WORKING PAPER 55

Innovative Approaches to Agricultural Water Use for Improving Food Security in Sub-Saharan Africa

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and D. J. Merrey

IWMI
International
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Comprehensive Assessment
of Water Management in Agriculture

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Contents

Summary v

Introduction 1

Water Resources—Some Basic Facts 1

Innovative Approaches to Water Development and Use in Agriculture 4

Conclusions 15

Literature Cited 16

Summary

This paper provides an overview of innovative options for developing and using water for food production in sub-Saharan Africa (SSA) in light of the growing scarcity and competition for water resources. These options include rainwater harvesting, selective development of wetlands for agriculture, exploitation of shallow groundwater, and recycling urban waste. The options are largely based on low-cost individualized technologies, which lend themselves to private-sector promotion. Water-demand management approaches are also discussed.

I. Introduction

The 1996 World Food Summit set a goal of halving the number of food insecure people from 800 million in 1995 to 400 million in 2015. But according to projections by the International Food Policy Research Institute (IFPRI), it is unlikely that this goal would be achieved before 2030, i.e., 15 years after the target date, at best. South Asia and SSA are the regions worst affected by food insecurity and malnutrition, being home to 60 percent of the world's food-insecure people and 75 percent of its malnourished children.

However, we cannot deny the considerable progress achieved in improving agricultural productivity and production over the past 30 years, especially in Asia. We observed increases in per capita cereal production and availability of food (except in SSA), decreased production costs and basic food prices, and growth in income levels and living standards. Such advances came about as a result of better crop varieties, agricultural practices and water-resources development, better access to irrigation, fertilizer and other inputs, and improved policies and institutions. But with these positive developments emerged some adverse side effects, such as waterlogging and salinization of irrigated lands, depletion of groundwater tables, and water pollution and human health problems. Over time, more efforts are focused in finding solutions to these negative externalities and consequences.

The aim of this paper is to discuss how innovative approaches to agricultural water use could contribute to alleviating food insecurity and poverty in SSA in a sustainable way.

II. Water Resources—Some Basic Facts

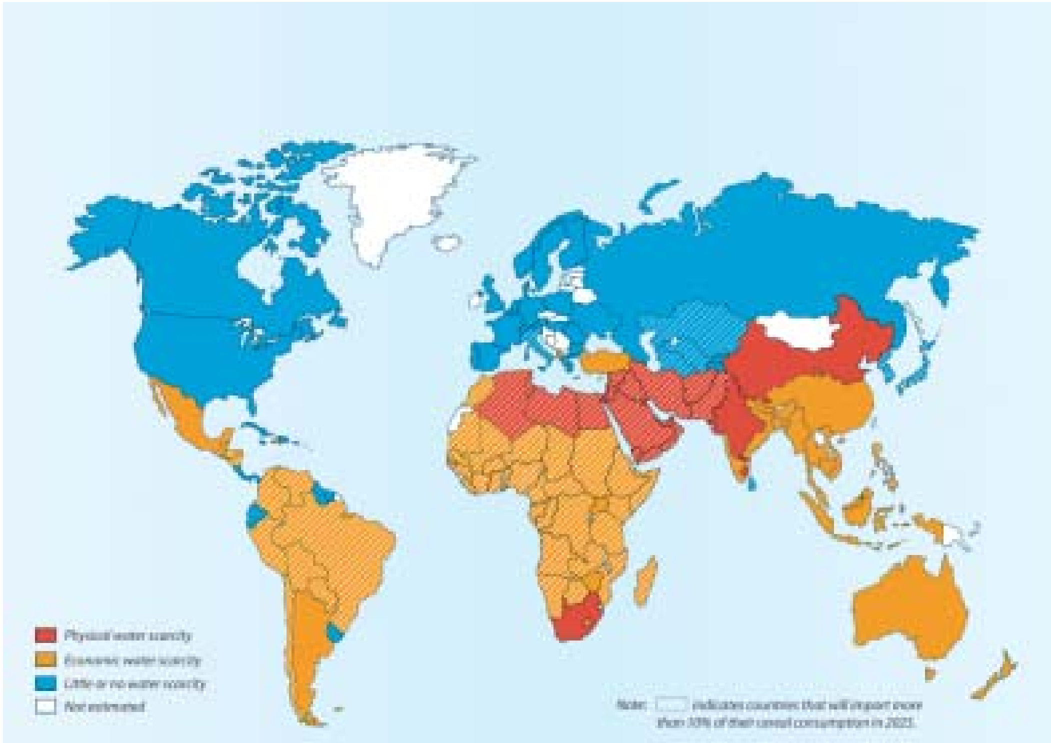
The water-scarcity map in figure 1, which synthesizes the results of a study conducted by IWMI, shows that all countries in Africa are projected to be either physically or economically water scarce in 2025. Given this scenario, imports are expected to increase to account for more than 10 percent of total cereal consumption in Africa. In SSA, cereal imports are projected to triple from 9 million metric tons in 1990 to 29 million metric tons in 2020 (Rosegrant and Perez 1995). In their "business as usual scenario," IWMI and IFPRI project an import requirement of 35 million metric tons for SSA by 2025 (Rosegrant et al. 2002).

Countries that are physically water scarce, like South Africa and North African countries, may not have adequate water resources to meet their projected water needs in 2025; and yet more than a quarter of the world's population will be living in these regions. A recent analysis using IWMI's "Podium" tool presents a more optimistic picture of the water and food nexus in South Africa, suggesting that "absolute scarcity" is an unlikely scenario (Kamara and Sally 2002).

Economically water-scarce countries potentially have enough water resources to meet their future needs, but they will not be in a position to make the additional investments required to actually harness and use these resources. This is the situation confronting most countries in SSA. Country-level situations and scenarios, however, mask significant differences within countries, both temporally and spatially. Some of these SSA countries have regions and river basins that already face serious physical water scarcity. An example is the Ewaso Ng'iro North basin in Kenya (Gichuki 2002).

Agriculture still accounts for at least 70 percent of the world's total water usage. To put this into a better perspective, let us examine how much water we "eat" compared to what we use for other purposes. Let us assume that a person's food requirement is 300 kg/yr. of cereal equivalent, sufficient to furnish a daily average per capita caloric intake of about 2,900 kcal. Assuming a water

Figure 1. The IWMI world water scarcity map.



productivity of one kg/m^3 (i.e., one cubic meter of water is consumed to grow one kilogram of food), 300 m^3 of water per year are consumed to grow this annual food requirement. This is equivalent to about 850 liters per person per day, which is more than 8 times the 80-100 liters per person per day needed for drinking, cooking, washing, etc. This simple analysis tells us that the "basic need" for sustaining existence is around 340 m^3 per person per year.

Table 1 shows that there are large disparities in freshwater withdrawals among the different regions. The proportion of water abstracted by the agriculture sector is highest in less-developed regions relative to domestic and industrial uses. Compared to other regions, SSA has the highest share of agriculture relative to other uses. This table also shows that per capita abstractions in developed countries are much higher than in developing countries, and lowest in Africa. These low water withdrawals in SSA are an indicator of underdevelopment and of the opportunity for further development of water resources.

With rapidly growing urban populations,[1] agriculture will have to compete with increasing urban (municipal and industrial) water needs. Water allocation for agriculture gives way to higher-value urban uses that may adversely affect food production. With food production already lagging behind population growth in Africa, reduced allocations for agriculture may aggravate the problem of food security.

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[2]Estimated at 34 percent of the total in 1999 compared to only 23 percent in 1980 (World Bank 2000).

Table 1. Annual freshwater withdrawals by region.

Region	Average annual internal renewable water resources (m^3/capita) 2000	Annual freshwater withdrawals			
		Per capita (m^3)	Agriculture %)	Industry (%)	Domestic (%)
Europe	3,981	704	39	45	14
North America	21,583	1,907	25	66	8
South America	34,791	518	71	11	17
Asia	3,668	627	81	9	7
Africa	5,159	307	85	6	9
SSA	-	-	87	4	9
World	7,045	664	70	22	8

Sources: UNDP et al. 2000; World Bank 2000; FAO 1995.

Water needs are directly proportional to population growth. For instance, the population in SSA is expected to increase to over one billion by 2025 with an annual growth rate of about 3 percent. The Forum for Agricultural Research in Africa (FARA) estimates that, to keep up with this increase and achieve food security by 2015, agricultural production must increase at an annual rate of 6 percent. This target has been adopted by the New Partnership for Africa's Development (NEPAD). To achieve this annual production growth, agricultural intensification is required. Effective and efficient use of water would be an important factor in achieving intensification and increased agricultural productivity (FAO 2000). FAO estimates that about 75 percent of the crop growth required by 2030 in SSA will have to come from yield increases (62%) and higher crop intensities (13%) while the expansion of arable land is expected to contribute the balance 25 percent.

Concerns for sustainability and possible adverse environmental and health impacts of wasteful water use and poorly planned development are giving way to another competing "use" (or nonuse) of water in addition to domestic/industrial and agricultural uses. For instance, the new National Water Act (1998) of South Africa specifies a "reserve[2] for the environment," defined as the *quantity and quality of water which is needed to protect basic human needs, and the structure and function of ecosystems to secure ecologically sustainable development and utilization.* This reserved amount is intended to protect the aquatic resources in rivers, wetlands, estuaries and other water bodies. According to Smakhtin (2002), reserving water for the environment may reduce available resources for other existing uses by 15 to 20 percent in South Africa. Other African countries have yet to address this environmental dimension of water resources development.

[2]Also known as environmental flows, in-stream flow requirements, environmental flow requirements or minimum flows for the environment or environmental water needs (Smakhtin 2002).

The challenge we face today in meeting the food and fiber requirements of a growing population, particularly in the light of greater demands for available water resources from other sectors, is how to increase the productivity of water and land in a sustainable manner. In the following sections we discuss some ways of how this challenge could be addressed in SSA through technical, institutional, as well as political solutions.

III. Innovative Approaches to Water Development and Use in Agriculture

Growing economic and physical scarcity of water, compounded by rising costs of developing new and further sources to meet increasing demands for water, calls for innovative ways of water use and development. There are two[3] ways of approaching this problem: a) managing supply, which includes developing new sources of surface water and groundwater, monitored and regulated use of wastewater in urban and peri-urban agriculture, promotion of water harvesting, and reuse of agricultural drainage, among others; and b) managing demand, which includes incentives (e.g., through policies) and mechanisms (e.g., through institutions) as well as new technologies that promote efficient use of water (high-precision irrigation), and water and soil conservation. An appropriate mix of supply and demand management will depend on the level of development and degree of water scarcity. While most of SSA will be primarily concerned with the augmentation of supply, it is not too early to start planning for improved demand management.

A. Increasing and Managing Water Supply

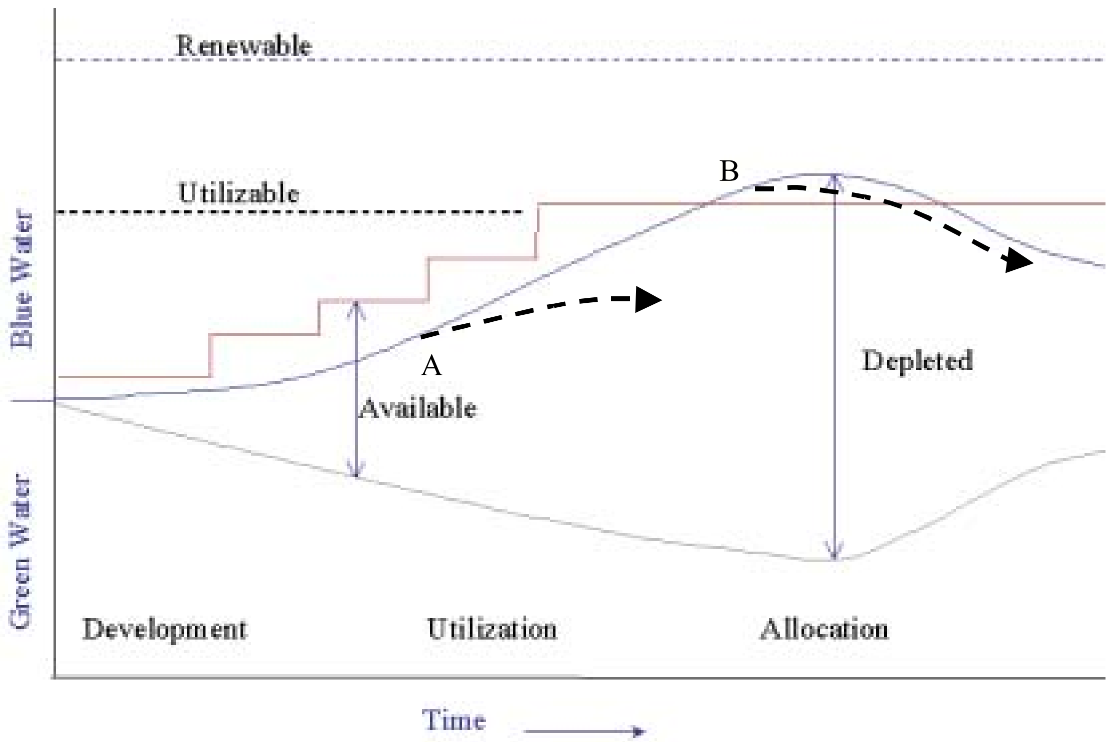
Developing and managing water supply through infrastructure to store or divert the water resources in a basin are obvious responses to the problem of water scarcity. This approach is limited by the amount of land, water and financial resources available and by the social and ecological considerations that must be respected to sustain such developments.

In the early stages of developing a river basin, the quantity of water available is not really a constraint and the primary concern is to increase access to available water by building infrastructure and expanding facilities for human use. As resource depletion occurs and river basins approach "closure," i.e., run out of water, the focus shifts to obtaining the most output from, or making the most productive use of, the available water. Inter-sectoral competition for water increases and allocating water among these sectors in an efficient, equitable and sustainable way become a major concern. Figure 2 illustrates this point in terms of stages of river-basin development. The need for appropriate mechanisms for carrying this out, including tools, institutions and organizations, is thus highlighted.

Some projections have suggested that just as large investments in formal irrigation were important in the Asian Green Revolution, so too such investments could make a major contribution to solving SSA's problems of food security. However, the environment for such investments has changed dramatically from the 1960s to the 1980s—in large part because of the success of Asian irrigation investments. Whereas food grain prices were previously high, reflecting global shortages, today they are too low to justify expensive formal irrigation investments—and the trend is for stable

[3]Rosegrant and Perez (1995) cite UNDTC 1991 and World Bank 1993 working definitions of supply and demand approaches with the first as including actions and policies that affect the quantity and quality of water at the entry point into the distribution system and the second as those that influence the use or wastage of water after the entry point.

Figure 2. Phases of river-basin development



Source: Molden et al. 2002.

or lower grain prices in future. The relatively high cost of irrigation development in Africa compounds this problem (Jones 1995). Further, recall the point of figure 1, the global water scarcity map: it is precisely those SSA countries facing the severest food-security problems that can least afford such expensive investments—they face “economic water scarcity,” which is really a scarcity of financial (and human) resources. In addition, the experience in SSA with large-scale public-irrigation investments has not been encouraging (see, for example, the papers in Blank et al. 2002). It is therefore imperative that Africa identifies more innovative cost-effective interventions to improve water and land management as bases of achieving food security and economic development.

Among the promising options under supply approaches are rainwater harvesting, development of wetlands, tapping of shallow aquifer, possibilities for conjunctive use of surface water and groundwater, recycling liquid and solid waste for urban and peri-urban irrigation, and desalination.

Water Harvesting

About 60 percent of the world’s cereal agricultural production is grown under rain-fed conditions (IWMI 2000). But we all know that crop production under such conditions remains vulnerable to the adequacy, reliability and timeliness of rainfall. Given these uncertainties, farmers are averse to taking risks and investing in inputs and improvements, resulting in low levels of productivity. Rainwater harvesting, which is the process of concentrating and conserving rainfall runoff in the field or in storage structures, such as tanks and ponds, can help mitigate the effects of the temporal and spatial variability of rainfall, and the high risks of intra-seasonal dry spells that characterize the water-scarce regions of SSA. Overcoming these constraints can lead to important contributions to poor people's livelihoods.

A growing number of studies (Ngigi 2002; Rockström et al. 2001; Rockström 2001; Rockström and Falkenmark 2000; WFS 1996) have shown that the yield and reliability of agricultural production can be significantly improved with water harvesting. The World Food Summit (WFS) cites three to fourfold yield increases with drip irrigation or hand-watering, made possible by water harvesting relative to dryland farming in Burkina Faso, Kenya and Sudan. While there is no reliable estimate of the overall potential of water-harvesting development, medium-sized and micro-catchment water-harvesting schemes can contribute to increased food production in semiarid areas (WFS 1996). We believe the potential for this is very large.

Farmers in the Yatenga province in Burkina Faso provide an example where water harvesting is used to improve production and increase income. As early as 1989, farmers in 8,000 hectares in 400 Yatenga villages were using an improved version of their traditional water-harvesting technique that involved building simple stone bunds across the slopes of their fields. Earlier in 1979, there was also the case of the farmers (mostly women) in the Machakos district in southern Kenya who used "fanya-juu" terracing, which involved digging a ditch and throwing the soil up-slope to form an earthen wall, maximizing the retention of rainwater (Postel 1992; Tiffen et al. 1994).

In Tanzania, there is evidence of widespread water-harvesting practices but mostly opportunistic, with some traditional techniques used for actively managing runoff collection and distribution (Gowing et al. 1999). Given the slow development and adoption of modern techniques, the authors observe that rainwater harvesting has been neglected by research and extension despite its potential for sustainable intensification, especially for dryland farmers. It is said that more than half of the rice production in Tanzania is grown under farmer-built and -managed water-harvesting systems. Sokoine University of Agriculture has been pioneering work on rainwater-harvesting technologies in Tanzania (Hatibu and Mahoo 2000).

Table 2 highlights water-harvesting technologies practiced in the Latin American and Caribbean (LAC) countries, some of which are probably not so different from those found in a number of African countries, such as the *in situ* systems and flood diversion (Hatibu 2003). The range of nontraditional water-harvesting practices used for agriculture in LAC include rainwater harvesting or use of natural or artificial depressions to store rainwater (both *in situ* and roof catchment), fog harvesting, runoff collection and flood diversion (Ringler et al. 2000). Fog harvesting involves the use of fine nylon nets strung between poles, a conveyance system and a storage area and costs $3 per cubic meter of water collected. Runoff collection from paved and unpaved roads (as well as surface and underground structures) goes through drainage ditches or street gutters and is then transported to farm areas. Floods are diverted through transverse dikes, *toroba* or small-scale diversion structures, and water traps.

The potential contribution of water-harvesting techniques in rain-fed areas include: a) reduced pressure to invest in conventional water augmentation through large dams and run-of-the-river diversion schemes, among others; b) relatively cheap technology easily available to poor farmers; and c) environmental benefits with reduced pressure on groundwater resources. Developments in water-harvesting systems, which include low-cost, labor-saving techniques as well as construction materials for building catchment bunds and distributing water, induce more adoption as they offer agricultural and ecological benefits. The advent of precision agriculture, which makes use of site-specific soil, crop and environmental data, and contour plowing and precision land leveling make water harvesting even more attractive. Conservation tillage, such as minimum till and zero till, together with precision agriculture and water harvesting, increases the effective rainfall used for crop production.

Table. 2. Nontraditional water sources and sectoral uses in LAC countries.

Technology	Sector			Countries
	Agriculture and livestock	Domestic	Industrial	
1. Rainwater harvesting				
-roof catchments	√	√	-	Argentina, Barbados, Brazil, British Virgin Islands, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Montserrat, Netherlands Antilles, Paraguay, St. Lucia, Suriname, Turks and Caicos, US Virgin Islands
- *in situ*	√	-	-	Argentina, Brazil, Paraguay
2. Fog harvesting	√	√	√	Chile, Ecuador, Mexico, Peru
3. Runoff collection	√	√	√	Argentina (cost range of \$0.60-1.20/m^3), Aruba, Brazil (cost/m^3 of \$0.67), Chile, Costa Rica, Dominican Republic, Ecuador (cost/m^3 of \$0.10-2.00), Panama, St. Lucia, Suriname, Venezuela
4. Flood diversion	√	-	-	Argentina, Brazil, Venezuela

Source: Adapted from Ringler et al. 2000 citing OAS/UNEP/IETC 1997.

However, despite the apparent advantages of this water-harvesting technology, social and economic conditions of farmers may be constraining adoption as indicated by the abandonment of some constructed water-harvesting schemes (WFS 1996). This suggests the need to realistically take into account expected gains in yield for certain levels of inputs, the risks involved, labor requirements and cash flow at the household level. Moreover, governments in arid and semiarid countries are still to acknowledge the value of water harvesting as part of rural development, specifically, as a central component of the water and agricultural development policy. Further research is required to understand and overcome the apparent policy and institutional constraints to scaling up these technologies, and to understand the possible hydrological limits to expanding water harvesting in upper catchments.

Development of Wetlands for Increasing Food Production

Wetlands constitute an increasingly important component of rural livelihoods in Africa. While the environmental importance of wetland ecosystems is widely recognized by now, the potential role of wetlands for poverty alleviation and livelihood security for the region is still hardly explored. Meeting the challenge of enhancing the productivity of agricultural and other uses of wetlands requires addressing a range of problems, such as climatic and hydrological variability and risks, availability of labor and other inputs, infertility of soils, institutional arrangements for land and water rights, and formulation and implementation of laws and policies. Productivity-enhancing measures may sometimes give rise to serious ecological risks. Some wetlands are hydrologically sensitive environments and are exposed to the risk of overabstraction and declining groundwater tables. Multidisciplinary research is thus required to produce and validate tools and intervention packages, which implementers can use to develop strategies and design projects that strike a better balance between production and protection. Optimal use of wetlands is expected to yield positive benefits for small farmers as well as for the conservation of the wetland environment and the overall conditions in the catchment.

Rwanda has about 165,000 hectares of wetlands over 50 percent of which is used for agriculture (FAO 1998). Cultivated *dambos* (inland wetlands) in Malawi, Zambia and Zimbabwe comprise about 10 percent of the total dambo area in these countries (FAO 1995). In Malawi, methods employed by farmers are either based on trial and error or by directly adopting methods from other areas. There is however a problem with directly adopting techniques without modification, as certain factors intrinsic to a locality from which a method is directly adopted can render the technology less effective or totally ineffective at another location.

Mozambique has five wetland ecosystems: marine, estuarine, riverine, palustrine and lacustrine systems. Wetlands are used for small-scale agriculture in southern Mozambique, with farmers benefiting from the use of residual soil moisture. However, a major limitation for further development is the need for high investment to drain and prevent floods, bad soil structure and risk of salt intrusion (FAO 1998).

Tanzania's wetlands are mostly used for crop production and grazing, resulting in conflicts between livestock grazers and crop cultivators. Policies governing the utilization of wetlands can assist in dealing with these conflicts. An estimated area of 851,310 hectares of wetland is suitable for irrigation in Tanzania. With growing recognition of the potential contribution of wetlands, the Tanzania Ministry of Agriculture has recommended that a number of issues be considered in the policy formulation of wetlands. These issues include the need for agriculture to make "a positive contribution towards wetland conservation, promotion of interagency coordination, identification of major sectors with direct encroachment into wetlands, fair representation of member institutions and legal entities, each wetland be classified, and demarcated and assigned a specific use, etc." (Kalinga and Shayo 1998).

Masiyandima et al. (2003), based on case studies of 4 Southern African countries (South Africa, Swaziland, Zambia, Zimbabwe), find that wetlands have a wide range of uses: a) cropping, b) livestock grazing, c) livestock watering, d) soil for domestic use, e) domestic water including bathing and washing, e) brick molding, f) harvesting plants for crafts, g) medicinal plants, and h) cultural uses. Crops produced include cereals (rice, maize, wheat), a variety of vegetables and spices, and fruits—for farmers' own consumption, for sale in the local market and for export. Based on their survey data, the authors report that crop production of wetlands contributes substantially to the total income and food requirements of farm families. Depending on whether farmers receive remittances or are fully dependent on wetlands, contribution to farmers' incomes ranges from 20 percent to 100 percent. The study shows that wetland food production contributes more than 50 percent of the total food consumed by farmers.

In West Africa, inland valley wetlands are exploited for rice cultivation, and are seen as highly productive. There are also millions of hectares of wetlands in East Africa, many of which are under threat due to unsustainable agricultural methods. Hence, the potential for both improving livelihoods and causing environmental disaster is very great.

Findings on dambo gardens in Zimbabwe indicate that where farmers have no legal rights to the water with the government restriction of cultivation of dambos because of potential environmental hazards, local communities can have a role of regulating water use through allocation of land for garden plots. In addition, research shows that dambo cultivation is not primarily responsible for soil erosion and reduction in downstream flows (Meinzen-Dick and Rosegrant 1997 citing Bell et al. 1987). Clearing of woodlands for dryland cultivation above dambo*s* contributed mostly to erosion and drying of streams just as overgrazing on uplands and in dambos was more destructive than irrigated gardens in dambos (Meinzen-Dick and Rosegrant 1997 citing Andreini 1993). However, local institutions are necessary to prevent overexploitation from too many plots and improper practices, which include the use of mechanical pumps and reticulated drainage (Meinzen-Dick and Rosegrant 1997 citing Rukuni et al. 1994).

Managed or regulated development of wetlands for irrigated gardens can provide an opportunity to improve food security through increased food production and incomes in Africa, especially Southern Africa (Malawi and Zimbabwe). Individual dambos*,* being small and often dispersed, are suited to smallholder farming with no centrally imposed cropping patterns, farmers having a choice of crops, and the easy adaptation of water flows to the needs of each crop. There are indications that with adequate infrastructure and support services, which include extension and service infrastructure for input and output marketing, user-managed irrigation afforded by the dambos can work (Meinzen-Dick and Rosegrant 1995).

Sustainable Management of Groundwater

In many countries with high levels of rural poverty, groundwater development offers major opportunities for promoting food and improving livelihoods. Simple and affordable innovations in water-lifting technologies, such as the treadle pump and the motor-pump technology, have the potential to dramatically improve poor people's access to groundwater, as experienced in Bangladesh, Eastern India, Nepal and some parts of Western Africa, such as Nigeria, Niger and Chad (Shah et al. 2000; Purkey and Vermillion 1995; Seckler 1990). The capital requirements to develop groundwater irrigation are generally low and its productivity is generally higher than that of surface irrigation. Farmers tend to exercise more care in using it because of the costs involved in lifting water, thus maximizing application efficiencies. It also offers farmers irrigation water "on-demand" and a relatively reliable source in times of drought.

Shallow aquifers refer to groundwater that is accessible using indigenous methods of well construction and low-cost techniques, such as hand-dug wells and tube wells (Purkey and Vermillion 1995; Seckler 1990; Horning et al. 1985; WFS 1996). Hand-dug wells are constructed using hand tools and can be either lined (with steel barrels or cement bricks, or steel-reinforced concrete) or unlined. In cases where hand-dug wells are not appropriate due to local conditions or they are either difficult to install or unable to yield water required for irrigation, tube wells provide an alternative. In West Africa, there are four common installation methods with the first three suitable for aquifers in weathered basement rock and alluvium while the fourth is suitable for any aquifer type: a) hand-auger, which relies on a simple auger operated by two individuals to make the hole after which a PVC pipe with a slotted screen is installed, b) wash bore method, which requires a motor pump and a separate water source, and which establishes the permanent well into the aquifer with a PVC pipe installed by pumping water through the pipe string, c) the "sludger" method, which relies on recirculating drilling fluid commonly laden with clay, and a PVC pipe with a slotted well screen installed, and d) the drill rigs method, which employs a variety of drilling techniques, such as percussion or rotary, depending on local conditions and often used for the installation of deeper tube wells.

One advantage of tapping shallow aquifers for small-scale irrigation is that it allows easy access to water sources because it requires a lower capital, making possible private investment by individuals or small groups of farmers. Violet et al. (1991) estimated the cost of private groundwater irrigation systems to be in the range of $800-1,600 per hectare, which is much cheaper than agency-directed large-scale gravity systems ($6,667-10,667 per hectare) or the village-based pump irrigation systems ($4,000-8,000). In addition, this groundwater source makes it unnecessary for farmers or farm workers to convey water over long distances. Another advantage of this source is that annual rain and floods contribute to its recharge and that the recharge can be increased artificially by using small structures, which allow water to infiltrate.

The National Fadama Development Project of the Government of Nigeria is one example of shallow aquifer development. This project was aimed to accelerate *fadama* (inland valley) development through small-scale irrigation as well as through installation of about 50,000 tube wells to irrigate 100,000 hectares of land. The program is based on the use of a simple technology for shallow tube wells, privatization of drilling activities and improved irrigation management through water user associations (WFS 1996). Even before this project began, the rapid expansion of groundwater lift irrigation in the fadama alluvial bottom lands was brought about by the introduction of small gasoline-powered motor pumps at the time of the Nigerian oil boom, with fuel costing only $0.15 per liter. The growth of lift irrigation was spontaneous with small motor pumps irrigating private holdings in every alluvial depression. This progress was further facilitated when the government subsidized the technology, but even after the subsidy was pulled out, farmers' interest in the technology remained.

However, two problems were associated with the motor/pump tube-well technical package for groundwater development: a) the lack of understanding of the hydrology of the fadama lands to properly match tube-well locations and specifications with the water-bearing stratum and sufficient water for irrigation; and b) the possibility for overexploitation, resulting in groundwater mining and depletion.

The benefits of groundwater development have to be weighed against the risks of overexploitation and contamination. For example, reducing pumping for irrigation is an obvious response, but this could adversely affect agricultural production, and ultimately impact negatively on the food security of the concerned regions. In such a context, promoting groundwater recharge and increasing water productivity to achieve the same production with less water are more attractive alternatives.

Conjunctive use of surface water and groundwater can minimize undesirable physical, environmental and economic effects and can optimize the water demand/supply balance. The potential of this option of storing excess surface water in the ground for retrieval and use during dry periods can be explored in a river-basin context. Woldearegay (2002) makes a case for a conjunctive or integrated approach to surface water and groundwater resource development in northern Ethiopia given that most of its aquifers are of the shallow type. The surface water reservoirs recharge the groundwater systems. This process, in turn, serves as a natural filter addressing problems of surface-water contamination, with better-quality water from downstream (of the surface-water reservoirs) water wells. This integrated method of water development leads to optimum utilization and contributes to the proper management and planning of the water resource. In addition, while surface storage in the reservoir can supply water for most annual requirements, water from the groundwater storage can be kept as reserves for years with below-average rainfall.

Recycling of Waste in Peri-Urban Agriculture

Urbanization is proceeding rapidly on account of population growth and migration to cities. In SSA, the urban population has grown from about 23 percent of the total population in 1980 to 34 percent in 1999 (World Bank 2000). With this development, urban and peri-urban agriculture is increasingly becoming an important source of livelihoods, income and nutrition (box 1). It has a potentially important role in ensuring food security and reducing poverty and malnutrition. It is also a means of providing special support to women (WFS 1996). Specifically, urban and peri-urban agriculture has a niche in the production of both highly perishable market products—such as (green leafy) vegetables for cash crops, produced and marketed directly with very little processing, providing regular income to peri-urban farmers—and subsistence crops in home gardens (Drechsel and Kunze 2001; Cornish et al. 1999).

Box 1. Examples of growing urban and peri-urban agriculture in Africa, 2002.

City/Country	Type	Crop	Purpose
Nairobi, Kenya	Home gardens and open space	Vegetables and livestock products	Subsistence and nutrition (20-30% of households' food requirements)
	Open space	Vegetables	Export
Kumasi, Ghana	Home gardening by women	Vegetables, taru	Subsistence and nutrition
	Open space production inland valleys and lowlands with water access done by men	Leafy vegetables, maize, cutflower and ornamental plants	Local market (often as only source of income 2-3 times that from traditional rain-fed agriculture)
Accra, Ghana	Commercial	Pineapple	Export
Lome, Togo	Commercial	Basil leaves	Export
Dar es Salaam, Tanzania	Home gardening by women	Vegetables	Subsistence and nutrition
Kampala, Uganda	Home gardens or open space	Cassava, plantains, potato, cocoyam and maize	Subsistence and nutrition (60% of households' food requirements)
Lusaka, Zambia	Home gardens or open space	Vegetables and other staple crops	Subsistence and nutrition (20-30% of households' food requirements)
Harare, Zimbabwe	Open space and backyard gardening	Maize, vegetables	Subsistence (60% of households' food requirements)

Sources: Database of Resource Center for Urban Agriculture and Forestry (RUAF) and Cofie et al. 2003 citing Danso et.al. 2002.

Table 3. Increasing contribution of urban and peri-urban[4] crop production to total urban food supply, Kumasi 2001 (%)

Commodity	Kumasi metropolitan area	Peri-urban Kumasi
Spring onion	90	<10
Lettuce	90	10
Tomato	0	60
Garden eggs	0	60
Cassava	10	40

Source: Cofie et al. 2001 (The rest of the food requirement is either imported or comes from rural areas.)

This emerging economic importance of urban and peri-urban agriculture has created an incentive for private economic operators to invest in irrigation (table 3). In many cases, water is drawn from shallow wells (Horming et al. 1985). Alternatively, where the farmer cannot afford to invest in such sources, water is drawn from rivers or watercourses draining urban centers into which municipal and industrial wastewater is discharged with varying levels of treatment and monitoring. Controlled reuse of effluent from sewage works is already practiced in many countries. For instance, Hide et al. (2001) report that the effluent in Ruai in Kenya has been treated so that its microbiological quality falls well within the World Health Organization (WHO) guidelines for irrigation of crops without risk to workers and the public.

Raschid-Sally and Abayawardana (2002) point out that there is no comprehensive global figure for the extent of wastewater use. But available estimates indicate that about 900,000 hectares of cropland worldwide are irrigated using treated or untreated municipal wastewater, of which Mexico alone accounts for over 600,000 hectares. These extents still represent a very small percentage of the world's irrigated area. It is also worth mentioning the case of Israel, which has the largest wastewater reuse in the world, treating 70 percent of the country's sewage to irrigate 19,000 hectares of cropland. Moreover, reclaimed water was projected to supply more than 16 percent of Israel's total water needs by the start of the twenty-first century (Postel 1992).

In SSA, most wastewater used for irrigation is not treated. On the other hand, Barry (2002) reports that urban wastewater offers a stable source of supply, especially during droughts when governments give priority to urban water use. To address this problem, taking into account the needs of both peri-urban farmers and the urban population, Barry emphasizes the importance of participatory development of peri-urban agriculture and integrating government planning, investment and extension related to wastewater treatment with its subsequent use by (informal) private-sector farmers.

Further research on the practicalities of various technical and policy options related to wastewater use is needed to properly address concerns regarding possible health hazards to workers

[4]Defined as the area within a 40-km radius from the city center (Cofie et al. 2003 citing Adam 2001).

and the consuming public.[5] These options include crop restriction, low-cost[6] treatment at the point of use or additional pretreatment, alternative irrigation methods,[7] and controlled use of effluent.

On a related matter, the expansion of urban settlements results in (further) degradation and pollution problems, such as soil-nutrient mining in agricultural production areas, in addition to pollution and waste disposal in urban centers (Bhatia et al. 1993). Urban and peri-urban agriculture offers a win-win situation with waste disposal (an urban management and environmental problem) while increasing food security by exploiting the nutrient potential of the wastes. Together with this development, some related problems have been identified: farmers' unfamiliarity with the use of compost from waste; the choice of the "right" crops; the possible high costs of production (which include labor) and transport; and even if exploited to the maximum, recycled wastes may not prevent long-term decline in fertility in intensively used soils (Drechsel and Kunze 2001). Given this situation, and also in view of the high environmental and health risks from farming with recycled waste or wastewater, Drechsel and Kunze (2001) suggest the development of integrated nutrient strategies tailored to specific city situations, which should include consideration of farm and soil types, water supply, manure and inorganic fertilizer availability, and other biophysical and socioeconomic conditions.

B. Water-Demand Management

Water-demand management can help save water, increase economic efficiency of use, improve water quality, and even promote environmentally sustainable water use. Affordable irrigation technologies and water management practices can improve land and water productivity and contribute to better rural livelihoods. As the value of water increases, employing demand-management practices provides incentives for water conservation. Technologies like micro or drip irrigation that make use of low-cost plastic pipes, sprinklers, and even computerized control systems used widely in developed countries, can have potential application in water-scarce African countries.

Various approaches and experiments are being promoted on the ground, especially by NGOs but most such innovations fail to spread beyond their immediate domains of application. There are very few systematic appraisals and little empirical evidence in support of their claims to success. Therefore, there is a need to objectively analyze such innovations to understand the conditions under which they are viable, and then to support the uptake and promotion of the most promising among them.

In Africa, as discussed above, the likelihood that expansion of formal irrigation will be able to play a similar role and have the same productivity impacts as it did in Asia is remote. The experience with large-scale and even smaller community-managed irrigation schemes has been disappointing; costs of investment tend to be high in Africa, while the returns have been low.

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[5]See Hide et al. 2001 for further discussion.

[6]For example, short-term retention of water in pools or holding water in field-side drums before applying it to the crop.

[7]The use of improved irrigation methods, such as spray, and drip and trickle irrigation, is supposed to reduce risks to farm workers. Also, risks of crop contamination are reduced by direct application of water to plant roots since the soil and plant act as bio-filters and by stopping of irrigation well before crop harvest since most pathogens die within 15-30 days (Keraita 2002). WHO has set varying levels of fecal coliform contamination by type of irrigation method used.

It is likely that homegrown African innovations and adaptations will have a greater impact on this continent than on those transferred from elsewhere. System innovations, like water harvesting, drip irrigation and conservation farming have been developed and tested in Africa at field scale with some success. The sustainability of such innovations has been receiving growing attention in recent years, with an emphasis on participatory identification and adaptation of techniques (IPTRID 2001). However, insufficient attention has been paid to a) the ways and means of substantially increasing the uptake of these innovations, and b) the analysis of potential impacts on livelihoods and rural development if successfully upscaled.

Getting more crop output from the amount of water that is beneficially consumed by agriculture can significantly ease the strains of water scarcity and reduce the need for additional storage. This can be achieved through alternative agronomic practices (improved crop varieties, crop substitution, improved cultural practices), as well as through improved water application technologies and management practices that enable farmers to apply limited amounts of water to their crops in the time and amount that increase the productivity of water. Non-beneficial evaporation can be kept to a minimum and water-diversion requirements from the source reduced.

Sally et al. (2000) discuss issues related to the adoption of such approaches termed "precision irrigation" in a basin perspective: what it is, where in the basin it could be promoted, its use in supplemental irrigation, and how it could benefit poor people. They point out that precision irrigation is not necessarily an expensive "high-technology" option. Instead it refers to a broad range of technologies and water-management practices, such as bucket and drum and drip irrigation, and treadle pumps, which enable farmers with limited access to water to apply that water to their crops in the time and amount that increase the productivity of water. Precision irrigation can even be practiced with existing conventional technologies if proper timing of irrigation deliveries can be ensured. Thereby small, resource-poor farmers in water-scarce areas will be able to stabilize and even increase agricultural production by making more effective use of their limited supply of rainfall and water resources. This is especially important for farmers in dry, marginal areas of SSA in light of the growing evidence that the "costs" of water scarcity invariably tend to fall more heavily on the poor.

When properly located in a basin, such techniques offer considerable scope to reduce drainage flows to sinks, and to prevent groundwater buildup, waterlogging and accumulation of salts or pollutants. The authors also emphasize that obtaining the highest crop yield per unit of consumed water does not require full irrigation. Practicing supplemental irrigation with precision irrigation techniques can make good use of scarce water resources in arid regions: non-beneficial evaporation is minimized, and higher water productivity and greater overall crop production can be achieved. By increasing the reliability of water supply, precision irrigation techniques help stabilize crop production and ensure food security. The reduced risks that farmers face induce them to make higher investment and inputs to improve their production systems. These investments and inputs also open the way for enhanced incomes and general livelihood improvements, thus helping farmers break out of the poverty trap.

Finally, recent evidence suggests that the role of the private sector in expanding the use of water for agriculture is greater than previously perceived; and that the potential is very great. Sally and Abernethy (2002) present a number of interesting case studies from all over Africa, while Blank et al. (2002) provide information on how the private sector and NGOs are "changing the face of irrigation in Kenya." The growing availability of individualized technologies, such as small power pumps, treadle pumps, and low-cost small bucket and drip systems are suggestive of the future direction of irrigation in SSA.

IV. Conclusions

Feeding Africa's population, providing opportunities to escape poverty and achieving both food security and a high economic growth rate present a formidable challenge in which improving the management of land and water is crucial. Given the high degree of physical and economic water scarcity and the growing demands and competition for water from other sectors, there are fewer opportunities to expand irrigated areas. The emphasis must therefore shift to improving the productivity of water, and access to water by poor people, within the overall framework of an integrated, holistic approach to water-resources management. This requires us to get out of the groove of "old thinking"—for example, believing that government investment in formal irrigation is "the" solution—and to adopt more open, "new" innovative ways of thinking about solutions.

This paper suggests that much more effort and attention are required along the following lines:

- Harvesting of rainwater—by addressing the issue of how to upscale from successful pilot cases.

- Development of wetlands for agriculture—but striking a balancing between achieving their productive potential and avoiding any ecological catastrophe.

- Exploitation of shallow groundwater aquifers—but in a way that avoids undermining their sustainability as has happened in some areas of the world (e.g., groundwater mining and depletion are becoming an increasing threat in many countries in Asia, such as China and India, with the absence of overall government resource planning and management, which should include regulation among others).

- Recycling of liquid and solid wastes and nutrients from urban areas—but in a way that protects the health of producers and consumers, and does not harm the environment.

There are tremendous opportunities to apply both African-grown and African-adapted low-cost technologies for lifting and applying water for agricultural use, for example: bucket or drum and drip systems; treadle pumps and small low-cost power pumps; and conservation farming. A demand-driven approach with the private sector and NGOs playing the most significant roles is likely to be more effective than government-driven programs (Barghouti and Le Moigne 1990). The main issues that need to be addressed are to identify what institutional arrangements, support systems and policy requirements are needed at different scales to encourage innovation and enable adoption and sustainability of more productive, environmentally sustainable and profitable water- and land-management innovations.

To promote innovative approaches in water in agriculture, an enabling environment is very important. The review, by Brown and Nooter (1992), of successful small-scale farmer-controlled irrigation is still applicable: a) simple and low-cost technology; b) private and individual operation of the system; c) sufficient infrastructural support to permit access to inputs and to markets for the sale of surplus production; d) high and timely cash returns to farmers; and e) the farmer was committed and actively participated in the design and implementation of the project (see also Shah et al. 2002).

The recent World Summit on Sustainable Development and the launching of NEPAD at the highest political levels offer us an opportunity to reverse the negative trends of the past, building on positive experiences in Africa and elsewhere, and finally helping Africa achieve its vision of a better life for all.

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