being issued for limited amounts and periods to individuals and companies. The approach can be termed a short-term privatization of limited amounts of water to individuals and private groups.

Landownership and tenure in the majority of the countries in the region are governed by national land policies whereby land is public and vested in the President as a trustee. This implies that for the majority of smallholder farmers, landownership (and access to water) is highly insecure and fluid. Consequently, farmers are vulnerable to influential and powerful politicians as illustrated in the case study given by Huggins involving the Njoro Kubwa, the Kitobo and the Kamleza irrigation schemes in the Taveta division. Most literature on ownership and tenure emphasizes that there is a need for tenure security and that various types of tenure can be secure or insecure depending on social, legal and administrative institutions in a given society (FAO, Website).

Tenant-farmer system

The tenant-farmer system is common in the region, especially in Sudan. Each of the large schemes is managed by a public Agricultural Corporation, which makes all decisions and controls the provision of all services. The development of irrigation infrastructure up to the main canal level is the responsibility of the Ministry of Irrigation and Water Resources (MIWR). The agricultural corporation supervises the O&M of minor canals as well as the production units. If the water is from groundwater resources, then the Groundwater Corporation is responsible for its delivery to the minor canals. Tenant farmers are responsible for paying costs of all agronomic operations, which are also provided by the Agricultural Corporation. Farmers are allowed to keep only 49 percent of the net income from cotton.

The case of Mwea, so well described by Kabuta and Mutero, has shown that the tenant farmer system of providing land and irrigation services to farmers is now obsolete. The absolute control over all aspects of economic as well as over some aspects of the social lives of the tenants is obviously unacceptable in this era of democracy and freedom for individuals. In Zimbabwe, Mazungu and der Zaag (1996) observed that the economic control in smallholder schemes is such that the tenant farmers are not very different from employees of the government or irrigation institutions, the only difference being that the remuneration of farmers did not come in the form of a regular wage. After studying the tenant system in Sudan, USAID (1982) concluded that “the tenant farmer faces a dual role as a farmer and an employee, but has little role in the decision-making process, contributing to low productivity.” An alternative is urgently needed in nearly all countries.

Land management

Ong and Orego (2000) provide a very good case study of the major threat to irrigation schemes in the region and perhaps all over the world, due to environmental degradation. Damage to sources of water and irrigation schemes as a result of pollution, soil erosion and other land and water-degradation processes, is a major threat to the sustainability of irrigation systems.

Siltation of crop fields, canals and water reservoirs is perhaps the leading problem and threat to irrigation schemes everywhere. As a result, schemes are often reported to operate at less than 50 percent capacity and reservoir storage is quickly lost (Murray-Rust 1973, 334). The removal of silt from canals and reservoirs is, in many cases, a major cost item of the O&M budget. Often, the process is not implemented fully due to the inefficiency of public institutions managing the canals. Consequently, there is a continuous annual shrinkage of the irrigated area leading to eventual abandonment of schemes. These problems are common in the region. For example, in Sudan, the main reasons given for poor performance of irrigation are high costs of clearing silt from canals, reduction of canal capacity caused by weed growth, and high loss of water from reservoirs, especially by evaporation.

The problem lies in the poor management and conservation of the catchment area, especially where it is under cultivation. Unfortunately, for a long time now, thinking on land conservation has been dominated by forestry. Therefore, in many cases, deforestation is cited as the main cause of soil erosion and depletion of water resources. However, research has started to show that:

- forests are net consumers of water (Calder 1994),
- generally, in countries such as Tanzania, most of the land is under forest, woodland or bush cover, and
- land that is well managed under grass cover yields more water for a longer period after rains than a forested area (Hornung and Newson 1986, 62).

Therefore, the issue may not be deforestation as often argued, but poor management and conservation of land once it has been cleared of forests and put into other uses, especially crop cultivation (EAAFRO 1979).

Irrigation Technologies

It was suggested, in this paper (see under *Database on Irrigation*, 306), that technology is an important component in the determination of irrigation potential and its successful exploitation. There are three major issues related to irrigation technologies. The first is the need for technologies to improve water availability and use efficiency. The second is the establishment of institutional arrangements for technology development and transfer to ensure that appropriate technologies are available to the farmers. The third is the issue of O&M of infrastructure and machinery.

Improving availability and productivity of water

In the region, irrigation is dominated by the classical approach of flooding the land to saturate the entire root zone at particular intervals. Often, the application schedule is designed so that the water in the soil is completely depleted before the next application. Alternatives to this wasteful practice are available but they continue to be ignored because most of the new techniques do not conform to the training and understanding of irrigation by current planners, designers and engineers (Lambert and Faulkner 1989).

Water storage is a challenging area for technological development, since current approaches to water storage are very expensive. Storage of water is common and widely practised in southern Africa, significantly in South Africa, Namibia and Zimbabwe. Poor development of groundwater limits the exploitation of the “free” storage capacity provided by the earth's crust. Often, groundwater-development schemes are concerned more with water abstraction with minimal deliberate efforts to recharge the aquifers.

A higher potential for expanding production under irrigation lies with technologies for increasing the productivity of water. The purpose is to optimize growing conditions for crops as well as to minimize soil degradation in the long term. The amount of control is low in rain-fed farming, minimum in flood irrigation and maximum in controlled environment farming, such as greenhouses. Technologies for achieving high levels of control are already available. One example is the technique that uses high frequency, low volume, partial-area application of water and nutrients to crop fields (FAO 1997). These techniques need to be adopted in sub-Saharan Africa. However, there are serious obstacles against a wider-scale adoption of technologies for efficient irrigation. One of the obstacles is the lack of incentives among farmers to invest in water-efficient systems. The principal causes of this problem have been already discussed (see under *Ownership and access to land and water,* 311) in relation to low price of water and poor enforcement of water permits. To control wasteful uses of water through pricing mechanisms there is an urgent need to foster attitudinal changes in putting a value on water.

Further, effective irrigation is not only a matter of water-application hardware but also an outcome of the value of the products being produced. Therefore, productivity of irrigation water can be enhanced by switching to high-yielding and high-value varieties of crops. However, the option has its limitation due to the current concerns about food sufficiency and security as well as limited markets for high-value crops.

Technology development and transfer

Poor research or lack of research, training and extension services hinders irrigation development, to a great extent, in most of the countries covered in this review. In Tanzania for example, research on irrigation is almost negligible. Apart from inadequate research and development, most countries in the region have little or no local irrigation industry dealing with the manufacturing, distribution and servicing of irrigation equipment. Further, due to the long-term dependence of foreign firms for the construction of irrigation infrastructure, the local engineering and construction firms have very little experience with irrigation.

Operations and maintenance

Perhaps the weakest links in irrigation systems of most countries reviewed in this paper are O&M. There are generally four main causes to this problem. The first is poor feasibility, planning and design (especially choice of technology) of many projects. The second is the weak management structure and capacity of public or private O&M institutions as well as of farmers themselves. The third is shortage of funds either because the farmers are making very little and are thus unable to pay or that they are unwilling to pay because the service is very poor or they have not seen benefits from previous payments. The fourth is the problem associated with rapid siltation of canals due to poor management of catchments.

O&M problems are common for all the irrigation technologies available. However, poor O&M are frequent and have more drastic effects on mechanized systems, which normally have low tolerance to poor maintenance. According to Scheltema (2000, 16) findings in Kenya show that the management of a pump-fed system by a group is often beyond the capability of the farmers' community. The same is made clear by the case study from Zimbabwe (Matsika 1996, 39) given in box 2.

Mode of Ownership and Management

An irrigation system involves many subsystems and the most important include:

> *Box 2. The Zimbabwe case study.*
>
> The Mundotwe irrigation scheme is pump-operated and practices communal irrigation among its beneficiaries. In 1994, the pump broke down in the middle of the wheat season, and the irrigators had no money to repair it. They approached the District Development Fund (DDF) for services. Many irrigators prefer the DDF because it does not charge transport and labor costs. Unfortunately, DDF had no funds (the fund allocation for this project had been exhausted). The irrigators had no choice other than to go to a commercial firm. Through the commercial firm the pump was repaired but since the farmers had no cash to pay, they had to take a loan at 32 percent interest.

a) The water subsystem

- the water resource (surface or subsurface)
- means of abstraction
- infrastructure for transporting and delivering the water to the irrigated farm, including storage
- systems for water application and spreading on the farm
- structures for drainage and disposal of any excess water

b) The agricultural subsystem

- agricultural land
- machinery and other production hardware
- farm structures other than those for managing water

c) The market subsystem

- input supply

- processing infrastructure
- means of transportation

In relation to the mode of ownership, three important issues were raised in the Kenyan case studies. These are types of ownership, role of key players and private investment. This section discusses these issues using examples from other countries in the region, and makes suggestions on how problems related to ownership and management can be overcome.

Types of ownership

Private ownership of irrigation facilities, especially by individuals or companies, is the most common mode in southern African countries of Zimbabwe and South Africa. For example, in Zimbabwe about 89 percent of the reservoirs are privately owned. Further, in South Africa, full privately owned and managed irrigation schemes are common for all crops and all sizes. At the same time, in countries like Tanzania, privately owned large-scale irrigation schemes are limited to estate farms for commercial export crops, such as tea and sugarcane. Large-scale irrigation of food crops is normally dominated by publicly owned irrigation schemes. These are either parastatals or large-scale smallholder systems normally referred to as Farmer-Managed Irrigation Schemes (FMIS). The exception to this is found in Sudan where large FMIS are involved in the cultivation of cotton.

The technology choice has a very important influence on the mode of ownership and vice versa. For example, gravity-fed furrow or flooding systems tend to require public or group ownership. At the same time, pump systems tend to work better under individual ownership, with numerous instances of failure under public or group management.

Management and the role of different players

Irrigation, especially by smallholder farmers, involves many key players. This complicates management, especially O&M of irrigation infrastructure. Under parastatal or large-scale or estate farms, management should be straightforward, due to full ownership of the whole system. With smallholder farmers the situation is different since different subsystems are often owned and managed by others. In this case, the most important players are:

- government agencies, donors and NGOs that normally provide for the construction of the infrastructures as well as their O&M
- farmer groups, associations and cooperatives that may operate and maintain several subsystems
- service providers who may provide whole services and specialized technical inputs such as repair of pumps
- traders who often deal with equipment and input supply, transportation, processing and packaging as well as marketing of produce
- large-scale farmers or companies that may provide certain services to smallholder farmers (see box 1)

In many countries, farmer-support systems are underdeveloped and there is no clear demarcation of roles for the different players. Most irrigation schemes are dominated by a management approach where a single parastatal company or farmers' organization attempts to control all aspects of production and marketing under irrigation.

The trend to privatization involves the transfer of entire management of large irrigation schemes to private companies or WUAs. It would, for example, be difficult for a WUA or farmer cooperative to take over large irrigation schemes as is being attempted in the Mwea irrigation scheme. In his paper Gichuki describes the success story of Homegrown (K) Ltd., which is a private company operation, that has total control of ownership, management, production and marketing.

In many cases, farmer management is not likely to do much better than the parastatal management. This is because it is difficult for a single company to exploit economies of scale while dealing with different business areas and modern technologies, which require a high degree of specialization. On the other hand, there is unwillingness among irrigators to leave several subsectors to others due to inadequate regulatory mechanisms for ensuring that each player deliver as expected. There is a shortage of good examples where private or public O&M service providers have performed to the satisfaction of the farmers and other players. Poor O&M services lead to low performance of the system and low crop returns for the farmer. These result in a vicious circle common in many community irrigation schemes, the circle of poor O&M→low production→low profit→inability to meet O&M costs→poorer O&M.

Private investment

In this paper we briefly attempted to differentiate between private and public irrigation schemes (see under *Public v private irrigation,* 308). The era of fully public schemes where the government plans, finances and implements irrigation projects is gone. These kinds of schemes have tended to give irrigation, in general, and large schemes, in particular, a bad name (box 3). Therefore, full or partial private ownership of irrigation schemes appears to be the vogue for the future.

There is already a substantial amount of private investment in irrigation taking place in the region. Most private investors, except in South Africa and Zimbabwe, have invested in irrigation schemes for traditional cash crops such as tea and coffee. Recent investments,

Box 3. The Bura disaster (after Gunnel 1986).

The Bura Irrigation and Settlement Project (BISP) is located downstream of the Kiambere dam in the Tana river basin. It was initiated by the Government of Kenya in the 1980s with a World-Bank-loan and other donor support. After spending more than US$100 million, the project managed to put a maximum of 6,000 hectares under irrigation. However, the whole project has now totally collapsed because the soils were proven unsuitable for the type of irrigation that was being attempted. The only remaining outcome of all the investment comprises the settlers who are now living in abject poverty and are dependent on food handouts. Even water for domestic use has become a problem.

notably in Kenya, have been in high-value export crops such as vegetables and flowers. It is now estimated that about 40 percent of irrigated land in Kenya is in private hands.

Trends in private irrigation, at least in Kenya and Tanzania, show that most of the investment has been in market-oriented production. Most of the private, large-scale irrigation is found in coffee, tea and sugarcane estates. In Tanzania, for example, there are 4,500 hectares of tea estates under irrigation. Smallholders have often invested in irrigation for vegetable production. Box 4 gives examples of small-scale irrigation development in Tanzania through private investments.

The low inclination by the private sector to invest in irrigated production of cereals is clearly shown in the failure to privatize irrigated maize and rice parastatal farms in Tanzania.

Box 4. Night storage for equitable distribution among highland and lowland irrigators.

The same District in Kilimanjaro region (Tanzania) comprises highlands and lowlands (eastern and western). Whereas the highlands are endowed with streams and rivers and are relatively wet, the lowlands, especially the western lowlands, are semiarid. During dry seasons, farmers/irrigators in the highlands utilize almost all the waters in the streams. As a consequence, the lowland farmers get no water at all. This situation has become a source of conflict between the two groups of farmers. To solve this problem, they devised a system whereby stream/river night flow is stored in small reservoirs/ponds locally called *ndiva*.These ponds are normally constructed in the highland zones. Through the use of furrows and channels, the lowland farmers release the stored water during the day for irrigation. This system has helped a lot in solving some of the water-demand requirements for the lowland farmers and has received full support from both groups. Farmers maintain these ndivas through communal works during distillation, and in case of major repair (such as leakage) where inputs (such as cement) are required they contribute money or equivalent for the repair.

The privatization process in Tanzania, which used to have nearly 300 parastatals, has been going on for the past 5 years. The public agriculture sector included three major organizations. The largest is the National Food and Agriculture Corporation (NAFCO), the second largest, the Tanzania Sisal Authority (TSA) and the third largest, the Sugar Development Corporation (SUDECO). All the five irrigated sugarcane estates have been privatized and nearly all the sisal estates are gone but it has proven very difficult to find private investors for the NAFCO farms, which are all dealing with food crops including irrigated rice and maize production and rain-fed wheat production. The reason for this may lie in the continued decline in the global prices of major food crops, such as rice and wheat (Denning et al. 1996, 105).

Private investments are also very common in the processing and transportation subsectors. At the moment, however, most of the processing facilities are for rice and there is a shortage of processing capacity for fruits and vegetables. Another service to irrigation, which has attracted substantial investment, is the manufacturing, importation and servicing of simple equipment such as hand pumps (Palanisami, Internet).

The area of water supply as a service has not attracted private investment. Even in countries such as Zimbabwe, private investment in water infrastructure is undertaken to satisfy the water needs of the investor rather than providing for commercial services to other farmers. The most limiting factor is that current regulations on water allocation and permits are not conducive to private investment in water-supply infrastructure.

Commercialization

Commercial operations, by definition, have to make a profit large enough to justify the investment. Under *Mode of Ownership and Management*, 314, an attempt was made to identify possible key players in an irrigation system. In an ideal setup the cultivator will be the central link in the chain. The farm-gate price that the farmer receives for his products must be high enough to pay for all the inputs, services and labor (including that of the farmer himself) and must provide a modest profit. The same analysis applies to all players in the system. Two fundamental requirements for successful commercial irrigation are a) a viable and fair linkage between all the players and b) each party making a living and profit from its business. If one of the players fails to make a living and profit the whole system will be affected. This section attempts to discuss the findings from Kenya and the other countries on the difficulties of ensuring free and undistorted linkages between different players in an irrigation system.

Profitability

Profit is the main reason for investing in irrigation although some farmers, communities or countries do it as a survival mechanism. To realize a profit, the farmer must minimize the cost of necessary inputs and maximize income through high farm-gate prices. On both fronts, the existing evidence shows that a smallholder farmer irrigating food crops face many problems. First, it is only in rare cases that the capital cost of irrigation infrastructure has been successfully recovered from farmers. Many schemes are struggling even to recover O&M costs. Therefore, all indications are that privatization and commercialization of services will lead to a steep increase in the costs incurred by the farmer. Further, there is very little indication that the farm-gate price of food crops will increase in the near future. This means that irrigated food production will face declining returns. How then can private investment in irrigated food production by smallholder farmers be justified?

It may seem that private smallholder irrigation will be more profitable if applied in the production of high-value crops for niches. However, there are the problems of accessing these markets as discussed in the Kenyan case study papers. Therefore, it is appropriate that we should now turn to the issue of marketing.

Marketing

The issue of marketing is touched upon by several of the Kenyan papers but Freeman and Silim (2000) and Scheltema (2000) give it in detail. These two papers show that farmers' produce is sold either freely to consumers, processors, cooperatives and trades, or under contract to all groups except consumers. Both approaches have their problems as discussed below.

Remote locations with poor transportation and communication make the transaction costs of marketing produce very high. It is, for example, difficult for the farmer to meet contractual requirements of quality and time of delivery. For this reason, it is difficult to secure contracts; or buyers give farmers low prices as a security against expected delays in delivery. Poor communication puts farmers at a disadvantage due to limited availability of market information to them. Often, farmers cause lower prices by competing against each other due to uncoordinated production schedules. Farmers' crops tend to reach the market at the same time and the system swings from periods of glut to periods of shortage. In this situation, and especially with perishable crops, the farmers end up with diminished bargaining power. On the other hand, the small-scale nature of production leads to high collection costs for the buyer, reducing profits and thus the price they can offer to the farmer.

Since irrigation increases the certainty of production, it should make production under contract more viable and attractive. However, very little effort has been made to develop strong marketing institutions. Farmers try to overcome some marketing problems by forming cooperatives to market their produce. However, cooperatives have failed even for highly commercial crops such as coffee and cotton. The main reasons have been corruption and mismanagement but, most importantly, failures to adopt commercial practices (FAO 1999).

Equity

Water is a mobile resource and thus, depending on the size of a water basin, the water may have millions of stakeholders who often have differing and sometimes conflicting demands on the resource. Equity is a term used to refer to fairness in the access, distribution and sharing of the benefits and costs of water by stakeholders. The stakeholders are those who will either benefit from using the water for irrigation or be affected negatively (directly or indirectly) when the water is used for irrigation, or have other interests on the water. Therefore, equity must be established across gender, among farmers within one scheme, between upstream and downstream schemes, across different sectors and between nations.

Gender

Introduction of irrigation should be compatible and enhance a fair division of labor between men and women in the society. If there is an imbalance existing in the demand for labor from men, women and children, efforts should be made to remove this in the choice of design and technology for irrigation. Inequity in income distribution and control is a major problem in rural areas. This is a result of the cultural behavior in rural Africa where either men or women control different crops. For example, in northern Tanzania, women control bananas while men control coffee. In other farming systems, rice is under the control of men while women manage sweet potatoes. Therefore, an irrigation design, which destroys potato fields in favor of rice, will create or increase inequity between men and women.

Among farmers

Competition for water among users in the same scheme has been discussed in several papers from Kenya, notably by Gichuki (2000). The inequity is caused by many factors that can be grouped into three categories: a) hydraulic and engineering, b) agronomic and c) social. Hydraulic factors lead to tail-end problems where farmers at the end of the scheme get less water. This problem often occurs when water is allocated for a fixed period or time instead of on a quantitative basis, which requires expensive flow-measuring facilities. Agronomic factors cause inequity, for example, through differences of soils, crops or on-farm techniques. Two farmers with differing soils will obtain different benefits from the same amount of water. This will create friction among the farmers. In relation to social factors, it is important that there are strong institutions for distribution of water.

Upstream and downstream relations

In a watershed or river basin, all water resources are linked and equitable distribution in quantity and quality between upstream and downstream users is often difficult to achieve. Often, upstream users abstract more water and either deplete it through consumptive uses, such as transpiration or through nonconsumptive uses, such as pollution. Often, there is no catchment plan that would place the most polluting uses downstream and nonconsumptive, nonpolluting uses (e.g., hydropower generation) at the upstream end. This problem is a consequence of lack of overlap between watershed boundaries and social boundaries. It is only in rare cases that a catchment falls under the control of one farmer, clan, district or even country. In this situation those in the upstream normally have a first claim on the water and they try to retain most of it as discussed by Gichuki. To ensure equity, it is necessary to develop catchment/basin approaches to water-resources development and use. There should be a negotiated plan acceptable to all stakeholders. The case study shown in box 4 demonstrates a simple idea, which has tremendously improved the downstream-upstream relationship in irrigation systems of the highlands of Tanzania.

Across sectors

As countries become more developed, utilization of water for irrigation tends to yield lower benefits when compared to other uses, such as domestic, industrial, environmental conservation and leisure. Therefore, opportunity costs of using water in the different sectors become the deciding factor in water allocation. Should water be delivered to Nairobi to serve a tourist paying US$500 per night in a hotel and thus indirectly use the water to earn foreign exchange or use the same water to irrigate a crop of maize? The theoretical answer to this question can be found in the principle that transferring water from lower- to higher-value uses increases water productivity. In practice, questions regarding policy and politics come into play and the final decision may not make the most economic sense.

Between nations

Equity between nations in access to riverbasin water is very important in eastern and southern Africa. Most of the river basins stretch over several countries. The Nile basin covers the largest number of countries, nine in total. The concept of holistic integrated catchment/basin management is difficult to implement with so many different countries involved. These countries are at different levels of economic, social and political development. Close economic partnership between these countries is the key to collaboration in integrated basin management.

Outstanding Issues for Research

The synthesis given in a previous section (*Results and Issues,* 308) has shown that there are many areas where irrigation development in the region is either operating from false premises or is based on outdated approaches, which require urgent revision. At the same time, the region is also endowed with rich experiences from attempts of different countries to develop the irrigation sector. Therefore, a lot can be learned from both successes and failures within the region. However, due to inadequate research, few of these experiences have been put to beneficial use. For this reason, the purpose of this section is to identify critical issues, which require research efforts to develop a firm foundation of information and knowledge for transforming irrigation in the region. The selected issues include policy and the role of government, public institutions and international agencies; technology development; O&M; and commercialization and trade.

Policy and the Role of Government, Public Institutions and International Agencies

The role of governments is still not very well defined and not uniform in the region. In countries like Sudan, the government controls aspects of irrigation from policy making to actual production. On the other hand in Zimbabwe, for example, most irrigation is outside the direct control of the government. What is the correct balance? The philosophy of market economy dictates that governments should refrain from prescriptive policies that stipulate how much cultivated land should be irrigated. Governments should provide basic conditions for commercially sustainable development of the irrigation subsector. This requires the government to ensure that policies, legislation and strategies are in line with the promotion of effective and productive utilization of water resources for agriculture. These are summarized in the following subsections.

Policies and policy instruments of the government

The irrigation subsector is affected by the majority of government sectoral policies. The most important are:

- water resources policy
- agricultural policy, especially the food security strategy
- landownership, tenure and conservation policies

- social and economic infrastructure policy
- transportation and communication policy
- industrial and trade policy

These can be divided into three categories. In the first category is the agricultural policy, especially the food-security strategy. It is under this policy that a national irrigation agenda is normally designed. The second category comprises the water and land policies. These determine the availability of the basic resources to an actually implemented irrigation plan. The rest comprises the third category, which determines the commercial viability of any scheme. Due to poor policy analysis and research, irrigation is often designed only as an instrument of agricultural policy, with limited integration into the other sectoral policies. On the other hand, the high cost of development of irrigation projects is often caused by the fact that they are developed with multiple goals in mind. For example, the Bura scheme was intended to develop remote areas with no infrastructure, in addition to increasing agricultural production and alleviating poverty of the beneficiaries.

Therefore, research on policy analysis is urgently required to answer the following questions:

- How can irrigation be designed and reoriented so as to fully exploit possibilities made available by different sectoral policies?
- Which components of sectoral policies and policy instruments require revision in order to promote the commercial irrigation subsector?
- What are the necessary legal instruments?

Regional collaboration and trade

Irrigation development can benefit and also contribute to trade in food at the regional level that allows water resources to be put into use in the areas of best comparative advantage for a catchment, basin or country. East and southern Africa, taken together, have abundant water resources, which are currently underutilized because of a mismatch in the physical location of water versus good land for irrigation versus technological and managerial skills for commercial irrigation. Since most of the major rivers in the region cut across several countries, the basin approach cannot be achieved without international partnership. Two communities already exist in the region, namely, the Southern Africa Development Community (SADC) and East Africa Community (EAC). Analysis of policy research is urgently required to evaluate how these and other groupings can be used to promote trade in food and other agricultural products, so as to create a conducive environment for commercial irrigated agriculture in the region.

Database development

Data on land, water and irrigation are poor in nearly all the countries. Without a radical improvement of these databases, policies, plans, strategies and designs cannot be made with certainty and are bound to fail. Moreover, private and commercial irrigation as well as equitable allocation of water requires precise planning and management.

There is a need for major research programs by both international and local research organizations to do the following, for example:

- Develop practical methodologies for river-basin analysis to ascertain the potential for irrigation in various catchments/basins, given the specific conditions (e.g., infrastructure) and opportunity cost of using water in other sectors.
- Take advantage of tools such as GIS to develop comprehensive databases and decision-support systems. These will assist planners and designers to test several scenarios and get answers to "what if" questions in the process of policy making and planning agricultural, water resources and irrigation systems. This will, for example, involve the use of reference basins.

Existing public schemes

Many of the public irrigation projects were planned to pursue the policy of national food self-sufficiency. There is also confusion about irrigation's contribution to poverty alleviation. These have proven to be bad criteria for irrigation development. What is the best way to utilize existing public irrigation schemes? Many say it is privatization. But is this really the right solution for huge infrastructural systems, such as those found in Sudan? Unfortunately, we do not know because of limited research in this area. Further, the failure to find private buyers for irrigated rice and maize farms in Tanzania indicates that private investors are not eager to make further investments in some schemes.

There are five options on how to deal with existing public schemes, which are:

- Optimization, where public schemes are reengineered to emulate private irrigation schemes, and become just as competitive in both costs and benefits.
- Privatization of schemes operated by parastatals.
- Contract-out management and operations. In this case, the government retains ownership especially of water-control infrastructure, but contracts out their O&M to the private sector.
- Management transfer to farmers. This is an option more valid to the tenant-farmer-based irrigation schemes.
- Develop markets for irrigated crops.

Each of these options can find applications depending on conditions in a country, basin or scheme. Therefore, research is required to generate models, which can be used to make decisions on which option to follow and how. The most important factors to be analyzed will include:

- existing skills and management capacities in the government, private contractors and water users

- socioeconomic setup, coherence and local institutions to ensure community cooperation
- type and design of the infrastructure already in place and the O&M requirements
- types of crop being irrigated and the agronomic patterns being followed
- capacity of the private sector to provide input supply and marketing services

Technology Development

In-field water application

Since irrigation professionals involved in planning and design are predominantly civil engineers, the choice of technology in many irrigation schemes has been dominated by civil engineering structures and systems. Many of these systems are highly deficient in the aspects necessary for effective management of water in the root zone. This approach should be changed.

The ultimate goal of irrigation technology is to make irrigation a competitive economic enterprise comparable to other sectors in the generation of benefits from the utilization of water. This can be achieved through the development, adaptation and adoption of effective in-field water-application systems. The principles of how this can be achieved are already known. What is needed is an applied and adaptive research program that will develop site-specific technologies to meet the following:

- socioeconomics of land and water
- crops being grown and the agronomic practices and inputs being used
- scale of irrigation
- technical skills of farmers and others of water services
- extent of risk of degradation of land

Water resources development

The special and temporal variability of rainfall requires technologies for facilitating transfer of water either from periods when water is in high supply to periods of shortage, or areas with high water supply to locations with scarcity, or both.

The first demands water storage systems while the second requires interbasin transfers. The development of effective groundwater strategies is one option of water storage that has not been fully explored and exploited and represents a good area for research. Interbasin transfer of water is only practiced to a small extent in the region. It is a technology that can be used to overcome the mismatched location of water and the best land for irrigation.

O&M

All the aspects of policy and strategy change discussed in section under *Outstanding Issues for Research* (p. 323) will have tremendous effects on O&M. Much is not yet known on how best to organize O&M under different irrigation strategies and systems. At the moment, O&M services receive little attention and what is received is generally very poor. There is a debate on what the real causes are. Suggested causes include the following:

- Farmers do not pay water charges due to several reasons (e.g., low returns).
- Poor management and corruption within O&M organizations.
- Poor water distribution among farmers, which leads to the breakdown of group cohesion.
- Low technical capabilities of O&M organizations due to lack of specialization.
- The O&M organizations are often not accountable to the farmers.

The challenge for research is to find the best arrangements for ensuring the following:

- The O&M services are efficient in terms of water delivery to the farmers.
- The farmers are charged a fee that is transparently related to the amount of water received, which they can pay.
- The O&M service provision is sustained even if provided by private businesses.

Commercialization and Trade

Any enterprise that aims at commercialization has as its main motive the making of profits. For many farmers engaged in irrigation, their biggest challenge is marketing and the market forces they have to deal with. Although irrigation improves confidence in production, market forces may work against the farmer. Prices may be reduced due to flooding of the market or buyers may collude to lower prices even during periods of short supply. It is imperative, therefore, that research and training focus on developing strong marketing institutions and build the capacity of individual farmers. Training on managing irrigation according to commercial practices should be strongly emphasized.

Conclusions

From this synthesis, the following conclusions on “The Changing Face of Irrigation in Kenya and Their Relevance to Eastern and Southern Africa” can be made:

1. The database on irrigation is inadequate and of low quality. Any effort aimed at improving the quantity and quality is constrained by technology and low priority accorded to the building of databases.

2. Rainfall is the major source of irrigation water, but its availability and distribution are highly skewed. Lack of water storage exacerbates the situation.

3. The general assumption that there is a scarcity of water in general and for irrigation in particular in Kenya and the region as a whole is somehow misleading. The problem is that large volumes of water may be available for only a short duration and sometimes in a restricted area. People lack the technologies for overcoming its poor spatial and temporal distribution.

4. Many of the problems associated with ownership and accessibility to water stem from the fact that water is viewed as a public good and free access to it is considered as a human right. In all the countries reviewed, water belongs to the state, with rights/permits issued for limited amounts and periods to individuals and companies. Water-rights systems in the region may have contributed to low rates of private-sector investment in irrigation.

5. Landownership and tenure in all the countries are similarly not conducive to the commercial irrigation subsector.

6. Current irrigation technologies practiced in most countries reviewed are dominated by the classical approach of flooding the land to saturate the entire root zone. This approach involves a very low level of water control. Technologies for achieving high levels of water control are available but these need to be promoted vigorously and should be supported by research, training and extension services.

7. In recent years, the ownership and management of irrigation projects are in transition in most countries in the region. The trend is towards privatization and many governments are attempting to transfer the entire management of large irrigation schemes to private companies or WUAs. Parallel to this, private investment in irrigation is gaining momentum with emphasis on high-value export crops such as vegetables and flowers.

8. Irrigation requires a substantial amount of capital investment. Consequently, farmers require assured markets and prices to make a profit. Contrary to this, many farmers in the reviewed countries face marketing problems, which are partly due to lack of research and training in marketing.

9. As a mobile resource, water has numerous stakeholders among whom can be farmers, input suppliers, actors from other sectors and even nations. In all the countries reviewed, conflicts among different stakeholders exist over the distribution and sharing of water resources. To ensure equity, therefore, it is necessary to develop catchment/basin approaches to water-resources development.

Literature Cited

Baecher, G.; R. Anderson; B. Briton; K. Brooks; and J. Gaudet. 2000. *The Nile basin-transboundary. Opportunities and constraints analysis*. Washington D. C.: United States Agency for International Development. (http://www.glue.umd.edu/~gbaecher/recentbooks.d/ETOCA%202000.pdf)

Barker, R.; and B. Van Koppen. 1999. *Water scarcity and poverty*. IWMI Water Brief 3. Colombo, Sri Lanka: International Water Management Institute.

Calder, I. R. 1994. *Eucalyptus: Water and sustainability*. A summary Report. ODA Forestry Series No. 6. London: Overseas Development Administration. 14 p.

Denning, M.; K. Harnevik; and M. Brdarski. 1996. *Food security in east and southern Africa.* Department for Natural Resources and the Environment/SIDA. Stockholm: Swedish International Development Agency (SIDA). 200p

EAAFRO (East African Agricultural and Forestry Organization). 1979. Hydrological Research in East Africa. *East African Agricultural Journal* 43: 248–254. (Special Issue)

FAO (Food and Agriculture Organization) Website: www.fao.org/agriculture

FAO. 1986. *Irrigation in Africa south of the Sahara.* FAO Investment Centre Technical Paper No. 5. Rome: FAO. 175 p.

FAO. 1995a. *Agricultural investment to promote improved capture and use of rainfall in dryland farming.* FAO Investment Centre Technical Paper No. 10. Rome: FAO. 46 p.

FAO. 1995b. *Irrigation in Africa in figures.* Water Report No. 7. Rome: FAO. 336 p.

FAO. 1997. *Small-scale irrigation for arid zones: Principles and options*. Rome: FAO.

FAO. 1999. *Capital formation in Kenyan farmer-owned cooperatives: A case study.* People's Participation Series no. 12. Rome: FAO. 44 p.

Freeman, H. A.; and S. N. Silim. 2000. Commercialization of smallholder irrigation: Economic and social implications in semiarid areas of eastern Kenya. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Gichuki, F. N. 2000. Water scarcity and conflicts: A case study for the upper Ewaso Ng'iro North basin. Overview of irrigation development in Kenya. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Gunnel, Barbara. 1986. The great Bura irrigation scheme disaster. *African Business* 18 (April 1986).

Hornung, M.; and M. D. Newson. 1986. Upland afforestation: Influences on stream hydrology and chemistry. *Soil Use and Management* 2(2): 61–65.

Huggins, C. 2000. Water policy and law in a water scarce country: Implication for smallholder irrigation in Kenya. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

ICID (International Centre for Irrigation and Drainage). *Country profiles.* http://www.icid.org/country.html

Kabutha, C.; and C. Mutero. 2000. From government to producer-managed smallholder rice schemes: The case of the Mwea irrigation scheme. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Lambert, R. A.; and R. D. Faulkner. 1989. A low cost irrigation package for micro-scale irrigation in Africa. In *Land and Water Use,* ed. Dodd and Grace, 603–611. Rotterdam: Balkema.

Mati, B.M. 2000. Use of information systems for smallholder irrigation and drainage planning and management. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Matsika, N. 1996. Challenge of independence: Managing technical and social worlds in a farmer managed irrigation schemes. In *The practices of smallholder irrigation. Case studies from Zimbabwe,* ed. E. Mazungu and P. Van der Zaag, 29–46. Harare: University of Zimbabwe Publications.

Mazungu, E.; and P. Van der Zaag, eds. 1996. *The practice of smallholder irrigation: Case study from Zimbabwe.* Mount Pleasant, Harare: University of Zimbabwe. 235 pp.

MoAC (Ministry of Agriculture and Cooperative). 1999. *National irrigation development plan.* Kenya.

MoFA and DANIDA (Ministry of Foreign Affairs and Danish International Development Agency). 1997. *Small holder irrigation improvement.* Dar es Salaam. 30 pages.

MoW (Ministry of Water). 2000. *Towards a management strategy for the Usangu catchment: Sustainable management of the Usangu wetland and its catchment (SMUWC).* Interim Report. Mbeya. 107 pp.

Mrema, G. C. 1984. Development of small-holder irrigation in Tanzania: Problems and prospects. In *Proceedings of African Regional Symposium on Small Holder Irrigation, 5–7 September 1984, Harare, Zimbabwe.*

Murray-Rust, D. H. 1973. Soil erosion and reservoir sedimentation in a grazing area west of Arusha, Northern Tanzania. In *Studies of soil erosion and sedimentation in Tanzania*, ed. A. Rapp, L. Berry and P. Temple, 325–349. Research Monograph Number 1. Dar es Salaam: Bureau of Resources Management and Land Use Planning. University of Dar es Salaam.

Ngigi, S. N. 2000a. Preliminary evaluation of irrigation development in Kenya. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Ngigi, S. N. 2000b. Review of irrigation development in Kenya. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Ong, C.; and F. Orego. 2000. Link between land management, sedimentation, nutrient flows and the smallholder irrigation in the lake Victoria basin. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Oweis, T.; A. Hachum; and J. Kijne. 1999. *Water harvesting and supplementary irrigation for improved water use efficiency in dry areas*. SWIM Papers No. 7. Colombo, Sri Lanka: International Water Management Institute.

Palanisami, K. *Economics of irrigation technology transfer and adoption*. (FAO, Internet).

Rockström, J.; P. E. Jansson; and J. Barron. 1998. Seasonal rainfall partitioning under runon and runoff conditions and sandy soil in Niger: On farm measurements and water balance modeling. *Journal of Hydrology* 210: 68–92.

Scheltema, W. 2000. Smallholder management of irrigation in Kenya. Overview of irrigation development in Kenya. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Seckler, D.; D. Loldern; and R. Barker. 1999. *Water scarcity in the twenty-first century.* Water Brief 1. Colombo: International Water Management Institute. pp. 11.

Sijali, I. V.; and R. A. Okumu. 2000. New irrigation technologies in Kenya. Paper presented at the Third SWIM Workshop on the Changing Face of Smallholder Irrigation in Kenya, 19 October 2000, Nairobi, Kenya.

Stern, R. D. 1980. The calculation of probability distribution for models of daily precipitation. *Arch. Met. Geoph. Ser B.* 28: 137–147.

USAID (United States Agency for International Development). 1982. *Sudan: The Rahad irrigation project.* A.I.D Project Impact Evaluation Report No. 13. Washington D.C.

Withers, B.; and S. Vipond. 1974. *Design and practices.* London: BT Batsford Limited. pp.306.

World Bank. 1990. *Sudan–Reversing the economic decline.* Country Economic Memorandum. Washington, D.C.