CHAPTER 2

Profile of Agricultural Water Development

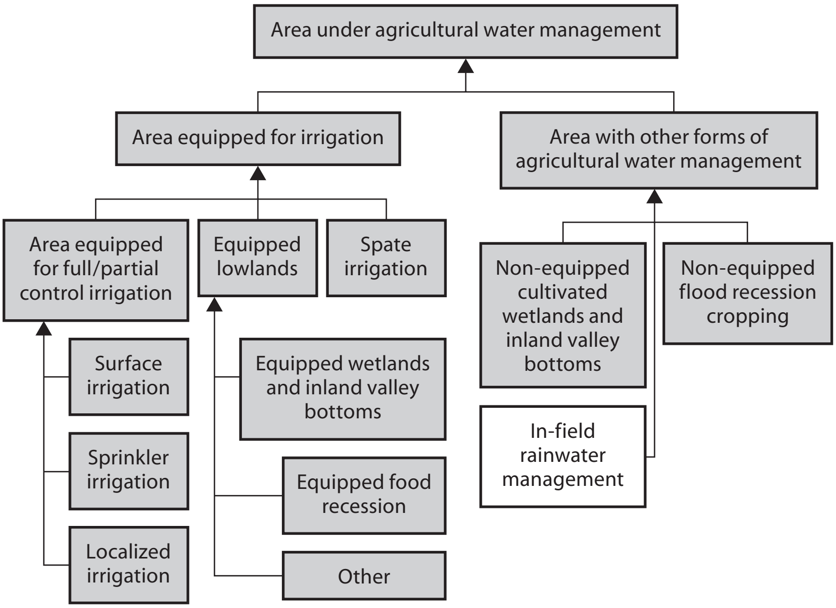
2.1 Agricultural Water Management Typology

The agricultural water management typology used in this report generally follows that adopted by FAO for AQUASTAT, its global database on water and agriculture, (http://www.fao.org/ag/aquastat). The AQUASTAT typology (Fig. 2.1; see also the Glossary) distinguishes between areas 'equipped for irrigation'[1] and those with 'other forms of agricultural water management'.

Although 'water harvesting' has generated considerable interest in recent years, it was not included in the typology shown in Figure 2.1. The main reason was that although it was listed in the AQUASTAT survey questionnaire, few data were received for this type of water management and there were apparently some doubts over their reliability. Part of the problem appeared to be the lack of a commonly accepted definition of the term.

1. According to the terminology adopted in FAO (2005a), 'equipped lowlands' include: (a) cultivated wetlands and inland valley bottoms which have been equipped with water control structures for irrigation and drainage; (b) areas along rivers where cultivation occurs making use of water from receding floods and where structures have been built to retain the receding water; and (c) mangrove swamps developed for agriculture.

Figure 2.1 Agricultural Water Management Typology



Note: Adapted from FAO 2005a (areas in grey correspond to the AQUASTAT typology).

Nevertheless, water harvesting can be defined as the "collection of rainfall for direct application to a cropped area, either stored in the soil profile for immediate uptake by the crop or stored in a reservoir for future productive use" (FAO, 2005a). Thus, in the present context water harvesting consists of the collection and concentration of water for irrigation. What distinguishes it from other types of operations to collect water for irrigation is scale: FAO (2005a) defined three categories of water harvesting on the basis of catchment area, varying from roof catchments to areas of up to 200 hectares. For the purpose of this report, therefore, water harvesting is considered to be *micro-scale collection of rainfall runoff for irrigation* (see also Annex 4 and IFAD 2007). It is therefore assumed to fall under the category of 'areas equipped for irrigation' in Figure 2.1, even though it may not have been fully captured by the AQUASTAT survey.[2]

Because this report is concerned with agricultural water management in its widest sense, it has adopted a modification to the typology

2. This is not to suggest that this type of water development for irrigation is any less important to those who depend on it for their livelihoods.

described by FAO (2005a) (Fig. 2.1) to include 'in-field rainwater management' for dryland crop production. This was not considered by the AQUASTAT survey but is defined here as *operations to enhance the effectiveness of rainfall for dryland crop growth*. What distinguishes it from water harvesting is that instead of *collecting* runoff for irrigation the purpose of in-field rainwater management is to *reduce* runoff and evaporation losses by improving infiltration and storage in the soil profile.

2.2 Agricultural Water Development Characteristics

According to the 2005 AQUASTAT survey (FAO, 2005a), there are about 9.1 million hectares of land in sub-Saharan Africa under some form of water management today. Of the 9.1 million hectares (Table 2.1), 7.1 million hectares are 'equipped' (i.e., developed with irrigation infrastructure). Of this, 6.2 million hectares are under full or partial control irrigation and 0.9 million hectares consist of spate irrigation and equipped lowlands. The remaining 2 million hectares are flood recession and wetland cropping areas not equipped with any water control system. It is estimated that of the equipped area of 7.1 million hectares, only about 75 percent (around 5.3 million hectares) is operational.[3]

More than 33 million people derive their main income from agricultural water managed areas. Although there are no reliable data, it is estimated that at least 6 million households, representing more than 33 million people, live directly on earnings from the subsector.[4] These are almost certainly significant underestimates because AQUASTAT probably under-reports areas under individual private smallholder irrigation (including urban and peri-urban irrigation), micro-scale irrigation (including water harvesting), and 'other forms of water management'. Furthermore, the estimates take no account of those households engaged in wage labor for agricultural water management, including those employed in large-scale private commercial irrigation.

At least twenty countries have more than 100,000 hectares of water managed areas. The distribution of the water managed area by the main

3. The AQUASTAT database is compiled on the basis of national data provided by FAO member countries, with appropriate cross-checking and quality control. However, the quality of data is variable and definitions also often vary from country to country. Hence the statistics quoted should be regarded as indicative rather than firm.

4. This is based on the assumption that at least one-half the total of 9.1 million hectares under water management is operated by smallholders, that each smallholder household averages of 5.5 persons, and that each household cultivates an average of 0.75 hectares of water-managed land.

Table 2.1 Area in Sub-Saharan Africa under Agricultural Water Management by Type

Type of water management	*Area (million ha)*	*Share of area (%)*	*Major countries*	*Other representative countries*
Equipped				
Full water control				
Surface[a]	4.9	54	Sudan, Madagascar, South Africa	Ethiopia, Nigeria, Tanzania, Mozambique, Senegal, Mali, Angola, Somalia, Zimbabwe, Mauritania
Sprinkler	1.2	13	South Africa	Zimbabwe, Kenya, Malawi, Côte d'Ivoire, Swaziland, Zambia, Mauritius
Localized	0.2	2	South Africa	Zimbabwe, Zambia, Malawi
Sub-total full control	6.2	69		
Partial water control				
Lowlands	0.6	6	Mali, Zambia, Guinea, Niger, Nigeria	Côte d'Ivoire, Senegal, Burundi, Guinea Bissau
Spate	0.3	3	Somalia, Sudan	Eritrea, Cameroon
Sub-total partial water control	0.9	9		
Total equipped area	7.1	78		
Non-equipped[**]	2.0	22	Nigeria, Angola	Sierra Leone, Chad, Zambia, Rwanda, Burundi, Mauritania, Malawi, Mali, Uganda
Total water managed area	9.1	100		

a. If irrigation type not specified, surface irrigation has been assumed.

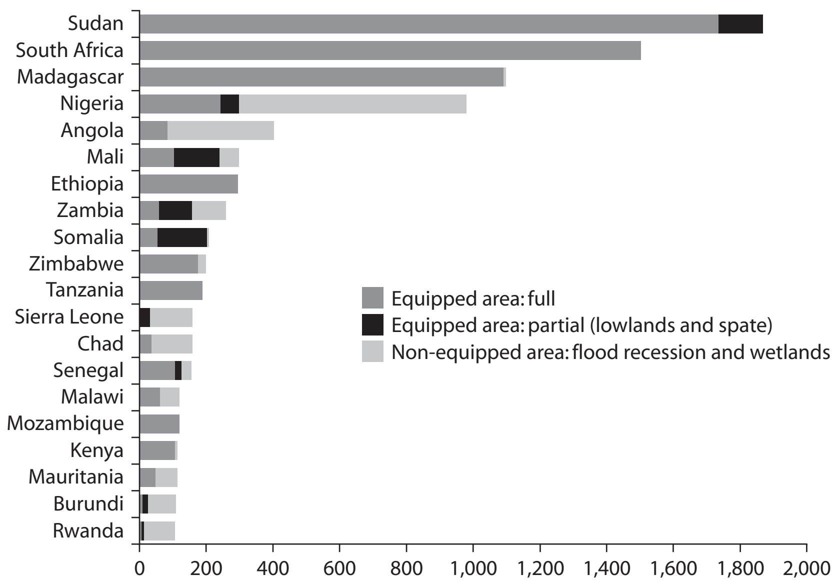
b. Other forms of water management (non-equipped flood recession and wetlands cropping, but excluding in-field rainwater management).

Source: FAO, 2005a.

sub-Saharan African countries where agricultural water management is important is shown in Figure 2.2[5]. Sudan, South Africa, Madagascar, and Nigeria are the main countries for irrigated agriculture (Table 2.1). Other countries with more than 100,000 hectares of full water control irrigation are: Ethiopia, Kenya, Tanzania, Zimbabwe, Mozambique, and Senegal. In several countries, equipped partial control irrigation (spate and lowlands) predominates: Somalia, Malawi, Mali, and Zambia. In Nigeria, Angola, Sierra Leone, Chad, and Zambia, non-equipped flood recession and wetlands cropping systems are important (see also Summary Table 4).

Water withdrawals for agriculture are very limited—just under 2 percent of the total renewable water resource—and water storage is well below levels in other regions. Total withdrawals for agriculture in sub-Saharan Africa amount to 105 billion m^3, less than 2 percent of the total renewable

Figure 2.2 Water Managed Area by Type ('000 hectares)



Source: FAO, 2005a.

5. Summary Table 4 gives details of irrigated areas for all sub-Saharan Africa countries.

water resource (see Summary Table 3). Most countries in the region have low levels of water storage infrastructure, averaging 543 m^3 per capita, compared to 2,428 m^3 in South America and well below the world average of 963 m^3 per capita. In Kenya, for example, total storage capacity per capita is only 126 m^3 per capita, less than 4 percent of the level in Brazil (based on ICOLD data and on IWMI 2005a, World Bank 2004a).[6]

Surface water is overwhelmingly the water source for irrigation. FAO (2005a) indicates that 90 percent of the area under full or partially controlled irrigation in sub-Saharan Africa is supplied from surface water. There is a concentration of irrigation directly linked to water courses in the Nile, Niger, Orange, Senegal, Volta, and Zambezi river basins.

Groundwater irrigation is also locally important. FAO (2005a) also indicates that approximately 10 percent of the area under full or partially controlled irrigation is supplied from groundwater. However, because groundwater is used extensively by private individual small and micro-scale irrigators, many of whom would not be included in AQUASTAT survey data, this too is almost certainly an underestimate.

Large-scale irrigation schemes have generally been developed and managed by governments.[7] Large-scale irrigation schemes have generally been developed by public agencies in several sub-Saharan Africa countries, particularly Sudan, Madagascar, and Nigeria. On almost all these schemes, public agencies have been responsible for operation and maintenance, often with little or no recovery of costs from farmers. However, in recent years farmer organizations have been increasingly involved in management and operation and maintenance (see section 4.6 below).

Development and management of smaller schemes increasingly involves farmers. Many of the small- to medium-scale schemes were also constructed by government and are managed by public irrigation agencies, although they are increasingly being turned over to farmer-management, for example, in Zimbabwe, Senegal, Mauritania, Niger, Mali and South Africa. In recent years, most small-scale development by the public sector has been done in partnership with farmers, and with the understanding that farmers will take over the scheme's operation and maintenance (see section 4.6 below).

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6. In fact, water storage infrastructure for agricultural water is very much less than the figures cited because a significant proportion of the infrastructure is largely for hydropower. In addition, regional averages are inflated by a small number of very large dams.

7. For definitions of large, medium, and small-scale, see Glossary.

At least one-half of the water managed area is privately developed and operated. Privately developed and operated areas include some large-scale sugar estates in Southern Africa, thousands of smaller schemes operated by large-scale commercial farmers, and numerous informal smallholder schemes—as well as many thousands of individually owned and operated areas (mainly gardens). Some private smallholder irrigation is for subsistence (as with Malagasy paddy production in the *bas fonds*, which cover over 800,000 hectares), but some is market-driven agriculture for urban markets, for example in peri-urban areas and in inland wetlands, often dependent on micro-irrigation technologies. *Dambo* irrigation in Zambia, for example, is thought to cover 100,000 hectares.

The total extent of in-field rainwater management in the region is unknown but adoption is thought to have been limited. In-field rainwater management practices such as minimum tillage and other methods of water conservation farming have been promoted in the region, but details of how widely these have been adopted are difficult to find. Nevertheless, it is known that 7.8 percent of smallholder farmers in Zambia, for example, adopted planting basins in the 1999/2000 season (Hageblade et al., 2003). It was also reported that 97 percent of all households in 27 villages surveyed in one district of Niger in the 1990s adopted planting pits, stone bunds, or *demi-lunes* under the Indigenous Soil and Water Conservation in Africa Program (Hassane et al., 2000). "A good number of (smallholder) farmers" also adopted tied ridges to create planting basins for cotton in southern Zimbabwe (Nyamudeza et al. cited in IFAD, 2007). Details of subsequent 'disadoption' were not available, although some of the Zambian farmers gave up after a period of time as a result of being unable to maintain conservation farming practices or when promotional input programs ended (Hageblade et al.). Overall, however, compared with the total area under dryland cropping in the region, adoption of in-field rainwater management for dryland cropping appears limited.[8]

2.3 Water Managed Crops and Productivity

Cereals, largely rice, are the principal irrigated crop. High-value horticulture and industrial crops—largely cotton and sugar—are also important

8. It could be argued that this impression is contradicted by the widespread construction of bunded fields (known as *majaruba*) by rice farmers in East Africa. However, such fields are often constructed as a part of an irrigation system and water management is not strictly for dryland crops (IFAD, 2007).

irrigated crops. Cereals are the predominant irrigated crop in sub-Saharan Africa, accounting for almost 50 percent of the harvested irrigated crop area (Table 2.2). Rice is the principal crop for 25 percent of the harvested irrigated crop area, and is especially important in the humid and sub-humid zones. Other irrigated cereals cover 24 percent of the harvested crop irrigated area and include irrigated maize and irrigated wheat. Irrigated wheat is important in Southern Africa and Ethiopia which together account for 80 percent of sub-Saharan Africa wheat production. High-value horticulture, roots, tubers, and industrial crops—largely cotton and sugar—are also important irrigated crops covering 33 percent of the harvested irrigated crop area. Fodder production and fruit trees together account for 12 percent, largely in Southern Africa, particularly South Africa.

Table 2.2 Harvested Irrigated Crop Area in Sub-Saharan Africa ('000 ha)

Region[a]	*Rice*	*Other cereals*	*Vegetables, roots, tubers*	*Industrial crops*	*Fodder*	*Tree crops*	*Other*	*Total*
Sudano-Sahelian	242	721	181	397	142	5	5	1,693
Gulf of Guinea	28	38	73	50	—	—	32	221
Central	27	8	10	55	—	4	1	105
Eastern	108	193	169	123	—	6	85	684
Indian Ocean Islands	1,062	—	1	38	—	—		1,101
Southern	21	460	344	510	418	77	236	2,066
Total	1,488	1,420	778	1,173	560	92	359	5,870[b]
Share of total cropped area (%)	25	24	13	20	10	2	6	100

a. The regions shown are those adopted by FAO (2005a). The grouping of countries within these regions is based on geographical and climatic homogeneity, which has a direct influence on irrigation. See Map 1 for the groupings.

b. The total cropped area of 5.9 million hectares in this table is commensurate with the equipped area of 5.3 million hectares that is thought to be currently operational, assuming that overall cropping intensity exceeds 100 percent.

Source: FAO, 2005a.

Irrigated production is a small contributor to sub-Saharan Africa's overall staple food production, but plays an important role for import substitution for wheat and rice and for cash crops. Irrigation is important (Table 2.3) for sugar cane (69 percent irrigated), for wheat production (20 percent irrigated), for rice (33 percent irrigated), for horticulture (26 percent irrigated), and for cotton (11 percent irrigated). For production of staple food crops other than rice and wheat, irrigation plays only a minor role complementary to dryland crop production.

Irrigated cereals yields achieved by smallholders are generally low by global standards and have improved only slowly in recent years. In 1997/99, the average paddy yield in sub-Saharan Africa was 1.6 t/ha, compared with 2.9 t/ha in South Asia and 4.2 t/ha in East Asia (Table 2.4). The contrast with yields in North Africa is even more stark: the average paddy yield in Egypt for 2004 was 9.8 t/ha (FAOSTAT). There have been some yield increases in the region in recent years (average paddy yields up 20 percent 1979–1999) but much slower than in Asia

Table 2.3 Percentage of Total Irrigated Production (2005 figures)

Crop	*Total sub-Saharan Africa production (million tonnes)*	*Irrigated production (million tonnes)*	*Share of irrigated in total production (%)*
Sorghum	21.6	0.9	4
Maize	40.7	0.4	1
Wheat	5.0	1.0	20
Rice	12.4	4.1	33
Fruits	57.5	15.0	26
Vegetables	25.4	7.9	31
Sugarcane	69.5	48.0	69
Cotton	4.1	0.5	11

Source: FAO, 2006 based on FAOSTAT data.

Table 2.4 Paddy Yields in Sub-Saharan Africa, South Asia, and East Asia (kg/ha)

Region	*1979/81*	*1989/91*	*1997/99*
SSA	1,347	1,659	1,629
South Asia	1,910	2,602	2,917
East Asia	3,374	4,134	4,180

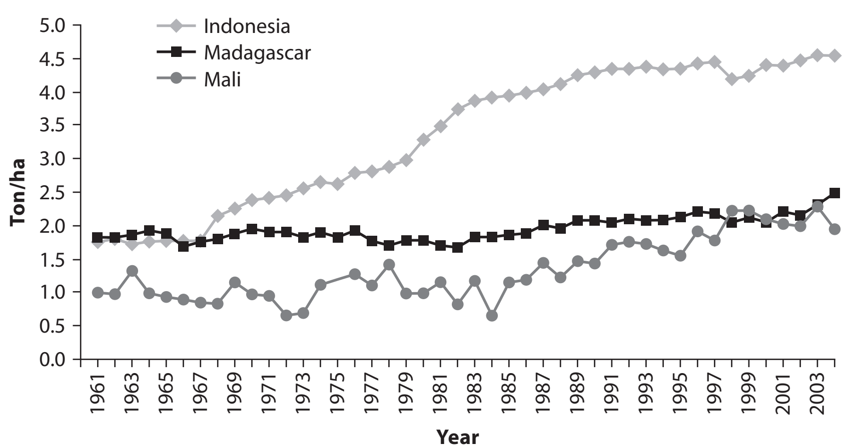
Source: FAO, 2003a.

(South Asia up 53 percent in the same period). Essentially, Green Revolution intensification of paddy cultivation has not yet occurred in sub-Saharan Africa. Average paddy yields in Madagascar, for example, have increased by just 20 percent in the last 20 years to about 2 t/ha, while those of Asian countries that were once at the same level have more than doubled (Figure 2.3). However, in a few large-scale well managed sub-Saharan Africa schemes like the Office du Niger in Mali, yields have attained 'Asian' levels (5–6 t/ha).

Overall, irrigated production in sub-Saharan Africa is characterized by low productivity. Low yields in irrigated production in sub-Saharan Africa can be attributed to unreliable water supplies, poor water control and management, low input use, poor crop husbandry, and to difficulty in accessing profitable output markets. In Madagascar, irrigated paddy yields could be increased by 50–80 percent simply by improved water control and in-field management (Table 2.5). Farmers in sub-Saharan Africa still lag far behind other developing areas in fertilizer use. Average fertilizer use remains at 9 kg/ha in 2002/03 compared with 100 kg/ha in South Asia, and 135 kg/ha in East Asia (FAO, 2004).

In Madagascar, 69 percent of the area under irrigated rice is cropped without any mineral or organic fertilizer applications, and the relation between fertilizer use and yields is transparent (Table 2.6; World Bank, 2003). But perhaps the single most important factor is access to markets: the correlation of low irrigated productivity with remoteness from mar-

Figure 2.3 Paddy Yield in Madagascar, Mali, and Indonesia



Source: FAOSTAT.

Table 2.5 Madagascar: Effect of Water Management on Paddy Yields (kg/ha)

Level of water management	*Lac Alaotra*	*High plateaux*
High	3,282	3,535
Moderate	2,490	3,424
Low	2,139	2,740

Source: World Bank, 2003.

Table 2.6 Madagascar: Regional Comparison of Irrigated Paddy Yields

Region	*Average irrigated yield of paddy (kg/ha)*	*Fertilizer use (% of cultivated area)*
High plateaux	3,200	76
Lake Alaotra	2,632	40
Middle West	1,966	22

Source: World Bank, 2003.

kets is very strong in sub-Saharan Africa. In Madagascar, the distance of a rice plot from a road was found to have a strong negative effect on paddy yields (World Bank, 2003). It is probably the market factor which most influences other determinants of productivity. For example, where market-driven incentives are present, Malagasy farmers will invest in water control structures, fertilizers, and crop husbandry improvements.

Although less is known of dryland crop production under in-field rainwater management practices, the few available results indicate that, as for irrigated cropping, productivity gains can be considerable when farmers also have access to yield-enhancing inputs but declines when access is reduced. Farmer yields obtained from conservation farming plots have often been more than double those from plots on which conventional tillage is practiced.[9] However, these increases appear to be closely connected to the level of extension support and input packages (including HYV seeds) provided by projects. Once project support falls away, so do yields (Hageblade et al., 2003).

9. For example, the mean maize yield achieved by farmers in the 2001/02 season in Thaba Nchu, South Africa was 2.4 t/ha with in-field rainwater management compared with 1.7 t/ha without water management (Botha et al. cited in Beukes et al., 2003). Similarly, mean maize yields in Zambia during the 2001/02 season were 1.5 t/ha with conventional plowing but 2.9 t/ha with planting pits (Hageblade et al.). Mean millet yields for 1991–1996 were 125 kg/ha without water management and 765 kg/ha with *tassa* planting pits (Hassane et al., 2000; see also Annex 4). And maize yields in Tanzania's Arusha Region were two to three times higher with conservation tillage than without (Jonsson et al., 1998).

2.4 Which Crops Have Proved Viable Under Water Management?

Staple Food Crops

Irrigated rice cultivation in sub-Saharan Africa has proved viable, at least for the local market, provided that yields are relatively good and investment costs are not too high. In Sierra Leone, irrigated production shows both good farmer returns and economic viability for local sale (domestic resource costs (DRCs) well below unity, Table 2.7), but not for export (DRCs above unity). In Mali, intensive irrigated rice production (yields of up to 6 t/ha and cropping intensities of 1.2) is competitive for the domestic market and for some border areas of neighboring countries (World Bank, 2005k). In general, irrigated rice production in the sub-humid zones of sub-Saharan Africa is viable if: (a) investment costs are relatively low ($5,000/ha has been suggested as a 'cut-off point' for single-cropped paddy at an average yield of 3.3 t/ha [IFAD, 2007]);[10] (b) more intensive production systems are used (yields up to 5–6 t/ha and double cropping may be needed to justify a high-cost irrigation schemes); and (c) production is for import substitution. Many factors influence the cut off point. For example, investment in rice production with simple run-off and bunding techniques in valley bottoms in Madagascar can be viable even at yield levels of 2 t/ha. Market isolation is another factor because this will increase economic farm gate prices for local rice production and hence the cut off point (IFAD, 2007). Box 2.1 is an example from Mali.

Non-rice cereals have proved less viable under irrigation, particularly with the continuing decline in world prices. The relatively low value of

Table 2.7 Returns to Irrigated Rice Production in Sierra Leone

Crop regime	*Net financial return (US$/ha)*	*DRC[a] import parity*	*DRC[a] export parity*
Boliland with intensive production (including HYVs)	653	0.73	1.33
Riverine flood recession with intensive production (including HYVs)	892	0.72	1.31

a. Domestic resource costs.

Source: World Bank, 2005h.

10. The ceiling cost would be higher if double cropping were possible.

Box 2.1

In Mali, Irrigated Rice with Higher Value Cash Crops and Irrigated Rice Monoculture are Expected to be Profitable

Under the Mali National Rural Infrastructure Project, various types of new irrigation schemes are being developed for rice production, some with cash crops in the rotation, some in monoculture.

At the large M'Bewani scheme, Office du Niger will develop 1,300 hectares of new irrigated land. Paddy yields are expected to be 5.0–5.5 t/ha, and onions, shallots, and tomatoes will also be grown. Cropping intensity is assumed to be 120 percent. For an investment cost of $4,230/ha, the estimated economic rate of return at project appraisal is 16 percent.

Farmer-managed small-scale irrigation perimeters (250–500 ha) are expected to pursue rice monoculture because the schemes are very far from market centers where cash crops could be sold. For the same reason, local rice prices are relatively high. Paddy yields are expected to be 4.0–5.0 t/ha and cropping intensity at 120–150 percent. For an investment cost of $5,000/ha, expected rates of return are 12–18 percent.

Source: World Bank, 2005k.

other cereals on the world market means that domestic market prices may not be high enough to make irrigated production a viable investment in sub-Saharan Africa, particularly because yields are typically below world averages (see section 2.3 above). For example, in Nigeria, most public irrigation schemes were designed for cereals production when priorities were self-sufficiency in food rather than increased farmer incomes and economic viability. With the liberalization of the Nigerian economy and the continued decline of world cereals prices, much of this food crop production (especially on pump schemes) has become uneconomic (World Bank, 2001). That there are 1.4 million hectares of irrigated land in sub-Saharan Africa cropped to non-rice cereals is probably a reflection of subsidies on capital and O&M costs, rather than viability (FAO, 2006 and Annex 5).

Mixed cropping of cereals and cash crops can boost viability. On large-scale schemes in Mali close to markets, for example, combining paddy and cash crops contributes to good rates of return (Box 2.1). Irrigated dry beans have also been found to be highly profitable by smallholders in Southern Africa and can considerably boost viability in mixed cropping systems.

Improving dryland production could be the better option for non-rice cereals—and in-field rainwater management could be the key. Research to date on in-field rainwater management for dryland crop production has demonstrated its agronomic feasibility, but the issue of viability has received less attention. However, monitoring data obtained from a pilot project in Niger (Box 2.2) have provided one of the few opportunities for benefit-cost analysis on in-field rainwater management for dryland crops, i.e., the *tassa* planting pit system. The *tassa* cost approximately $100/ha to construct and have an economic life of three years, after which they must be re-dug. In a year of poor rainfall, farmer yields of millet from the *tassa* systems were a massive 50–60 times those obtained from the control plot, although the difference was much less in years of good rainfall (Hassane et al., 2000). Taking account of the good and bad years over a 6-year period, an analysis prepared for the component study on poverty reduction (IFAD, 2007) indicated a benefit-cost ratio of 1.9 at a discount rate of 10 percent—meaning that the ERR would have been far greater than 10 percent. This one example shows that investment in in-field rainwater management can be viable for non-rice cereal crops such as millet, even in the semi-arid zones. There is thus good reason to suppose that viable technologies exist or can be found to increase the effectiveness of rainfall for other deep-rooted non-rice staples, such as maize and wheat, produced under dryland conditions.

Horticulture

Irrigated horticulture is a fast growing activity. Markets for irrigated horticulture have been growing, with most production for local markets. In Kenya, for example, total production of fruits and vegetables in 1996 was 3.1 million tonnes, of which more than 3 million tonnes was consumed locally or used as an input to processing, and only 90,000 tonnes were exported as fresh produce (Sally and Abernethy, 2002).

Horticulture is developing especially fast around cities—and even within them. Peri-urban and urban horticulture is a rapidly growing phenomenon. In Accra, for example, an estimated 60 percent of all urban households are engaged in subsistence-oriented backyard farming, while market-oriented urban vegetable production on urban open spaces supplies 60–90 percent of the city's consumption of perishable vegetables, feeding more than 200,000 people every day (Obuobie et al., 2006).

Box 2.2

Improving In-Field Rainwater Management in the Semi-Arid Areas of Niger

In common with many semi-arid areas, Niger has suffered land degradation as a result of population pressure and drought. An IFAD-assisted project tested a number of locally-based technologies to bring land back into production, reduce inter-annual variability of output, and enhance the resilience of farming systems to climatic risk. One key success was the development of a modified form of the *tassa* practice. This continued to expand spontaneously to new plots after the project had closed.

The *tassa* practice consists of digging holes some 200–300 mm in diameter and 150–200 mm deep and covering the hole bottoms with manure. This helps to promote termite activity during the dry season, thus improving water infiltration further. Farmers then plant millet or sorghum in them. *Tassas* have allowed the region to attain average millet yields of over 480 kg/ha, in comparison with only 130 ha/kg without *tassas*. As a result *tassas* have become an integral part of the local technology base. The technique is spreading at a surprising rate.

Three main factors contributed to success: (a) an action-research approach that combines flexibility, openness to farmer initiatives, a forward-looking attitude, and willingness to negotiate; (b) a technology that yields quick and tangible benefits, yet is simple, easily replicable, and fits well with existing farming systems; and (c) a technology that can adjust to the changing local context. The *tassa* is based on a local practice that, although not high-performing, is effective.

Tassas appeal to farmers because they yield quick and appreciable results, restoring productivity of land that was previously unfit for cultivation while mitigating agro-climatic risks and increasing food availability in participating households by 20–40 percent. They are easily replicable because they entail only minor adjustments to local hand tools and do not involve any additional work during the critical sowing and weeding periods. Because they can be constructed by individual farmers without external assistance, *tassas* are particularly interesting to youths because they make it possible to cultivate plateau lands, which have become a valuable resource in the face of growing pressure on land.

Source: Mascaretti in Dixon et al., 2001.

As urbanization puts more pressure on the land, intensification of urban and peri-urban gardening is increasing.[11]

Horticultural production for export has become a boom area for some countries, and the poverty reduction impact is significant. High-value irrigated horticulture is bringing ready benefits to smallholders. In countries such as Ethiopia, Kenya, Senegal, Mali, Niger, Zambia, and Mauritania, entrepreneurs have developed new export markets for high-value irrigated produce, and have recruited and supervised smallholder producers to supply customers. Fruits and vegetables are now Kenya's third ranking foreign exchange earner, providing livelihoods to as many as 100,000 small farmers (IWMI, 2005f,; Box 2.3).

The Rural Household Survey (2000) in Kenya found that gross margins per hectare are 6–20 times higher for irrigated French beans for export than for maize-dry bean intercropping. One-half of the French bean growers owned their own irrigation equipment compared to 10 percent for other farmers; and the average per capita income of the

Box 2.3

Horticultural Growth and the Poor in Kenya

In Kenya, data from the 2000 Rural Household Survey suggest that almost all farmers, rich and poor, participate in some form of horticultural production. The percentage contribution of horticulture to income is fairly constant across income and farm size categories. Production is predominantly for market. Even among the poorest 20 percent of Kenyan farmers, 41 percent of the fruit and vegetable output is marketed (Minot:38).

Smallholders account for about 47 percent of Kenya's fresh produce exports. If the farm gate price is 60 percent of the f.o.b. price, this would bring gross revenue of $47 million to Kenya's smallholders annually. Estimates of the number of smallholders benefiting vary considerably, between 20,000 and 100,000 households, so that average horticultural export earnings for a family would be in the range $500–2,350.

Source: IWMI, 2002.

11. However, urban and peri-urban horticulture is often based on the use of untreated wastewater which, in the absence of regulation, is creating some environmental and health risks.

French bean growers was double that of other farmers (Minot in IWMI, 2002). The poverty reduction impact is significant (Box 2.2).

Horticulture is driving profitable investment in irrigation. In Kenya, about 48,000 hectares are under small-scale irrigation schemes, largely for horticulture (FAO, 2005a). Most are farmer organized systems where farmers share the cost of a pump and distribution system (Ngigi in IWMI, 2002). Rapid growth has been accompanied by new irrigation technologies. Small-scale drip irrigation systems have been improved by the Kenya Agricultural Research Institute and disseminated by local NGOs. Several types of treadle pumps costing less than $80 have also been introduced (IFAD, 2007).

Industrial Crops

Crops such as sugar cane and cotton have been proven to be viable under irrigation, but only where relatively high yields are achieved. Large-scale commercial sugar estates throughout the region have demonstrated that investment in irrigation and transport infrastructure as well as processing plants can be viable where water supplies are adequate, the construction of new dam storage is not needed, and relatively high cane yields can be obtained, as in Swaziland where yields averaged 94 t/ha in 2004 (FAOSTAT). Similarly, irrigated cotton can be viable if relatively high yields (e.g., on the order of 3–4.5 t/ha) can be obtained or where the bulk of investment costs have been sunk. Smallholders often cultivate these and other industrial crops as 'outgrowers' under contract arrangements with the processing plants, through which the latter provides inputs, extension advice, and a guaranteed market outlet and price. An example of this type of arrangement is provided by Nakambala sugar estate in Zambia.

Mixed Agricultural Water and Livestock Systems

Livestock are an integral part of most irrigated production systems. In irrigated agriculture in the region, livestock are important for animal products and for draft power and manure in irrigated crop production (IWMI-ILRI, 2005e). In Madagascar, for example, irrigated paddy yields are positively correlated with the availability of animal draft, and areas of animal concentration have a much higher use of manure (World Bank, 2003). Irrigated crop residues are used for animal feed within the region's mixed farming systems and large-scale irrigation systems have the region's highest livestock densities: on the Gezira Irrigation Scheme in Sudan, for example, 90 percent of farmers keep animals, and 30 percent of income is from livestock. Irrigated agriculture also interacts with pastoral systems: crop residues on the Gezira scheme maintain animals during the long trek to the Khartoum market.

However, irrigated fodder production is generally not viable in the region. Livestock production in sub-Saharan Africa depends more on grazing than in other regions of the world. FAO estimate that fodder currently accounts for only 3.5 percent of all crop output in the region (FAO, 2006). Irrigated fodder production is rare except in South Africa (see section 2.3 above). However, where there is good market access, irrigation water can be profitably used to grow fodder crops for fattening and the production of meat and milk—as in the intensive, stall-fed production systems around Mount Kenya. Because most fodder crops are perennial, their production under dryland conditions with in-field rainwater management is probably not an option except where rainfall patterns are bimodal.