# 8

# Nile Basin farming systems and productivity

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## Key messages

- Farming systems in the Nile are highly variable in terms of size, distribution and characteristics. The most prevailing system in the Nile Basin is the pastoral system, followed by mixed crop–livestock and agro-pastoral systems, covering 45, 36 and 19 per cent, respectively, of the land area.
- While productivity in irrigated agriculture in the Nile Delta and Valley is high, productivity is low in the rest of the basin with rain-fed agriculture being the prevailing agricultural system.
- The average water productivity in the Nile Basin is US\$0.045 $m^{-3}$, ranging from US\$0.177 $m^{-3}$ in the Nile Delta's irrigated farms to US\$0.007 $m^{-3}$ in the rain-fed dry regions of Sudan.
- Water productivity variations in the basin closely follow land productivity variations; thus land productivity gains result in water productivity gains.
- While improved scheme management is key to improving productivity in low productive irrigated agriculture in Sudan (i.e. in Gezira), interventions like supplemental irrigation, rainwater harvesting and application of soil water conservation techniques can increase productivity in many rain-fed areas that receive favourable rainfall throughout the year, including Ethiopian Highlands and the great lake areas.

## Introduction

Agriculture is a major livelihood strategy in the Nile Basin, sustaining tens of millions of people. It provides occupations for more than 75 per cent of the total labour force and contributes to one-third of the GDP in the basin. Enhancing agriculture could directly contribute to poverty alleviation in the region as most of the poor live in agricultural areas, and are therefore largely reliant on agriculture as their primary (and often only) source of income and living. Increased agricultural production can also be effective to reduce the cost of living for both rural and urban poor through reduced food prices (OECD, 2006).

Basin-wide agricultural development and management of water resources on which production depends require an appropriate understanding of the environmental characteristics, farmers' socio-economic assets, and the spatial and temporal variability of resources. Exposure to risk, institutional and policy environments, and conventional livelihood strategies all vary over space and time. Hence, it is difficult to design intervention options that properly address all these different circumstances (Notenbaert, 2009). Therefore, agricultural development should take a farming systems approach aimed at delivering suites of institutional, technological and policy strategies that are well targeted to heterogeneous landscapes and diverse biophysical and socioeconomic contexts where agricultural production occurs (Pender, 2006).

One major constraint that agricultural development faces in the Nile Basin is water scarcity, in terms of both physical water scarcity and economic water scarcity. In areas with physical water scarcity – arid and semi-arid areas – the agriculture sector competes for water with domestic and industrial sectors, and it is likely that water allocation for agriculture will decrease as the population grows (Ahmad *et al.*, 2009). In areas with economic water scarcity, investments in water storage and control systems will increase water availability; nonetheless, polices are needed to ensure that water is used wisely (de Fraiture *et al.*, 2010). This requires agricultural development strategies to aim for more productive use of water and to maximize the profit gained from the water consumed.

This chapter describes major Nile farming systems that are sometimes referred to as agricultural production systems. It introduces the concept of agricultural water productivity (WP) and provides an overview of crop WP across the Nile Basin (livestock WP is addressed in Chapter 9). Then we will briefly present several case studies on agricultural production from across the Nile Basin.

## Farming systems classifications for the Nile Basin

A farming system can be defined as a group of farms with similar structure, production and livelihood strategies, such that individual farms are likely to share relatively similar production functions (Dixon *et al.*, 2001). The advantage of classifying farming systems is that, as a group of farms and adjacent landscapes, each operates in a relatively homogeneous environment compared with other basin farming systems. This provides a useful scheme for the description and analysis of crop and livestock development opportunities and constraints (Otte and Chilonda, 2002). A farming systems approach facilitates spatial targeting of development interventions including those related to water management and offers a spatial framework for designing and implementing proactive, more focused and sustainable development and agricultural policies.

Farming systems classification for this study was performed based on a classification described by Seré and Steinfeld (1996). For the purpose of distinguishing the degree of agricultural intensification and industrialization, and inclusion of spatial variability of dominant crops in mixed farming systems, we integrated global crop data layers from the Spatial Allocation Model (SPAM) data set (You *et al.*, 2009) with the Seré and Steinfeld classification. Crops were assigned to four crop types: cereals, legumes, root crops, and tree crops (Table 8.1). In some cases, one specific crop group dominates the landscape by covering at least 60 per cent of the land area. In other cases, cropping patterns are more diverse with two or more crops combined covering at least 60 per cent of the land area. The combination of both layers enabled the creation of a new hierarchical systems classification that gives a clearer indication of the main crop types grown. Pastoral, agro-pastoral, urban and peri-urban areas were also differentiated. For the purpose of this chapter, we excluded any indication of agro-ecology because of the trade-off between clarity, readability and the variety of criteria included.

*Table 8.1* Crop group classification for mapping Nile Basin farming systems

| *Broad farming system classes* | | *Major Nile crops* |
|---|---|---|
| *Where >60% of production* | *Where <60% of production* | |
| Cereals | Cereals+ | Maize, millet, sorghum, rice, barley, wheat, teff |
| Legumes | Legumes+ | Bean, cowpea, soybean, groundnut |
| Root crops | Root crops+ | Cassava, (sweet) potato, yam |
| Tree crops | Tree crops+ | Coffee, cotton, oil palm, banana |

*Note:* Forage crops and sugar cane were excluded. The + symbol indicates that the crop is mixed with other commodities

The resultant modification of the Seré and Steinfeld (1996) farming systems classification for the Nile is shown in Figure 8.1, which includes two levels. The first retains division of the land area into grazing-based farming systems, mixed rain-fed crop-livestock systems, and mixed irrigated crop-livestock systems. Although conceptualizing irrigated areas as mixed crop-livestock systems is counterintuitive, Africa's highest livestock densities are associated with irrigation (Chapter 9). The second level splits mixed crop-livestock systems into eight sub-criteria based on type of crop (cereals, tree crops, root crops, and legumes) and the degree of dominance of each crop type. For example, in Figure 8.1, 'cereals' implies that cereals make up at least 60 per cent of farm production whereas 'cereals+' indicates that cereals are most common but are mixed with other important commodities.

The degree of intensification in major farming systems in the Nile is shown in Figure 8.2. Agricultural potential and market access were two criteria that we used in order to assess intensification potential in the existing farming systems. Areas with high agricultural potential were defined as irrigated areas and areas with length of growing period of more than 180 days per year. Good market access was defined using the time required to travel to the nearest city with a population of 250,000 or more. We applied a threshold of 8 hours for travel. According to the results besides the Nile Delta, Nile Valley, and irrigated areas in Sudan, areas around Lake Victoria have high potential for agricultural development.

The Nile's farming systems vary greatly in size, distribution and characteristics. Mixed crop-livestock, agro-pastoral and pastoral systems occupy about 36, 19 and 45 per cent, respectively, of the land area (2.85 million $km^2$) of the basin excluding urban, peri-urban and other land uses. The mixed crop-livestock systems are composed of large-scale irrigation (28,000 $km^2$) and rain-fed cultivation and pasture (1.0 million $km^2$.). These farming systems are also home to a population of about 160 million, with 139 million living in the mixed rain-fed systems and with the large-scale irrigation systems having the highest densities of about 1681 persons per $km^2$.

Numerous biophysical constraints to farm production, particularly in densely populated areas, potentially limit agricultural production. About 50, 33, 28 and 9 per cent of the mixed irrigated, mixed rain-fed, agro-pastoral, and pastoral systems, respectively, are degraded. Aluminium toxicity, high leaching potential and low nutrient reserves are especially acute in mixed rain-fed systems while salinity and poor drainage are problematic in some irrigated areas.

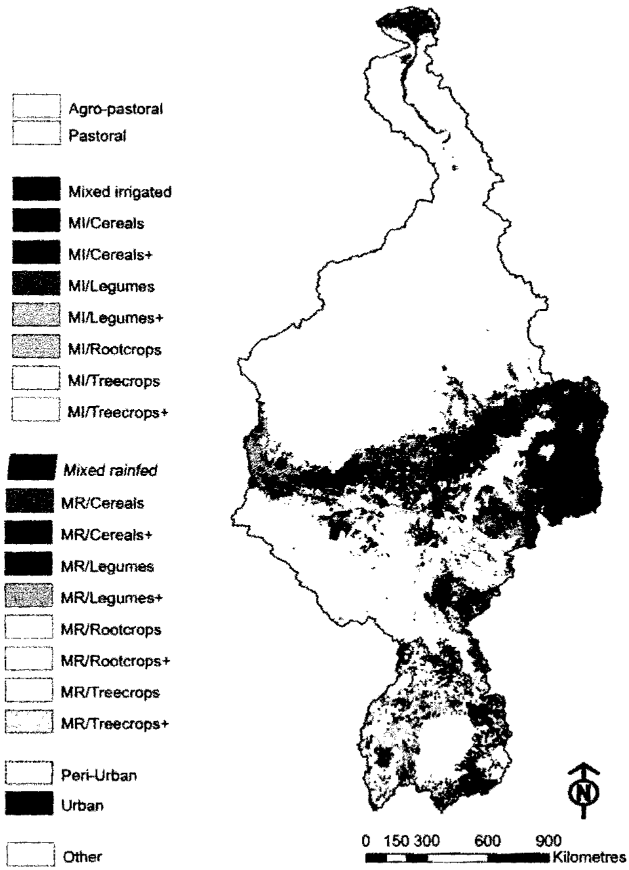



*Figure 8.1* Farming system map of the Nile Basin

## Agricultural productivity in the Nile Basin

### *Land productivity*

Land productivity is the ratio of farm output per unit of land cultivated. Figure 8.3 shows land productivity of sorghum and maize. These two major Nile Basin crops serve as proxies for a wide range of water-dependent food crops. Sorghum and maize cover 20 per cent (8 million ha) and 10 per cent (4 million ha), respectively, of the cropped area in the basin. Well over 90 per cent is produced through rain-fed cultivation, particularly in the mixed rain-fed crop-livestock farming systems. The average land productivity of sorghum in the rain-fed system in the Nile is about 0.64 tonnes (t) $ha^{-1}$, ranging from 2 $t \cdot ha^{-1}$ in the southeastern part of the basin, Tanzania, where annual rainfall is about 1000 mm, to less than 0.2 t $ha^{-1}$ in the dry regions of Sudan. Irrigated sorghum is cultivated in parts of Egypt and some Sudanese states namely White Nile, Sennar, Kassala, and Gadaref. The average land productivity of irrigated sorghum is about 3.1 t $ha^{-1}$ and ranges from 6.3 t $ha^{-1}$ in the Asyiut State in Egypt to 1.2 t $ha^{-1}$) in the Blue Nile State, Sudan. The average yield of rain-fed maize in the basin is near 1.3 t $ha^{-1}$,

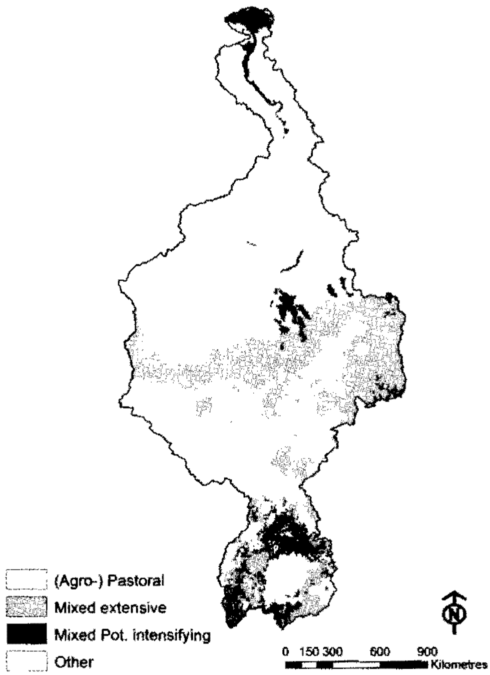



*Figure 8.2* The degree of intensification in the Nile Basin

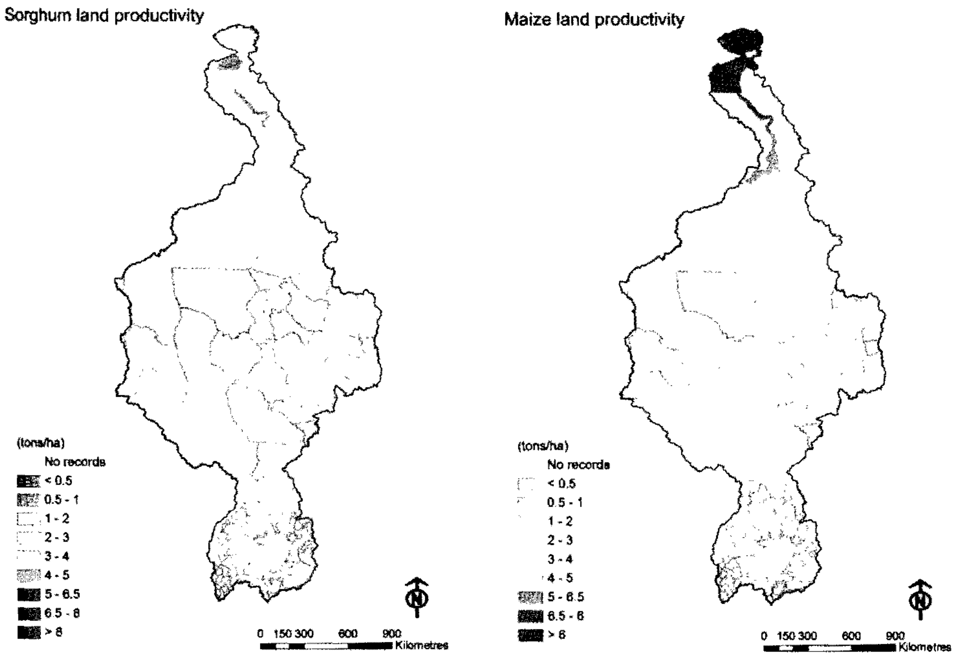



*Figure 8.3* Land productivity of (a) Sorghum and (b) maize in the Nile Basin

ranging from 2.7 t $ha^{-1}$ in East Wellega, Ethiopia, to less than 0.3 t $ha^{-1}$ in southern Darfur, Sudan. Irrigated maize production averages 8.3 t $ha^{-1}$ in Egypt. The huge gap between irrigated and rain-fed yields suggests that water availability and access are key constraints to maize and sorghum production. Similar spatial variability in land productivity characterizes about 70 crops commonly found in various parts of the Nile Basin.

The economic value of land productivity, known as the *standardized gross value of production* (SGVP), in the Nile Basin varies from US$20 $ha^{-1}$ in some Sudanese states to more than US$ 1832 $ha^{-1}$ in Egypt (Figure 8.4). In general, Sudan has the lowest land productivity except in states like Gezira where irrigated farming dominates. The densely populated highland areas of Ethiopia and the great lakes region also have a relatively high SGVP. Low land productivity in many areas suggests that significant yield gaps remain (Figure 8.4). One major factor contributing to gaps in crop yield is low agricultural WP.

### Standardized gross value of production (SGVP)

Different pricing systems and local market fluctuations complicate efforts to estimate the total value of agricultural goods and services in large transboundary river basins. One way to overcome this challenge is the use of an index, the SGVP, which enables comparison of the economic value of mixtures of different crops regardless of the country or location where they are produced. This index converts values of different crops into equivalent values of a dominant crop and uses the international price of a dominant crop to evaluate the gross value of production. For the Nile River Basin, wheat was chosen as the base crop. About 70 other crops were pegged to the 'wheat standard' by assessing the price gaps between each of them and wheat in each country. The International price of wheat (US$ $t^{-1}$) from 1990 to 2005 was used as the standard value against which other crops were pegged. For details, refer to Molden *et al.*, 1998.

## *Crop water productivity*

Large gaps between actual and potential crop yields reflect the presence of socio-environmental conditions that limit production. In much of the Nile, lack of farmers' access to available water is the prime constraint to crop production. With increasing numbers of people and their growing demand for food, combined with little opportunity to access new water sources, great need exists to make more productive use of agricultural water.

WP is the ratio of benefits produced, such as yield, to the amount of water required to produce those benefits (Molden *et al.*, 2010). WP varies greatly among crop types and according to the specific conditions under which they are grown. WP can be estimated at scales ranging from pots, to fields, to the watershed, and to river basins. The typical unit of measurement for single crops is kg $m^{-3}$ (e.g. Qureshi *et al.*, 2010). At larger scales WP estimates need to include multiple crops, and monetary units such as US dollars per cubic metre are used. The WP index serves as a useful indicator of the performance of rain-fed and irrigated farming in water-scarce areas. It can further help with planning water allocation among different uses while ensuring water availability for agro-ecosystem functioning (Loeve *et al.*, 2004; Molden *et al.*, 2007).

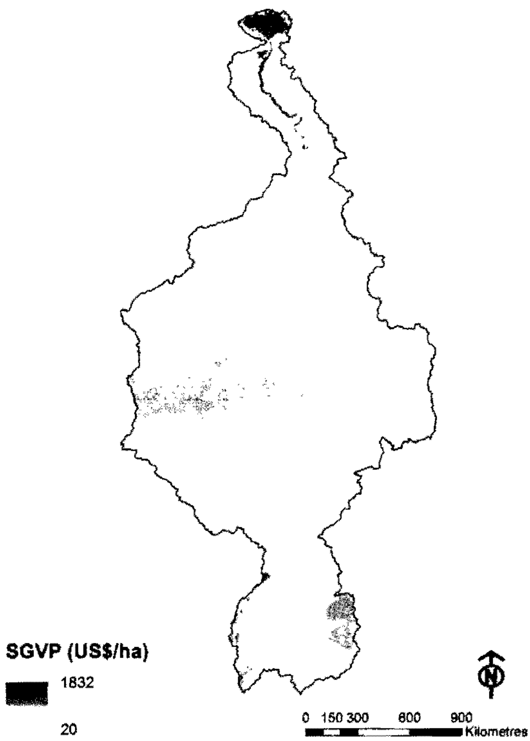



*Figure 8.4* Economic land productivity in the Nile Basin (standardized gross value of production per hectare)

Mapping WP across the Nile Basin enables understanding of spatial distribution of effectiveness of water use. To assess consumptive water use of crops in the Nile Basin we used actual evapotranspiration (ETa) data produced by WaterWatch. Variation in the ETa across the basin is high. It ranges from 8 mm $yr^{-1}$ in the desert to nearly 2460 mm $yr^{-1}$ from free water surfaces at the Lake Nasser (Figure 8.5). Except for the Nile Delta, irrigated agriculture covers a very small fraction of the land in the Nile Basin. Therefore, ETa is chiefly a result of natural processes and is driven by the availability of water. The pattern and variation in the ETa map, thus, can represent the general water availability pattern, although areas along the river and the delta are exceptions to this rule. From this point of view, the map depicts that water availability is relatively high in the southern part of the basin and, as we move to north, water becomes scarce and vegetation becomes possible only close to the river.

SGVP and ETa were calculated to estimate crop WP across the Nile Basin (Figure 8.6), which is US$0.045 $m^{-3}$, and the minimum, maximum, and standard deviation of WP are US$0.007, US$0.177 and US$0.039 $m^{-3}$, respectively. As in land productivity, WP shows a huge variation across the basin.

Based on WP, spatial distribution of the basin can be divided into three zones: the *high productivity zone*, the *average productivity zone* and the *low productivity zone*.

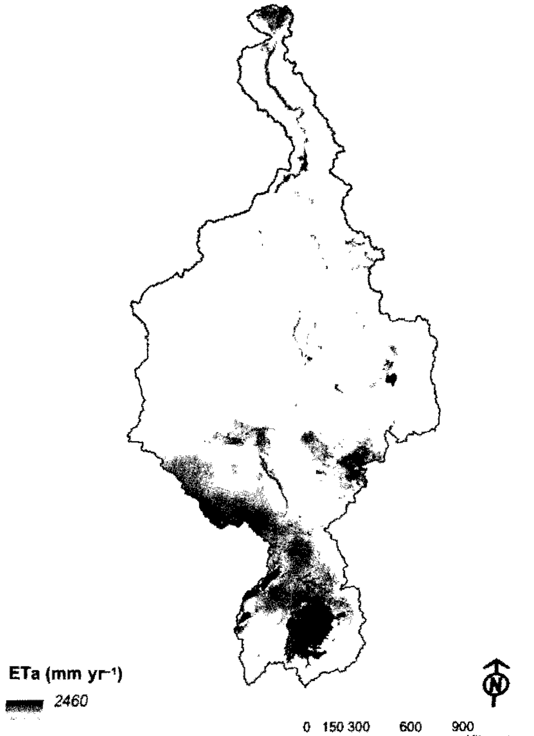



*Figure 8.5* Actual evapotranspiration (ETa) in the Nile Basin in 2007

## *High productivity zone*

The high productivity zone includes the delta and irrigated areas along the Nile River in the northern part of the basin. This zone is characterized by intensive irrigation, high yields and high-value crops. These characteristics collaboratively contribute to the high level of the WP attained and are in fact correlated. Access to irrigation results in higher yields; higher yield results in higher incomes; and higher incomes result in higher investment in farm inputs by farmers. Furthermore, access to irrigation and higher income make it possible for farmers to afford growing high-value crops that often have higher risk and require better water management. Further improvement in already high lands and WP might be possible using a higher rate of fertilizer application or adaption of new technologies but the environmental and economic cost might prove to be too high to make it a feasible option for future plans. However, interventions like supporting cropping rotations that produce higher economic returns and promoting aquaculture mixed with crops might be viable options for investment to gain more benefits from water and eventually increase overall productivity of water.

## *Average productivity zone*

The average productivity zone consists of two major areas, one in the eastern part (Ethiopia mainly) and the other in the southern part (areas around the Lake Victoria). Despite the fact that

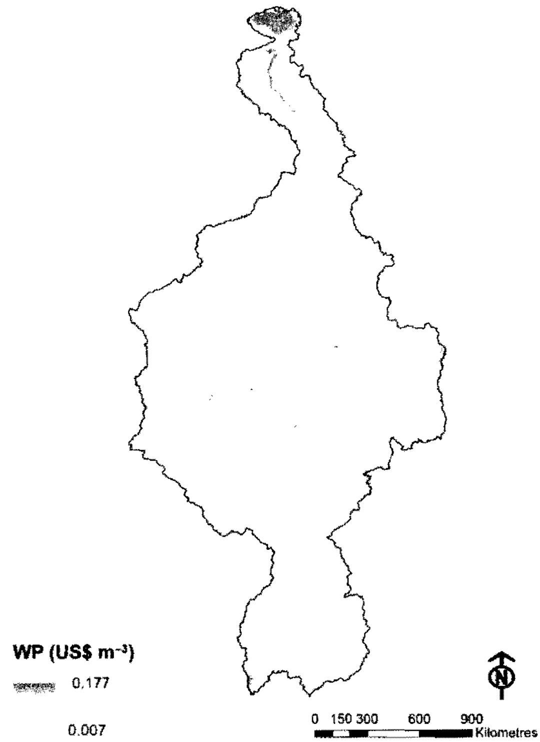



*Figure 8.6* Crop water productivity in the Nile Basin

most of the areas in this zone receive relatively good amounts of rainfall, the predominantly rain-fed agriculture has rather low yields and, therefore, relatively low WP. This indicates poor farm water management practices and farmer's financial inability to invest in on-farm inputs like fertilizer, good-quality seeds, etc. The fact that rainfall is sufficient to grow crops in this zone opens a wide prospect for improvement in this region. Two parallel strategies that could be applied are, first, improving farm water management and, second, promoting irrigated agriculture. Common methods to enhance farm water management are supplemental irrigation (wherever possible), rainwater harvesting and application of soil water conservation techniques. These methods have proved to be effective in many parts of the world and helped to gain significantly more yields. Promoting irrigated agriculture, however, requires investment in water control and storage infrastructure. The main obstacle for irrigated agriculture in this zone is accessibility to water rather than its availability. For example, in Ethiopia, due to lack of storage infrastructure the majority of generated run-off leaves the country without being utilized. Controlling these flows and diverting the water to farms can drastically improve both land and water productivity.

## *Low productivity zone*

The low productivity zone covers the central and western part of the basin. Agriculture in this zone is rain-fed and it receives a low amount of rainfall. In most areas rainfall amounts received cannot meet the crop water demands and therefore crops suffer from high water stress. As a result, yields are extremely low. In this zone improving water and land productivity is contingent upon expanding irrigated agriculture. A good example that shows how irrigation can bring in improvements is the Gezira scheme in Sudan. This scheme is located in the same zone (geographically) but irrigation has resulted in significantly higher WP in the scheme compared to its surrounding rain-fed areas. However, due to poor water management, WP in the Gezira scheme is much lower than in irrigated areas in northern parts of the basin (i.e. in the delta).

## Irrigated agriculture

### *The Gezira scheme, Sudan*

The Gezira scheme is one of the largest irrigation schemes in the world. It is located between the Blue and White Nile in the south of Khartoum (Figure 8.7). The area has an arid and hot climate with low annual rainfall, nearly 400 mm $yr^{-1}$ in the southern part to 200 mm $yr^{-1}$ in the northern part near Khartoum. The area of the scheme is about 880,000 ha, and represents more than 50 per cent of irrigated agriculture in Sudan. It produces about two-thirds of Sudan's cotton exports, and considerable volumes of food crops and livestock for export and domestic consumption, thereby generating and saving significant foreign exchange. The scheme is of crucial importance for Sudan's national food security and generates livelihoods for the 2.7 million inhabitants of the command area of the scheme (Seleshi *et al.*, 2010). The Sennar Dam, located at the southern end of the scheme, supplies water to Gezira through a network of irrigation canals of about 150,000 km (Plusquellec, 1990).

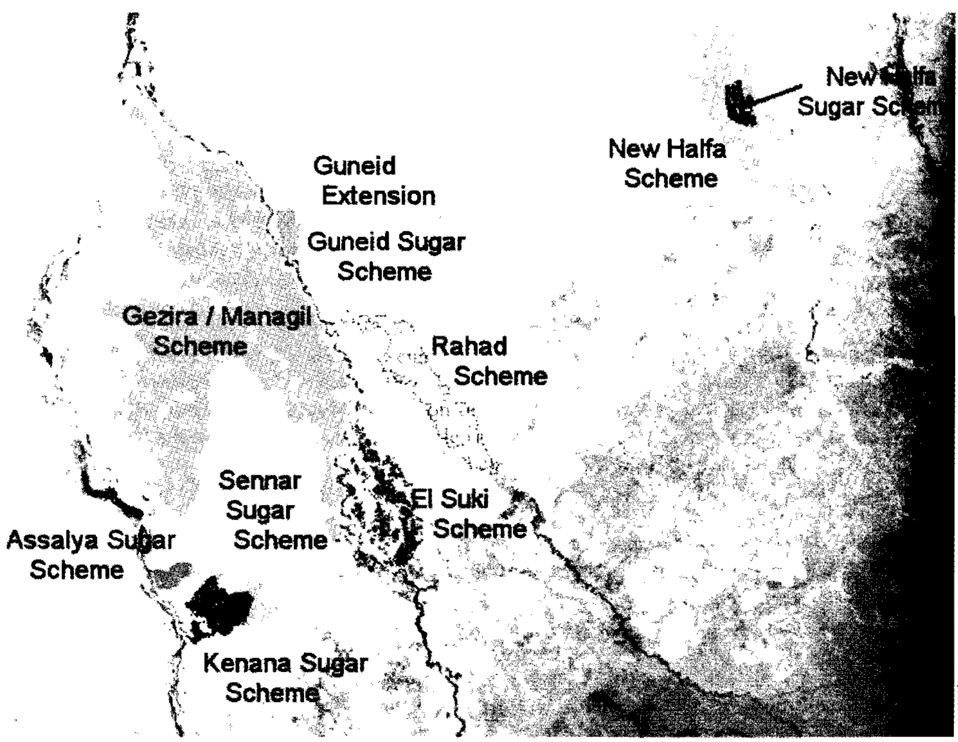



*Figure 8.7* Major irrigation schemes in Sudan

*Source:* WaterWatch, 2009

The main crops in Gezira are cotton, sorghum, groundnut, wheat and vegetables. Yields and cropping intensities are rather low and unstable, irrigation management is poor, and operation and maintenance are organized in a highly centralized way, as is cotton production and marketing (Laki, 1993; Al-Feel and Al-Bashir, 2012; Mahir and Abdelaziz, 2011; Yasir *et al.*, 2011). Cotton was a mandatory crop for farmers, and was financed and marketed by the government before introducing liberalization of choice of crop in 1981. After adoption of the liberalization policy in the agriculture sector, farmers started to grow other crops, such as sorghum, wheat and groundnut. As a result, the cotton area and production decreased (Gamal, 2009). However, despite the financial benefits of growing multiple crops for farmers, diversifying from cotton has implications on foreign exchange acquisitions by the government of Sudan (Guvele, 2001).

Figure 8.8a shows actual annual evapotranspiration in the Gezira scheme in 2007. Total water consumption in the scheme and its surrounding extensions is about 9.3 billion $m^3$ $yr^{-1}$, with an average ETa of 830 mm $yr^{-1}$. ETa shows a huge variation across the scheme, ranging from 150 to 1700 mm $yr^{-1}$, which shows water is poorly distributed. Evidently areas in the head end receive too much of water whereas areas in the tail end receive very little water. Therefore, ETa is generally considerably low in the northern part while some areas in the south have extremely high ETa for which a possible explanation could be the waterlogging issue.

Comparison of actual transpiration (Ta) and potential transpiration (Tp) is an indicator for assessing performance of crops. High Ta $Tp^{-1}$ ratio indicates good performance, while a low ratio is a sign of low performance because biomass production and subsequently food production have a close to linear relation with crop transpiration (Howell, 1990). This ratio is, in fact, suggested to also have a proportional relation with the ratio of actual yields to potential yields (de Wit, 1958; Hanks, 1974). Figure 8.8b depicts Ta $Tp^{-1}$ values in the scheme. As is evident from the figure, crop performance is generally very low. The average Ta $Tp^{-1}$ ratio in Gezira is about 0.5, and ranges from 0.1 to 0.85. This high variation is mainly attributed to poor scheme management and extremely uneven water distribution. In effect, except for some areas near the head end, the rest of the scheme suffers from high water stress.

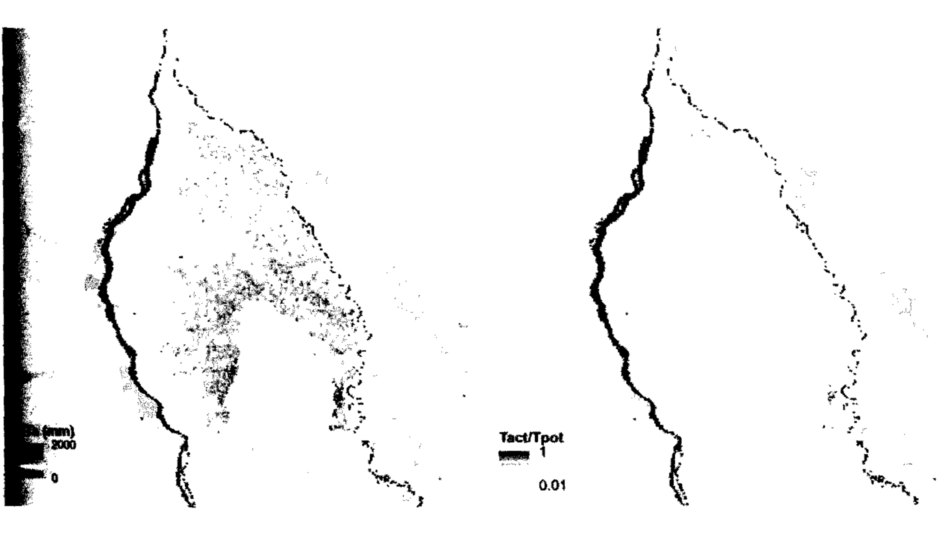



*Figure 8.8* (a) Annual actual evapotranspiration (Eta) and (b) ratio of actual to potential transpiration (Ta $Tp^{-1}$) in the Gezira scheme in 2007

*Source:* Background image is Globe Land Cover (2008, http://postel.mediasfrance.org/en/PROJECTS/Preoperational-GMES/GLOBCOVER)

To gain an insight into WP variation in the scheme, it was estimated based on produced biomass and crops consumptive water use. The results, then, were presented in a relative term that offers a basis to compare it within the scheme. As illustrated in Figure 8.9, in general, WP in the Gezira scheme is uniformly low and the variation does not follow the same pattern as that in actual evapotranspiration and Ta $Tp^{-1}$ ratio. There is no significant difference in WP in the head and tail ends of the scheme, although higher WP pixels, to some extent, are more prevalent in the tail ends than in the head ends. This shows that some areas in the head ends, despite having relatively higher yields (higher Ta $Tp^{-1}$) have low WP, the which indicates excessive evaporation as a result of poor water management.

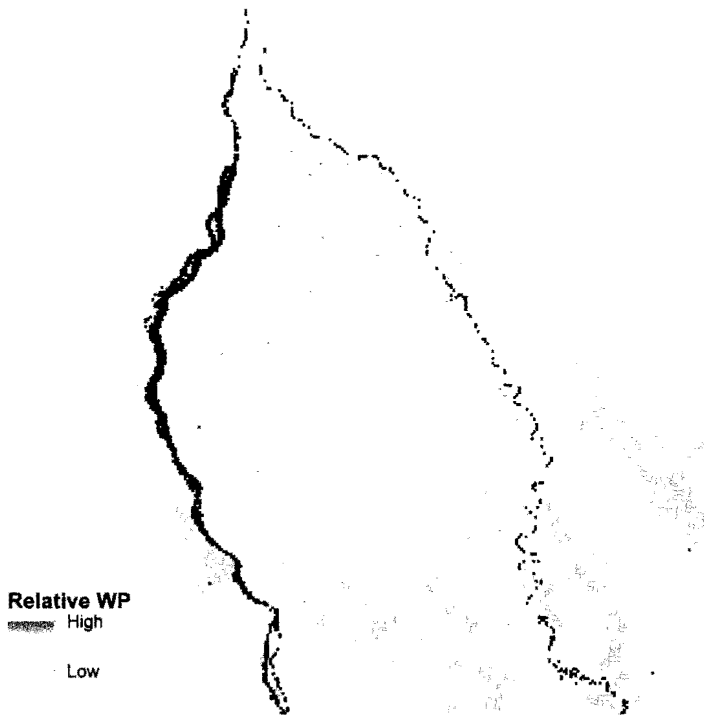



*Figure 8.9* Relative water productivity in the Gezira scheme

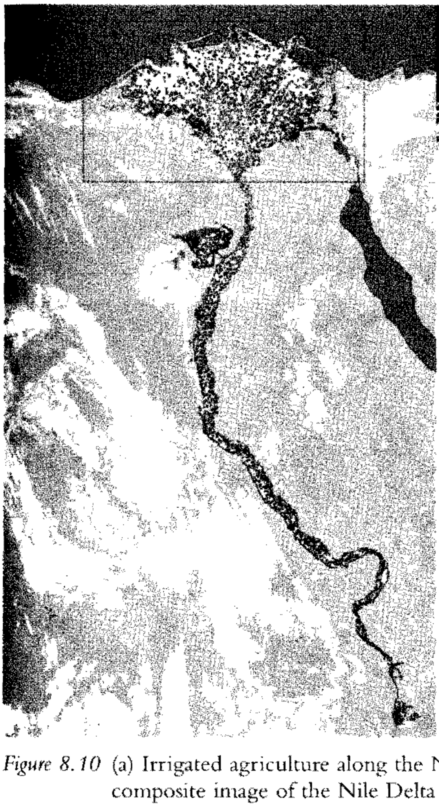
*Source:* Background image is Globe Land Cover, 2008

Opportunities to increase agricultural production in most areas of Sudan are limited due to severe water shortage. Therefore, improvement in managing available water in Sudan and in already existing irrigation schemes is a crucial factor to cope with food demands of the country's growing population at present and in the future. In the Gezira scheme, low performance is a direct consequence of poor management rather than of problems with water availability as the water supply appears to be adequate across the basin regardless of the location (Yasir *et al.*, 2011). Hence, agricultural policies have to target improving the scheme management to enhance scheme performance that will subsequently increase WP.

## *Irrigated Egypt*

The Nile is a lifeline for Egypt, its population and its almost entirely irrigated agriculture. Agricultural activities provide employment for 35 per cent of the labour force and contribute to 13.5 per cent of the country's GDP. The Nile River is the main source of water for Egypt, providing 55.5 billion of its 58.3 billion $m^3$ total actual water resources, out of which 85 per cent is committed to irrigating 3.42 million ha of cropped lands. The Nile Valley and Delta are the main agricultural areas of Egypt encompassing 85 per cent of the total irrigated area of 2.9 million ha (Figure 8.10a). The main cultivated crops are wheat, rice, clover and maize. Crop intensity is high and, in most of the areas, a double-cropping system is a common practice. Land productivity is also high in Egypt with the average yields of some crops in the country being among the highest in the world.

The Nile Delta covers two-thirds of the total irrigated agriculture (Stanley, 1996) and is the food basket of Egypt (Figure 8.10b). Figure 8.11a shows crops actual evapotranspiration in the Nile Delta in 2007. ETa in most areas across the delta is high with an average of 1200 mm $yr^{-1}$. Lower ETa at the areas close to the edge of the delta could be because these areas receive less water and have a lower crop intensity. As we move towards the centre, crop intensity grows, and so does ETa. Actual transpiration (Ta) is very close to potential, with an average Tp $Tp^{-1}$ ratio of 0.85 (Figure 8.11b). This indicates overall high performance of irrigated agriculture in the Delta, which is also reflected in its high relative water productivity (Figure 8.11c).



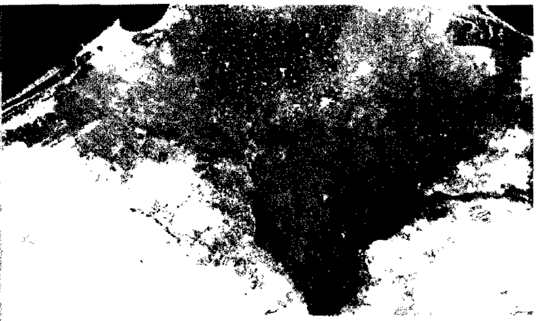


*Figure 8.10* (a) Irrigated agriculture along the Nile river banks and the Nile Delta; (b) false colour composite image of the Nile Delta based on Landsat thematic mapper measurements

*Note:* Red colour characterizes vigorous crop growth

*Source:* WaterWatch, 2009

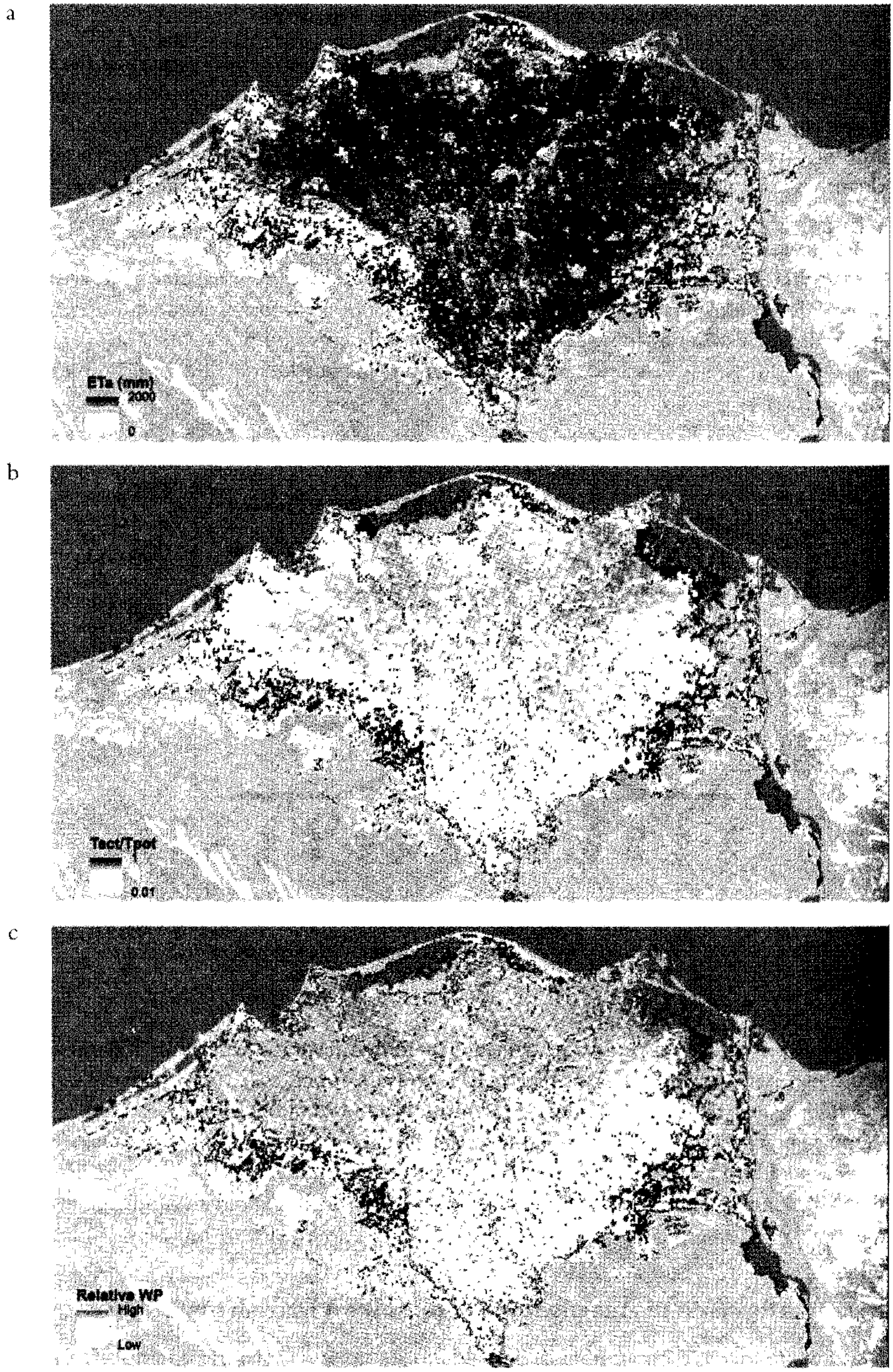



*Figure 8.11* (a) Annual actual evapotranspiration (Eta) and (b) ratio of actual to potential transpiration (Ta Tp–1); (c) relative water productivity in the Nile Delta in 2007

*Source:* Background image is Globe Land Cover, 2008

Despite the current high performance of irrigated agriculture, coping with water scarcity remains a challenge for any recent and planned agricultural expansions in Egypt. Therefore, maximizing physical and economic crop WP plays a vital role in drawing future sustainable agricultural development. Increasing economic WP can be achieved through enhancing cropping patterns and promoting high-value crops. Institutional bodies like agricultural extension offices and water user associations should play a more active role to provide farmers with the necessary information about financially rewarding crop rotations and individual crops, and coordinate with the farmers to cultivate the most profitable crops for different seasons and areas.

## Rain-fed agriculture

### *Rain-fed farming in the Nile Basin*

Rain-fed farming, covering 33.2 Mha, is the dominant agricultural system in the Nile Basin. Over 70 per cent of the basin population depend on rain-fed agriculture (Seleshi *et al.*, 2010). Sudan, with 14.7 Mha, accounts for 45 per cent of the total rain-fed lands, followed by Uganda, Ethiopia, Tanzania, Kenya, Rwanda and Burundi (Figure 8.12). Low rainfall does not allow rain-fed farming in Egypt, and rain-fed areas of Eritrea that fall within the Nile boundary are almost negligible.

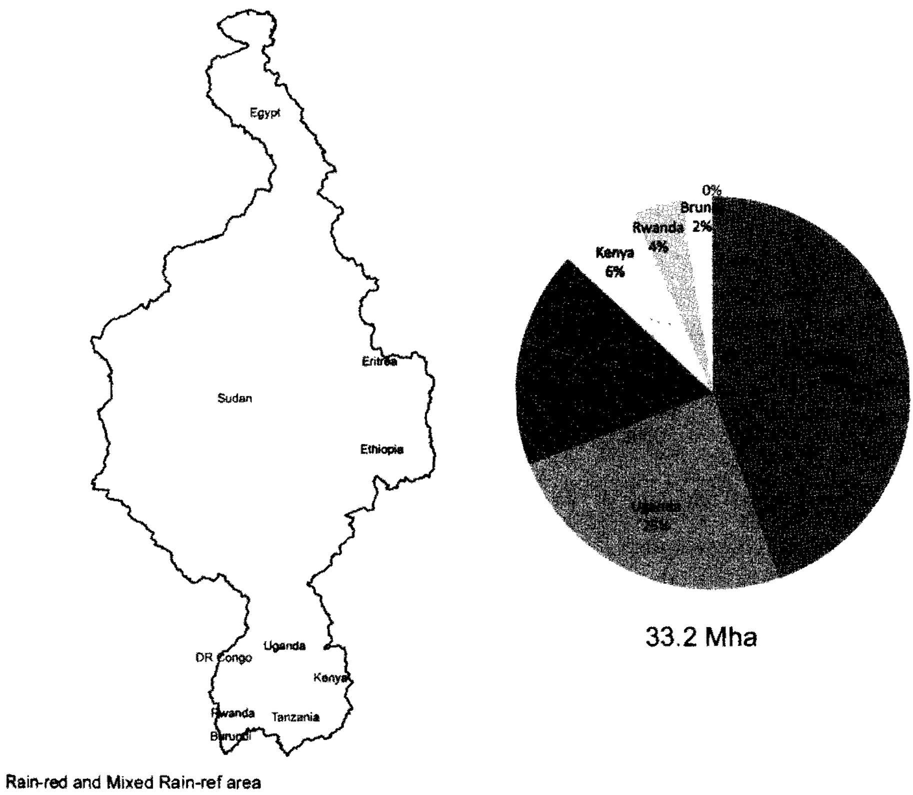



*Figure 8.12* Distribution of rain-fed agriculture in the Nile Basin

The main rain-fed crop in the Nile Basin in terms of cultivated area is sorghum, followed by sesame, maize, pulses and millet, covering 7.39, 3.68, 3.35, 2.94 and 2.86 Mha, respectively (Table 8.2). Rain-fed agriculture in the Nile Basin is characterized by low yields with the majority of crops having an average yield of less than 1 t $ha^{-1}$. Different sets of reasons have been proposed for the low yields in rain-fed systems from natural causes such as poor soils and drought-prone rainfall regimes to distance from urban markets (Allan, 2009). However, the opportunity of favourable rainfall in many rain-fed areas of the basin provides a high potential for yields to increase by improved farm water management techniques such as rainwater harvesting.

*Table 8.2* Rain-fed crops in the Nile Basin

| | *Crop area (ha)* | *Yield (t $ha^{-1}$)* |
|---|---|---|
| Sorghum | 7,392,154 | 0.64 |
| Sesame | 3,688,529 | 0.35 |
| Maize | 3,354,597 | 1.43 |
| Pulses | 2,943,231 | 0.86 |
| Millet | 2,869,540 | 0.58 |
| Groundnut | 1,793,453 | 0.68 |
| Sweet Potato | 1,661,132 | 4.63 |
| Banana | 1,647,751 | 5.77 |
| Other crops | 7,877,708 | – |
| Total | 33,228,095 | |

## Rain-fed farming in the Blue Nile

The farming systems of the upper Blue Nile region are categorized as mixed farming in the highland areas and pastoral/agro-pastoralism in the lowland areas. Mixed farming of cereal-based crops, teff, ensete, root crops, and coffee crops compose one system.

The major constraints for crop production are soil erosion, shortage and unreliability of rainfall, shortage of arable land, and weeds, disease and pests, which damage crops in the field; after harvest, there is also utilization of a low level of agricultural inputs (fertilizers, seed, organic matter) and shortage of oxen for cultivation. The magnitude of resource degradation in Ethiopia and the inability of the fragmented approaches to counter it are two key challenges reinforcing each other. The highland mixed farming systems are characterized by varying degrees of integration of the crop and livestock components. Crop residues often provide livestock feed, while oxen provide draught power, and cattle can provide manure for improvement of soil fertility. With increasing population pressure, there is increasing competition for land between crops and grazing, which often goes in favour of the crops. As grazing land is converted to cropland, the importance of crop residues as livestock feed also increases. There is a need for sustainable land management. Resource degradation is the most critical environmental problem in the Ethiopian Highlands (Woldeamlak, 2003).

Figure 8.13 shows crops ETa, gross value of production (GVP) and WP in the Ethiopian part of the Nile. Average crop water consumption is about 450 mm. GVP ranges from US\$286 $ha^{-1}$ in Zone 2 to US\$823 $ha^{-1}$ in Shaka, where high-value crops like coffee and fruit trees are

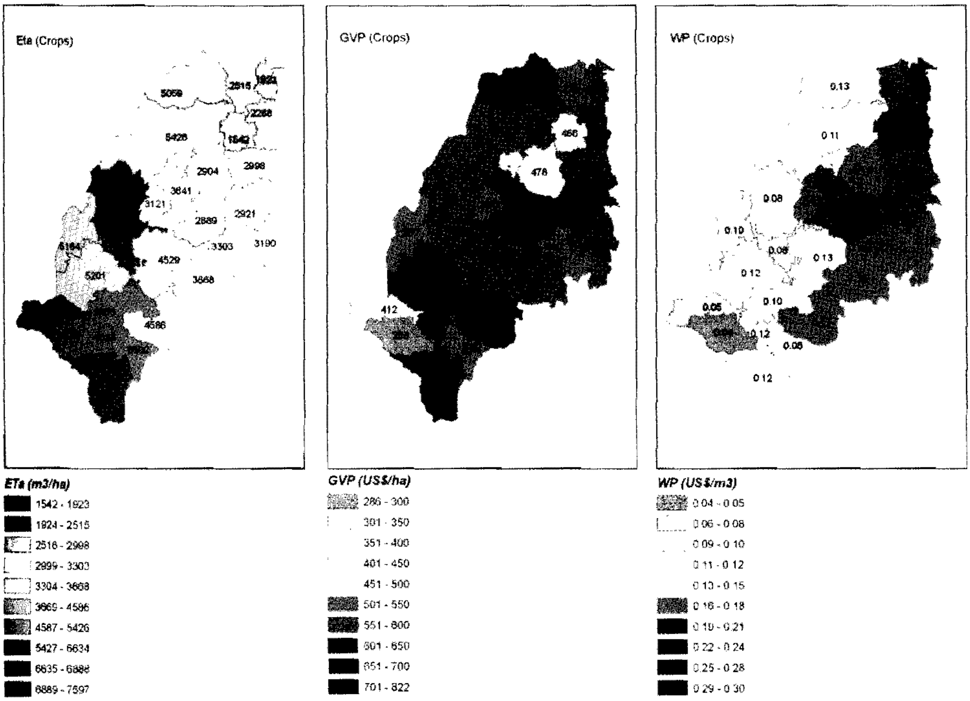



*Figure 8.13* Evapotranspiration, gross value of production and water producitivity maps of the Ethiopian part of the Nile

cultivated. Average crop WP in the area is about US$0.16 ha$^{-1}$, ranging from US$0.04 to US$0.3 ha$^{-1}$. Zone 2 has the lowest WP, mainly due to low land productivity, despite high water availability in the region. Generally, WP increases toward east, due to cultivation of high-value crops and the existence of irrigated farms.

## Overview of the Nile Basin fisheries and aquaculture

### *Fisheries*

Fisheries and aquaculture are an important component of agricultural production and productivity in the Nile. Nile Basin fisheries are mainly freshwater lakes, rivers and marsh sources and human-derived aquaculture. Freshwater fisheries have a large potential to enhance income opportunities for many thousands of people and contribute towards food and nutritional security of millions in Kenya, southern Sudan, Tanzania and Uganda. Figure 8.14 summarizes information on growth and the share of countries and major water bodies in inland fisheries production in the Nile Basin. Here we give an overview of fisheries and aquaculture, but further work is necessary to integrate these into the overall WP of the basin.

Lake Victoria, shared among Kenya, Tanzania and Uganda, produces up to a million tonnes of fish a year. The fishery generated about US$600 million a year in 2006 (LVFO, 2006). Lake

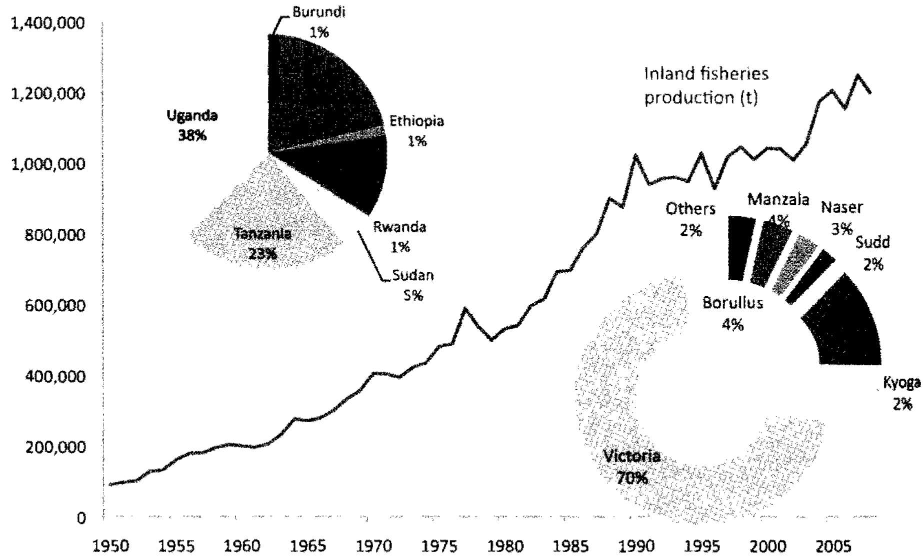



*Figure 8.14* Total inland fisheries production in the Nile (excluding Democratic Republic of Congo, in which most of the fishers production takes place outside of the Nile Basin)

*Sources:* modified from FAO data; Witte *et al.*, 2009

conditions and unsustainable fishing practices have affected the harvest of fresh fish, which has decreased by 40 per cent. New nets and hooks have helped, but still many remove small fish and the stocks are depleted.

The lake basin is used as a source of food, energy, drinking and irrigation water, shelter, transport, and as a repository for human, agricultural and industrial waste. With the populations of the riparian communities growing at rates among the highest in the world, the multiple activities in the lake basin have increasingly come into conflict. The lake ecosystem has undergone substantial and, to some observers, alarming changes, which have accelerated over the last three decades. Recent pollution studies show that eutrophication has increased from human activities mentioned above (Scheren *et al.*, 2000). Policies for sustainable development in the region, including restoration and preservation of the lake's ecosystem, should therefore be directed towards improved land-use practices and control over land clearing and forest burning.

Diminishing water levels and pollution have acute consequences for several economic sectors that depend on the basin lakes. It greatly affects the fishery by changing water levels. Water-level variations affect shallow waters and coastal areas which are of particular importance for numerous fish species, at least in certain stages of their lives. Pollution poses a problem for fishery productivity in the Nile Basin. Some areas of the rivers feeding the lake and the shoreline are particularly polluted by municipal and industrial discharges. Cooperation between all concerned authorities is necessary to search for coherent solutions to ensure the sustainability of the fisheries.

## *Aquaculture*

Aquaculture is the farming of fish, molluscs, crustaceans and aquatic plants in freshwater, brackish water or the marine environment. In 2008, aquaculture production in the Nile Basin countries reached 756,000 tonnes, which represents just over US$1.3 billion. Egypt is the main producer of farmed fish; since the mid-1990s it has rapidly expanded its aquaculture, extending its production from 72,000 tonnes in 1995 to 694,000 tonnes in 2008. Aquacultural expansion has contributed to increasing the total fisheries production in Egypt. The relative importance of Egyptian aquaculture to total fisheries production has increased from 16 to 56 per cent of total fisheries production between the years 1997 and 2007. Aquacultural activities in Egypt are more concentrated in subregions of the Nile Delta, where the water resources are available. Most of the aquacultural production is derived from farmers' use of earthen ponds in production systems.

Uganda is a distant second of the total basin aquacultural production. Kenya, Rwanda and Sudan are developing fisheries with the help of foreign aid to boost production which, together with other basin countries, represents 1 per cent of the farmed fish in the basin. Uganda's aquacultural export market, regional use and employment have risen dramatically over the past 10 years. The Government of Uganda is promoting aquaculture to boost livelihoods and food security of farmers with plans to either capture floodwaters or use groundwater to expand aquacultural production in the northern and eastern areas of the country (see www.thefishsite.com).

Egypt has given support for the development of aquaculture to promote farmers' livelihoods and provide nutritional benefit to poor farm families. The programmes instituted have been provided at minimal cost and often free of charge. Uganda has also started many fish programmes with foreign aid and government support. Egypt's advanced technical knowledge in aquaculture could be used to help train and support development of aquaculture in other basin countries.

## Conclusions

The Nile Basin is a large transboundary basin that is home to a population of nearly 160 million, with the majority of them reliant on local agricultural products for their food and on agricultural activities for earning their livelihood. Due to the size, the basin is host for different geographical areas, agro-ecological conditions, environmental characteristics, and farmers' socio-economic assets. As a result, farming systems in the Nile are highly variable in terms of size, distribution and characteristics. The results of the farming system classification exercise show that the most prevailing system in the Nile Basin is the pastoral system, followed by mixed crop-livestock and agro-pastoral systems, covering 45, 36 and 19 per cent of the land area, respectively. Agricultural production in the Nile Basin faces different biophysical constraints. The biophysical constraints of crop productivity include aluminium toxicity, high leaching potential and low nutrient reserves, mainly in mixed rain-fed systems and salinity and poor drainage in some irrigated areas.

However, water scarcity in terms of both physical water scarcity and economic water scarcity remains the major limiting factor for agricultural development in the basin. In the face of this challenge agriculture water sector calls for an improved management in order to increase and maximize WP. With the exception of Egypt, the Nile Basin's agriculture is predominantly rain-fed. Productivity is highly influenced by spatial variations of rainfall in the rain-fed system while in the irrigated areas farm and scheme management is the main determining factor in the productivity variation.

Measures like expansion of irrigated agriculture, implementing water conservation techniques (e.g. rainwater harvesting) for the rain-fed systems, improved scheme management in the irrigated areas, and increased water accessibility through construction of new control and storage infrastructures in areas where inaccessibility to water is the issue rather than unavailability of water, could largely contribute towards increasing productivity in the Nile Basin. However, these interventions have to be considered within a basin context, and further work is required to assess the impact of implementing these interventions on the hydrological cycle and water flows in the basin.

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