AGL/MISC/29/2000

WATER AND AGRICULTURE IN THE NILE BASIN

Food
and
Agriculture
Organization
of
the
United
Nations

AGL/MISC/29/2000

WATER AND AGRICULTURE IN THE NILE BASIN

Nile Basin Initiative Report to ICCON

Background Paper prepared by FAO

Bo Appelgren

Wulf Klohn

Undala Alam

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Land and Water Development Division

Rome, 2000

Foreword

This paper discusses – at the sub-basin level – the regional differences and comparative advantages for agricultural development and water resources utilization in the Nile Basin. It looks at **options for development**, projected in the regional context, and the importance of agricultural water use for social and food security in the different parts of the basin. Agricultural information derived from country data is aggregated into the sub-basins of the Nile, which are classified in this paper as the Southern Nile (Burundi, Democratic Republic of the Congo (DRC), Kenya, Rwanda, Tanzania and Uganda), Eastern Nile (Eritrea and Ethiopia) and Lower Nile (Egypt and the Sudan). Figure 1 shows the administrative boundaries of the riparian countries, and also the hydrological sub-basins of the Nile River.

With the exception of some forestry and irrigation potential calculations, data presented in this paper are an aggregate of country-based data. It is recognized that this can lead to some distortion, for example, with data from the Democratic Republic of the Congo, of which the Nile Basin is a very small part. To provide a consistent approach to estimates, data from 1989 are being used, as it was the base year for many of the projections, which have not yet been updated.

The agricultural sector, with its influential water use, is obviously linked to a range of social and environmental factors, such as food security, poverty alleviation, conservation of the natural environment and biodiversity. This paper's primary aim is to encourage the optimal utilization of agricultural water for social and economic benefits. Within this context, options are sought that support food security, rural welfare and sustainable agricultural development throughout the basin. Based on good practice and lessons learnt, such options are assessed for effectiveness, cost and the level of cooperation required. The sub-basin approach provides the environment for technical discussions of the wider issues and options linked to safeguarding the Nile Basin's resources.

The paper concludes with recommendations for different cooperative options, that are then translated into potential basin-wide and sub-basin programmes. The recommendations for development are aimed at both top-down and grass-roots level support, and also focus on policy and capacity building for self-development (by both institutions and individuals) and investment in agricultural development. In this context, cooperative measures on agriculture are crucial for planning (basin-wide and sub-basin) and dialogue (intra-basin and extra-basin) between the Nile Basin riparians and external partners.

Acknowledgement

The authors wish to express their gratitude for the assistance of many professionals and colleagues in FAO in providing important data and references.

Contents

page

List of acronyms used

COMESA	Common Market for Eastern and Southern Africa (Angola, Burundi, Comoros, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Rwanda, Seychelles, Somalia, the Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe)
DES	Dietary Energy Supply
DRC	Democratic Republic of the Congo
EU	European Union
GDP	Gross Domestic Product
GEF	Global Environment Facility
ICCON	International Consortium for Cooperation on the Nile
IGAD	Intergovernmental Authority on Development (previously known as Intergovernmental Authority on Drought and Development, IGADD)
LVEMP	Lake Victoria Environmental Management Program
LVFO	Lake Victoria Fisheries Organization
LVWRP	Lake Victoria Water Resources Project
SADC	Southern African Development Community
SSR	Self-sufficiency ratio, determined as a production-demand ratio
TCP	Technical Cooperation Programme of FAO
WCMC	World Conservation Monitoring Centre

Units

All units are SI units unless specifically indicated otherwise.

ha	hectare = 10^4 m^2
km^3	cubic kilometre = 10^9 m^3
t	metric tonne = 1 000 kg
$US	United States dollars

Chapter 1
An overview of agriculture along the Nile

The Nile flows 6 800 km from south to north, traversing 35 degrees of latitude, before finally discharging into the Mediterranean Sea. The agricultural sector in the Nile basin includes production and consumption of crops, fish, livestock and forestry products. Most of the Nile economies depend heavily upon the sector's commercial output for exports. Most of the population of the riparian economies rely upon subsistence production for food and income security.

The two main tributaries of the Nile are the White Nile, with sources on the Equatorial Plateau, and the Blue Nile, originating in the Ethiopian highlands. The Nile Basin encompasses different agroclimatic zones, which determine whether rainfed or irrigated agriculture is practised. Both major tributaries originate in relatively humid regions, with annual rainfall of 1 200-1 500 mm. The river flows through semi-arid regions with 400-800 mm rainfall, passing wetlands and fertile plains, then through the desert, prior to flowing into the sea. Managing and conserving the upper catchment areas is recognized as vital to sustaining the Nile's water resources.

The White Nile originates in a densely populated equatorial plateau, where rainfed agriculture is predominant. The potential to extend agriculture exists through wetland reclamation and irrigation around Lake Victoria and along the White Nile's main tributaries. Developing the irrigation potential would, however, require costly reclamation works. Lake Victoria covers approximately 67 000 km^2 (with an annual inflow of 20 km^3) and, together with other lakes downstream, regulates the White Nile. Lake Victoria's diverse environment supports large fish resources, which are harvested both commercially and for subsistence. Lake Victoria drains into the Victoria Nile, which enters Lake Kyoga and then Lake Albert, where it is joined by the Semiliki River. Flowing out of Lake Albert, the river becomes the White Nile, which flows into the Sudd.

Just below the Sudd, the White Nile is joined by the Sobat River, fed by rivers from the Ethiopian foothills. The wetlands of the Sudd extend over 16 200 km^2 (1980 estimate), but the surface area fluctuates with rainfall. Despite an extremely flat topography and nutrient-poor clay soils, the wetlands contain a wealth of wildlife and biodiversity resources. The fishing and grazing resources ensure the livelihood of pastoralists, who manage the largest cattle population in Africa.

The Blue Nile rises at Lake Tana in the Ethiopian highlands and joins the White Nile at Khartoum. Thereafter, the only other major Nile tributary is the Atbara River. The Blue Nile, the Atbara and the Sobat together contribute between 70-90% of the Nile's total low and peak flows. The Blue Nile and Atbara Rivers carry over 90% of the Nile's sediment. Degradation of the upper watershed environment through soil erosion, with consequent loss of productive land, has led to increasing sedimentation downstream. Nevertheless, irrigation potentials remain high in the Blue Nile catchment. However, water supply varies seasonally and water storage is costly and problematic.

FIGURE 1
The Nile and its sub-basins (see table on next page for key) (Source: FAO-AGLW)

Key to Figure 1
Map of the Nile Basin and its Sub-basins (Source: FAO, 1999)

	NAME	AREA (km²)	BASIN		NAME	AREA (km²)	BASIN
1	Abu Hut	21 425	White Nile	31	Lake Nasser	1 225	Nile
2	Akoba	38 220	White Nile	32	Lake Victoria	71 683	White Nile
3	Al Ghallah	19 959	White Nile	33	Mereb Wenz	31 667	Nile
4	Al Hawad	7 910	Nile	34	Nahr Atbarah 1	69 416	Nile
5	Al Ku	57 456	White Nile	35	Nahr Atbarah 2	23 217	Nile
6	Az Zayn	50 107	Nile	36	Nahr Atbarah 3	30 136	Nile
7	Bahr al Arab	104 288	White Nile	37	Nahr ad Dindar	62 493	Blue Nile
8	Bandah	116 295	White Nile	38	Nile 1	231 388	Nile
9	Baro Wenz	27 062	White Nile	39	Nile 2	81 593	Nile
10	Blue Nile 4	47 046	Blue Nile	40	Nile 3	27 175	Nile
11	Blue Nile 1	42 499	Blue Nile	41	Nile 4	3 707	Nile
12	Blue Nile 2	47 823	Blue Nile	42	Nile 5	115 664	Nile
13	Blue Nile 3	5 535	Blue Nile	43	Nile 6	28 093	Nile
14	Blue Nile 5	46 771	Blue Nile	44	Nile Delta	19 330	Nile
15	Buhayrat Abyad	63 338	White Nile	45	Nyando	55 121	White Nile
16	Dabus Wenz	14 509	Blue Nile	46	Semliki	64 876	White Nile
17	Damanhur	11 498	Nile	47	Simiyu	43 874	White Nile
18	Didesa Wenz	29 224	Blue Nile	48	Sooty Valley	90 073	Nile
19	Jema Shet	15 272	Blue Nile	49	Sopo	72 453	White Nile
20	Kagera	86 539	White Nile	50	Sue	85 504	White Nile
21	Khawr Adar	15 893	White Nile	51	Tekeze Wenz	66 805	Nile
22	Khawr Biban	15 320	White Nile	52	Victoria Nile	79 664	White Nile
23	Khawr Dulayb	9 659	White Nile	53	White Nile 1	13 487	White Nile
24	Khawr Kuteira	21 850	White Nile	54	White Nile 2	843	White Nile
25	Khawr Marchar	18 649	White Nile	55	White Nile 3	44 990	White Nile
26	Khawr an Nil	55 206	White Nile	56	White Nile 4	10 347	White Nile
27	Kidepo	76 933	White Nile	57	White Nile 5	134 110	White Nile
28	Kwahr M' boloko	77 793	White Nile	58	White Nile 6	161 130	White Nile
29	Kwahr Tendik	12 630	White Nile	59	al Malik	136 305	Nile
30	Lake Albert	7 505	White Nile	60	el Allaqi	81 671	Nile

Downstream of Khartoum, the Lower Nile enters the desert, where agricultural production is possible only with irrigation. Extensive drainage and wastewater re-use in the Nile Valley and Delta has led to salinization and pollution in the Delta region, with negative impacts on coastal fisheries and agricultural development.

Table 1 summarizes the areal context of any discussion of the Nile Basin. For each country, the portion actually lying within the Nile Basin varies, and, as statistics are usually country-based, applying whole-country data to a small area distorts the picture. This is especially true of data for DRC, and also for Kenya and Tanzania

TABLE 1
National areas within the Nile Basin

	Area in basin (km^3)	Percentage of total country area in Nile basin
Burundi	13 000	46
D R Congo	22 300	1
Eritrea	25 700	21
Ethiopia	366 000	32
Egypt	307 900	33
Kenya	52 100	9
Rwanda	20 400	83
Sudan	1 943 100	78
Tanzania	118 400	13
Uganda	238 700	98

Source: FAO Land and Water Information System

Table 2 tries to put the area concept into an agricultural production context based on climatic zones. In agricultural statistics, a distinction is often made between agricultural production in humid areas, semi-arid areas, and irrigated areas. In Table 2, the percentages are given of the various countries' different climatic zones actually situated in the Nile Basin. These allow an estimate to be made of Nile Basin-based agricultural production. Total agricultural production per climatic zone per country, multiplied by these percentages, gives an estimate of within-Nile Basin production per climatic zone.

Therefore, combining the percentage of a county's particular climatic zone within the Nile Basin (from Table 2) with the figures for cultivated areas (see Annex Table A5) provides a country-level estimate of rainfed cultivated area within the Nile Basin (see Annex Table A14).

TABLE 2
Proportion of each country's climatic zones falling within the Nile Basin

	Humid (%)	Semi-arid (%)
Burundi	46	0
D R Congo	1	0
Eritrea	0	49
Ethiopia	71	21
Egypt	0	92
Kenya	83	7
Rwanda	83	0
Sudan	99	89
Tanzania	13	14
Uganda	99	93

Source: FAO Land and Water Information System

Chapter 2
Social and economic conditions

The Nile Basin covers 3.1 million km^2 and includes some of the poorest countries in the world. In 1990, the human population in the Basin was estimated to be 160 million, and projected to increase to 300 million by 2010. Some of these countries are below the poverty line (GDP ≤ $US 300 per caput), with limited, or negative, economic growth (see Table 3 and Annex Table A1). With the exception of Egypt, Uganda, and in some measure Kenya, the Nile economies are expected to continue to depend upon low productivity subsistence agriculture for more than 50% of their GDP. Reported data (Alexandratos, 1995) on the agricultural sector suggests it employs, on average, 70% of the labour force, but represents only 22% of the cumulated economy in the Nile Basin countries. The sub-basin breakdown is Eastern Nile, 59.4%; Lower Nile, 17%; and Southern Nile 23.7% of GDP.

TABLE 3
Historic and projected socio-economic indicators on a sub-basin basis

	Eastern Nile	Lower Nile	Southern Nile	Nile Basin
		Historic – 1989		
GDP ($US million)	5 111	60 238	51 742	117 091
GDP growth (%)	-0.3	+0.7	+0.8	+0.1
Agriculture ($US million)	3 036	10 209	12 271	25 516
as % of GDP	59.4	17.0	23.7	21.8
Population (million)	47.9	75.7	114.4	238.1
of which agricultural	36.0	36.0	87.9	159.9
Population growth (%)	+3.0	+2.4	+3.4	+2.9
Labour force (million)				
Total	20.3	22.1	49.0	91.4
Agricultural	15.3	10.7	38.2	64.1
% in agriculture	75.1	48.3	77.9	70.1
		Projected – 2010		
GDP ($US million)	8 852	124 553	121 721	255 126
GDP growth (%)	–	–	–	–
Agriculture ($US million)	5 004	17 085	23 861	45 949
as % of GDP	56.5	13.7	19.6	18.0
Population (million)	88.9	119.8	235.2	443.8
of which agricultural	55.0	39.6	153.7	248.4
Population growth (%)	–	–	–	–
Labour force (million)				
Total	33.6	40.1	93.1	166.8
Agricultural	20.8	13.3	62.1	96.2
% in agriculture	61.8	33.3	66.7	57.7

Source: Alexandratos, 1995

With the exception of Egypt, most of the countries in the Nile Basin are classified as food insecure (FAO, 1998). Food security is threatened either by demographic growth or by a shortage of land or water, or both, and a limited capacity to absorb shocks such as drought, floods or civil conflict. To provide the minimum acceptable level of food security, food availability in the Basin would need to increase by 35-50% overall. In the short term, trade and food assistance can be used to ensure food security. To ensure that the most vulnerable acquire food, the focus is on food-for-work schemes paying below-market rates. As socio-economic conditions improve, the issue of food aid is expected to be re-examined. In the medium and long term, measures are expected to include agricultural development of the poorest sections of society, and fostering production and trade in food commodities within the Nile Basin.

Agriculture in national economies

The Nile economies are currently handicapped by their limited economic infrastructure and capacity. To improve agricultural production and encourage economic growth, these economies are expected to have to attract sustained public and private investment in the agricultural sector. Unless this challenge is met, these economies will continue to rely upon subsistence agriculture, and compete with each other to sell their low-value crop, livestock, forestry and fishery commodities internationally. The prospects for agricultural development and the status of particular food related issues in selected Nile economies are briefly described below.

Ethiopia: poverty and food insecurity

The statistics on Ethiopia paint a bleak picture: GDP per caput is $US 120. Approximately 60% of the population, the second-largest in Africa, lives below the poverty line. Economic growth trails behind population growth by approximately 3% per annum. The agricultural sector dominates economic production. It represents 50% of GDP, 90% of exports (coffee, hides, live animals, vegetables), and agro-processing comprises 80% of manufacturing. Small-scale farmers produce 90% of agricultural output, such as cereals (teff, maize, barley, wheat), pulses and oilseeds. Drought threatens almost half the country – approximately 20 million people – and food insecurity regularly affects over 50% of the population, with over 90% of these people concentrated in rural areas. Famine has been caused principally by drought and civil struggle, with the most recent and serious famines being in 1972-73 and 1984-85.

Since the mid-1970s, the economy as a whole and the agricultural sector in particular have been stagnating. Macro-economic policies, aimed at price stability, and direct governmental intervention in production and distribution marginalized growth, private initiatives and investment. Recent agricultural policy has passed through three phases: (i) the centralized command economy of 1974-1988; (ii) liberalization reforms during 1988-1991; and (iii) the post-1991 period, with additional liberalization measures. Some measure of recovery is visible today, as good rainfall combines with peace and stability.

Further development is thought to depend upon Ethiopia's capacity to address the interrelated issues of food security, poverty alleviation, environmental degradation and agricultural development constraints. Approximately half the Ethiopian highlands (270 000 km^2) are thought to be significantly eroded, with an additional 20 000 km^2 unlikely to sustain future cropping. Population pressure, leading to inappropriate agricultural practices, such as deforestation of steeplands land and overgrazing, is blamed for 80% of erosion.

Just as agricultural development needs to integrate poverty alleviation and environmental conservation, so other sectors of the economy need to integrate agricultural development. For example, providing an alternative source of income for vulnerable populations, especially in low-potential areas, can begin to address deeply ingrained socio-economic problems. The National Food Security Strategy aims to double per caput income in the next 15 years. Based on a regional-programme approach, the Strategy provides food insecure households with inputs and support for crop and animal production. The twin priorities are to improve livestock health and stock, and to improve water harvesting and small-scale irrigation facilities.

Egypt: rapid growth with emerging social and environmental issues

Reforms and liberalization policies adopted in the early 1990s have revitalized the economy, with growth and inflation almost balanced, and stabilizing food prices. Privatization of state industries has generated revenue to continue servicing Egypt's debt ($US 37 000 million). Recent reforms have also abolished most agricultural subsidies, but employment in the sector still represents 31% of the labour force (4.5 million people). Agricultural contribution to GDP and exports fell from 38% in 1975 to 20% in 1990 (FAO, 1998a). Agro-processing and marketing, however, do contribute an additional 20% to GDP.

Egyptian agriculture, covering 3.3 million ha in the Nile Valley and Delta, relies almost exclusively upon irrigation. From the High Dam at Aswan, water reaches the fields through seven barrages and 31 200 km of main canals. The cultivated area is supplied by 50 major canals, each servicing an area of 40 000-60 000 ha each. The major crops are cotton, rice, wheat, maize, sugar (cane and beet), berseem (alfalfa), beans, fruits and vegetables. Between 1990 and 1996, wheat production rose by 34%. Between 1995 and 1996, as a result of deregulation, cotton production jumped by almost 50%, reflecting a 40% increase in the cotton growing area. Similarly, in 1996, rice production reached a record 2.8 million t, of which 600 000 t was exported.

Box 1: From congested to new land. Water re-allocation and agricultural investment in the New Valley and New Sinai Projects

Egypt is looking to the National Project for the Development of Upper Egypt (NPDUE) to address congestion and environmental degradation in the Nile Valley and the Delta. The Project aims to increase cultivable land by 1.5 million ha over 20 years in the sparsely populated Toshka depression, East Oweniat and the New Valley oases. The NPDUE is also known as the Toshka, South or New Valley Project. Investment needed for the NPDUE is estimated to be $US 90 000 million, of which no more than 25% will be public money. Egypt hopes to attract private investment to cover the remaining costs.

Agricultural development, over 20 years, is projected to cost $US 8 000 million (8% of total investment). A variety of crops are expected to be produced, including alfalfa, orchard products, wheat and cotton for export to Europe and the Gulf states. The Sudan, Libya and Chad are also being seen as potential markets. The first phase of development will cover 210 000 ha, with 5 km^3 of water per year passing through the Toshka spillway from Lake Nasser.

In a similar way, the New Sinai Project aims at agricultural development of – ultimately – over 300 000 ha, based on transfer of Nile Water for irrigation in the Sinai.

Food supply and access are increasing, and Egypt's self-sufficiency rate in wheat is now 45%, up from 20% in the mid-1980s. Though the economy appears to be growing sustainably, the challenge lies in creating employment. Reforms towards a market economy, such as privatization of public enterprises, have led to job losses, and a new agricultural lease policy has displaced approximately one million tenant farmers. The labour market is growing annually by 3% (500 000 people), resulting in increasing competition for existing jobs. An additional challenge lies in tackling the widening inequity and welfare disparity between the urban and rural areas. Egypt's population growth is thought to be incompatible with existing agricultural land availability (0.05 ha per caput). Plans to expand irrigation to the South Valley and into the Sinai are being considered (see Box 1). Between 1952 and 1997, gains made in reclaiming 1.3 million ha of land were offset by the loss of 200 000 ha of high productivity agricultural land to urban and industrial expansion.

The official Egyptian policy provides options to increase water availability in the Lower Nile sub-basin, including recycling shallow groundwater and drainage water and re-using treated wastewater (Attia, 1997). Substantial increases are possible, but must be carefully regulated to control salinity, water-logging and water pollution. There might, however, be limited public acceptance and possible health and environmental hazards. Reducing conveyance losses in the system would make water available, but would entail expensive works. Water savings could be made by growing less water-demanding crops, such as reducing the current sugar cane and rice production, as 200 000 ha of sugar cane (requiring 12 000 m^3 of irrigation water per hectare) could be replaced with winter cropping of sugar beet (requiring only 1 000 m^3 per ha). The areas for rice, which needs 8 800 m^3 per ha, could be halved from 600 000 ha to 300 000 ha, which is estimated as the minimum area required to control soil salinity. However, the negative environmental and socio-economic consequences of such land-use changes would need to be assessed and may outweigh the benefits acheived from water saving and re-allocation to other uses.

The Sudan: famine in the breadbasket

The Sudan is oftern referred to as the potential breadbasket of Africa and the Middle East. It is endowed with abundant land resources for agricultural production. These areas include semi-arid and savannah lands with existing irrigation schemes, and wetlands in the south of the country. A number of long-term factors, however, contribute to the Sudan's continued poverty and food insecurity. First, sustained low economic growth has resulted in declining infrastructural and agricultural support. Second, grain production fluctuations due to rainfall variability have been exacerbated by national agricultural policies. These policies prioritized semi-mechanization and use of wage-dependent labour, but led to traditional production declining in marginal areas. Third, fiscal policies failed to control price fluctuations and secure food availability for marginal groups. Finally, civil conflict and droughts resulted in large-scale population displacement (World Bank, 1990a).

The Sudan's economy depends heavily upon irrigated cotton, which generates 43% of export income. The main irrigated scheme is at Gezira, with half the total cultivated area (900 000 ha). Other public schemes are the Rahad and New Halfa gravity schemes; two systems with flood control structures; and the many lift pump schemes along the Blue Nile, the White Nile and the Main Nile. Approximately 200 000 tenant farmers depend on these public schemes for their livelihood. However, irrigated crop production is performing below potential, especially in the White Nile pump schemes, where yields are half the national average. Cotton production dropped from 5.8 million t in 1983 to 2.3 million t in 1990. A combination of factors are thought to be responsible for this drop, including a decrease in cotton area (from 332 000 ha to 282 000 ha over the same period) and infrastructure deterioration.

Kenya: intensification in high potential areas

Agriculture plays a significant role in Kenya's economy and society, with 85% of the total population living in rural areas. The agricultural sector is divided into three subsectors – crop production (70%), livestock (25%) and fisheries (5%). Coffee and tea alone constitute 70% of all agricultural exports, and 50% of total exports. Exports of fish production from inland waters is also important, generating $US 80 million in 1996 from exports to the European Union. Domestic consumption is dominated by maize and beans. With the most productive agricultural land already extensively used, the aim is to intensify production. One measure is to ensure water security in times of drought by improving water management in drought-prone areas. With the smallholder sector growing in importance, the objective is to improve small-scale irrigation in the Lake Victoria-Nile Basin region.

Uganda: sound policies and external trade for sustainable recovery

Uganda's economy has shown noteworthy success (FAO, 1998a). GDP has been growing by 6.4% (other sub-Saharan countries have averaged 1.6%) and income per caput has grown by 50%. Combined with inflows of international loans and assistance, the economy is recovering from earlier ravages, and in 1998 generated $US 650 million, or 20% of its foreign debt. The debt:GDP ratio has also declined, from 80% to 50% between 1994 and 1998. The structural adjustment programme in Uganda has reduced the current account deficit from 50% to 10% of GDP. Debt servicing is down, from over 125% to 21% of GDP, and inflation is down from 237% to 11%. The key adjustments have been price liberalization, inflation control, currency devaluation and liberalization, reduction in government expenditures, privatization of industry, rebuilding of infrastructure, and restoration of financial and credit systems. Tax revenues, however, remain low due to considerable non-monetized activity, and slow implementation of value-added taxation. Speculation in the Ugandan shilling by neighbouring countries can result in liquidity problems for Uganda.

Agriculture dominates the Ugandan economy and society, contributing 44% of total output and employing 80% of the labour force. Production is concentrated in the south, with two growing seasons. Domestic food crops are roots and tubers, maize, beans, sesame and sorghum. Uganda is the leading coffee producer in Africa, with exports earning $US 100 million annually. However, coffee and other cash crops (cotton, tea and maize) are vulnerable to unfavourable weather and fluctuating international prices. Export diversification – comprising both low- and high-value crops – is thought to be generating 35% of all export earnings. Despite membership in the Common Market for Eastern and Southern Africa (COMESA), Uganda imports mainly from Europe and Asia, with agricultural products entering duty free.

Devaluation of the overvalued shilling and price liberalization led to increased agricultural exports, with commercial production following suit. Subsistence production has not matched commercial output, despite representing 40% of all agricultural output and being the foundation for local domestic food supply. Productivity and crop yields remains low, due in part to inadequate inputs, storage, transportation and distribution. The importance of the smallholder sector and its low resilience to external shocks is being recognized. Efforts to improve production in this sector include research, extension services, farmer linkages and rural-based agro-processing.

It is currently implementing a national "water-for-food" programme, which is combined with support provisions for agricultural inputs and infrastructure.

Regional food security

In societies that are malnourished, large sections of the population are weakened, with consequent effects upon those societies' capacity to enhance productivity and development. Food-insecure or malnourished rural populations are unable to take agricultural risks, nor can they invest in technology and agricultural inputs to improve productivity. Adverse weather conditions may wipe out the seed stock and force the rural population to emigrate. The rural poverty spiral is usually compounded by unsustainable practices and environmental degradation.

The concept of food security is predicated on the notion that all households have reliable physical and economic access to adequate food for all its members. The Dietary Energy Supply

(DES), expressed in calories per person per day, is used to assess food security. The critical threshold for national food security is a DES of 2 700. Establishing food security requires that all sectors of society can consistently access food supplies, either by production or purchase. Poverty and armed conflicts are major determinants of food insecurity.

Pre-conditions for sustaining nutritional improvements include appropriate macro-economic policies and development strategies, such as providing employment, intensifying growth and increasing agricultural production. In some cases, national policies have exacerbated rather than diminished poverty. For example, technological change and commercialization have excluded the poor because of tenant eviction, coerced production or forced procurement.

Estimates of DES in the Eastern and Southern Nile sub-basins indicate acute food insecurity for a large number of people in these regions. Vulnerability to famine in difficult years, or to armed conflict, is expected to continue such food insecurity. To reach the critical food security threshold, the DES would have to increase by 35-50% in these sub-basins. This estimate does not allow for population increases. Nutrition in the Eastern and Lower Nile sub-basins is mainly based on wheat, with a strong millet and sorghum component, especially in the Sudan. Nutrition in the Southern basin is based on roots and tubers, although Kenya is classified as consuming

TABLE 4
Food balance sheet, 1995-96

	POPULATION (million)	DIET TYPOLOGY	TOTAL	VEGETABLE PRODUCTS	ANIMAL PRODUCTS
				(Calories per day)	
Eastern Nile	61	wheat	1 799	1 701	97
Lower Nile	90	(wheat)	3 013	2 745	338
Southern Nile	135	roots & tubers	1 968	1 850	121
In comparison:					
France	58	milk, meat, wheat	3 555	2 205	1 350
China	1 226	rice	2 799	2 325	474
Brazil	160	maize	2 908	2 360	548

Source: FAO data.

mainly maize. Intake of animal products is dismally low in most of the countries. See Table 4 and Annex Table A2.

Though the Southern Nile economies have, overall, large reserves of unexploited arable land, they share with the other sub-basins the main causes of chronic undernourishment: poverty, weak infrastructure, high mortality rates and rapid population growth. The potential for increasing production in the Southern Nile sub-basin remains considerable. Production constraints are often of an agronomic nature, but research has not yet focused on the crop plants which might have a large potential for improvement. Increasing production of roots and tubers requires improvement in the situation of rural women, as they are often the principal producers of subsistence food. However, other responsibilities arising from poverty can stretch their capacity to manage available resources. This can result, *inter alia*, in land degradation. Arguably, any development in the Nile Basin should be integrated with a substantial improvement in the food and income security of the people living there.

Chapter 3
Agricultural demand and production

Total demand for agricultural products includes uses for food, industry, livestock feed and seed. Post-harvest losses are also part of the demand placed upon available agricultural resources. These demands are projected to increase from some 40 million t in 1989 to almost 74 million t by 2010 (see Table 5 for cereals, and also Annex Table A3). Production within the Nile Basin overall meets approximately 75% of demand and is expected to continue at this rate subject to variations in the sub-basins. The shortfall in production is met generally through trade. in some of the Nile economies the capacity to import food is limited at times. Agricultural production is divided, broadly speaking, into commercial or private activities for export, and subsistence production for local consumption.

TABLE 5
Historic and projected supply utilization of cereals ('000 tons)

		EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Demand	historic	7 118	22 375	11 128	**40 622**
	2010	13 510	36 182	24 163	**73 856**
Food	historic	6 504	15 772	9 966	**32 242**
	2010	12 470	24 912	21 390	**58 773**
Feed	historic	52	4 278	432	**4 761**
	2010	90	7 610	1 077	**8 777**
Production	historic	6 204	13 337	10 354	**29 894**
	2010	11 006	23 419	21 301	**55 726**
Trade	historic	-741	-8 723	-575	**-10 040**
	2010	-2 504	-12 763	-2 863	**-18 130**
SSR(1)	historic	0.87	0.60	0.93	**0.74**
	2010	0.81	0.65	0.88	**0.75**

Notes: (1) SSR = self-sufficiency ration = Production/Demand ratio, where Demand = (DES * population)/(1 - % post-harvest loss)
Source: Alexandratos, 1995

Average food consumption is only 80% of minimum DES requirement, and distribution is not equal. Therefore chronic undernutrition remains a constant spectre in the Nile Basin. To address the issue of food insecurity, increased agricultural production needs to be coupled with an overall increase in post-harvesting efficiency.

Product diversification is also believed to be important in improving nutritional balance, especially in the communities consuming mainly roots and tubers. Table 6 (and Annex Table A4) outlines the pattern of food consumption by major commodities for 1989, and projected consumption in 2010, but not the distribution and availability of food in the Basin.

From Table 6, it can be seen that the Lower Nile sub-basin dominates cereal consumption, though this food type is consumed throughout the Nile basin. In comparison, the Southern Nile dominates consumption of roots and tubers. Meat consumption is not of the magnitude of the other commodities, and would need to be increased to encourage food security. Demand overall

TABLE 6
Historic and projected total food demand by major commodity ('000 tons)

		EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Cereals	1989	8 725	19 920	10 913	**39 558**
	2010	12 473	24 895	21 392	**58 760**
Roots and tubers	1989	1 961	1 675	40 770	**44 407**
	2010	2 685	2 523	68 816	**74 024**
Meat	1989	477	1 434	1 008	**2 919**
	2010	782	2 140	2 040	**4 962**
Total	1989	11 613	23 029	52 691	**86 884**
	2010	15 940	29 557	92 248	**137 745**
Increase in total		43%	28%	75%	**59%**

Source: Alexandratos, 1995

is projected to increase by 60% by 2010, with the highest increases in the Southern and Eastern Nile sub-basins. Meat consumption in the Basin is expected to jump by 70% overall, from approximately 3 000 t in 1989 to 5 000 t in 2010.

CROPS

The primary staples in the Eastern and Lower Nile sub-basins are wheat, millet and sorghum. In the Southern Nile, roots and tubers form the primary staples, though maize is also heavily consumed in some areas. The key question in agricultural production is whether potential land and water resources, including development of spate irrigation and water harvesting practices, can meet increasing demand. Table 7 (and Annex Table A5) shows that the amount of cultivated land is largest in areas of rainfed agriculture. This may be related to the underuse of inputs to intensify agriculture production compared to irrigated areas, which have an assured supply of water.

TABLE 7
Cultivated area of commodities produced in rainfed and irrigated agriculture ('000 ha)

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Rainfed				
Cereals	5 183	5 335	7 894	**18 412**
Roots & tubers	543	58	6 990	**7 591**
Other	2 065	123	8 911	**11 099**
Irrigated				
Cereals	30	2 578	151	**2 759**
Roots & tubers	0	91	0	**91**
Other	135	2 344	125	**2 604**
Total				
Cereals	5 213	7 913	8 045	**21 171**
Roots & tubers	543	149	6 990	**7 682**
Other	2 200	2 467	9 036	**13 703**

Source: Alexandratos, 1995

Plant nutrition

As degradation and loss of soil nutrients in the upper catchment areas are major constraints to agricultural production, and as abating rural poverty is a priority, it is necessary to intensify production. The challenge of intensifying agricultural production is thought to have been met in part in areas of assured water supply, most notably in the Lower Nile sub-basin. This is reflected in the concentration of plant nutrition inputs in Egypt (see Table 8). Egypt is one of the highest fertilizer users in the developing world, and is expected to continue to use high inputs (see Table 9).

TABLE 8
Comparative fertilizer use by crop and fertilizer

Country[1]	Area ('000 ha)	Fertilizer (%) N	Fertilizer (%) P	Fertilizer (%) K	Rate (kg/ha) N	Rate (kg/ha) P	Rate (kg/ha) K
Wheat							
Egypt	855	100	100	0	178	36	0
Ethiopia[2]	770				13	26	0
USA[3]	19 925	86	49	15	74	41	59
India	23 502	94	94	94	84	39	5
Maize							
Egypt	704	100	100	0	250	36	0
Ethiopia[2]	1 100				7	14	0
Tanzania	1 908	10	10	10	80	40	1
USA	28 066	97	83	72	144	64	89
India	5 918	84	84	84	51	16	3
Rice							
Egypt	558	100	100	0	143	36	0
Tanzania	306	21	21	0	40	20	0
USA	1 358	98	34	37	150	49	56
India	42 167	78	78	78	69	56	9

Notes: (1) Year of data: Egypt, 1994; Ethiopia, 1995; Tanzania, 1992; USA, 1994; and India, 1990. (2) Ethiopia's rate data is an average for the crop and fertilizer. Application (fertilizer %) is not known. (3) Winter wheat data for the USA.
Source: FAO/IFA/IFDC, 1996.

TABLE 9
Historic and projected use of chemical fertilizer.

Country	Average 1994-96	2015	2030
Egypt	252	258	264
Ethiopia	20	24	28
(Europe)	(492)	(474)	(481)

Source: FAO-AGL communication, 1999.

Current production methods – extensive but low-input, low-yield subsistence farming – will require a substantial increase in nutrient replenishment and pest control. An increase in cultivated irrigation area up to maximum basin irrigation potentials implies an additional 7 million ha. The cost of additional fertilizer inputs is estimated to be $US 100 million annually, based upon adding 100 kg/ha, or 700 000 t/year. This, however, could potentially degrade existing water quality. But financial constraints coupled with fair nutritional use efficiencies (50%) may prevent a rapid increase in use. The limited nutrient discharges may even be beneficially re-used for downstream irrigation. In this respect the issue of chemical pollution becomes a matter of sound plant and soil nutrition management.

Cotton production, especially in the Lower Nile sub-basin, depends on regular pesticide use. Beyond cotton, present use of biocides in the basin is limited to horticulture. The use of herbicides in controlling water hyacinth in Lake Victoria and other Nile water bodies is a potential pollution issue.

Fisheries

Inland fisheries

Inland capture in the Nile Basin is dominated by Nile perch and tilapia from Lake Victoria. Aquaculture only makes a significant contribution to fish production in the Lower Nile sub-basin. Overall, fisheries statistics indicate little contribution to the economy and food production of the Nile Basin. The production figures, however, fail to emphasize the present and potential importance of inland fisheries to the local populations' food security. Not only is fish an important source of animal protein, it is also a means of generating income and employment for local communities (FAO, 1995d; Coates, 1995). Reliance on inland fish is especially high during adverse conditions, when food availability is even more precarious than usual. Inland catch data is believed to be under-reported, suggesting catch sizes are, in fact, larger (Coates, 1995; WCMC, 1998). Recent fisheries statistics are summarized in Table 10, and Annex Table A13 provides historic data.

TABLE 10
Inland freshwater fisheries in the Nile Basin

	FISHERIES (t/yr)	
	Country	Estimated in Nile Basin
Burundi	43 800	350
D R Congo	96 400	16 000
Eritrea	0	0
Ethiopia	8 800	280
Egypt	294 760	157 200
Kenya	61 300	48 500
Rwanda	3 100	1 600
Sudan	21 300	21 300
Tanzania	621 400	97 300
Uganda	225 000	225 000

Source: FAO Fisheries GIS

The potential to increase inland fisheries is significant, but limited to certain areas and water bodies. For example, catch sizes from the Sudd are currently 12 000 t/yr, while as much as 140 000 t/yr may be possible (FAO, 1995a). However, any potential catch is subject to the aquatic environment being protected from further degradation due to urban and agricultural pollution (FAO, 1995d). Optimization of use of the natural resources, and loss reduction in fisheries, will depend upon agricultural considerations integrating and involving the fisheries sector (FAO, 1998a).

Lake Victoria's catch represents approximately 25% of the total reported inland catch of Africa (FAO, 1995d). It is difficult to assess inland fish stocks because they respond rapidly to changing environmental conditions. Nevertheless, the consensus is that catch sizes have declined since 1990, though they remain substantial. With more than 80% of the Nile perch catch from Lake Victoria destined for international markets, the inland fisheries' contribution to the domestic supply of fish is limited.

However, fish are subject to importing country health and quality requirements, and the EU only recently lifted a ban on fish imports from the Lake Victoria region following a cholera outbreak in early 1997. The Lake Victoria Fisheries Organization was set up in 1994 by Kenya, Tanzania and Uganda to jointly research and manage the fish stocks of the Lake. Lake Victoria's importance to the fisheries sector goes beyond exports, and is critical at the artisanal level. Small-scale fishing production is consumed locally, and provides an important source of nutrition and income generation.

Inland capture from the Nile system represents over 95% of the Sudan's fish production. Artisanal or subsistence fishing, producing 10 000-11 000 t/yr, is practised country wide, especially in the southern areas subject to regular flooding. In contrast, commercial fishing, practised by private, semi-private and cooperative entities, is restricted to dams and reservoirs close to urban areas, and relies predominately upon Nile perch, labeo, tilapia and alestes. The majority of the catch is consumed fresh. Where preserved, it is primarily sun-dried without salt. The fisheries remain problematic, since quality is often low and catch loss can be high. In addition, aside from subsistence fishing, fish consumption is concentrated in Khartoum. Fish remains more expensive than meat, which is widely available. Post-harvest processes may need improvement to address the wastage of fish.

The Nile system within the Sudan has a surface area of 1 978 506 km^2 (FAO, 1997b). The fisheries potential is dominated by the vast southern wetlands. Reservoirs and rivers in the northern and central provinces, near the centres of consumption, make up the balance. Though some of these reservoirs are being tapped to capacity, an increase in production of about 14 000 t/yr is considered feasible, especially from Jebel Aulia and Lake Nubia. Though the southern regions have a larger potential, transportation and marketing constraints need to be overcome. An estimated 200 t/yr is produced from aquaculture. The potential for aquaculture is good in the reservoirs, or *hafirs*, of Darfur, Kordofan and Kassala provinces, which are far from areas with capture fisheries.

Aquaculture

Water conservation has become the highest priority in the Lower Nile sub-basin. Conservation measures include re-utilization of drainage water and introduction of market incentives for more efficient irrigation use. As salinity increases, with less irrigation water available, prospects for maintaining freshwater fish farms diminish. A major portion of the runoff entering Lake Qaroun and Lake Manzala is being re-used or diverted to other irrigation areas, with the result that salinity is increasing in the lakes. This is forcing local fish farms to shift to brackish and marine species. This shift is competing with existing coastal fisheries and endangering the production of 1 300 t/yr from the put-and-take fisheries. Aquaculture development will directly depend on the long-term uses of the lakes. However, these water bodies are also being considered for fresh water storage purposes, and are affected by continued land reclamation.

Aquaculture expansion is also constrained by competition for the limited amount of available land. More than 75% of production is from unlicensed fish farms operating on arable land. The need to re-locate aquaculture to non-arable land has become a top priority land issue. As a consequence, future horizontal expansion of fish ponds is closely linked to the capacity to integrate natural resource management. With an increasing demand for fish, production can be expected to re-focus on: (a) increasing existing farms' output; (b) incorporating freshwater aquaculture into existing farming systems; (c) intensifying use of inland water resources; and (d) development of brackish and marine aquaculture.

An indication of the growth in aquaculture in the countries of the Nile Basin is given in Table 11. The data are for the countries as a whole; it was not possible to extract basin-level data.

TABLE 11
National aquaculture production in the countries of the Nile Basin

	National aquaculture production (t/yr)									
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Burundi	25	24	25	30	50	50	55	55	50	10
D R Congo	723	759	760	700	700	730	700	750	750	750
Eritrea	–	–	–	–	–	–	–	–	–	–
Ethiopia	–	1	33	36	36	22	28	33	55	85
Egypt	45 000	50 000	55 000	55 916	52 877	54 195	45 380	46 887	45 473	53 302
Kenya	126	251	603	698	722	749	763	813	893	500
Rwanda	64	38	44	164	58	53	53	50	49	50
Sudan	43	45	100	234	203	200	200	200	1 000	1 000
Tanzania	35	37	375	375	400	350	200	150	200	200
Uganda	38	34	42	52	63	77	87	179	194	210

Source: FAO, 1998b

Coastal lagoon fisheries

The changing coastal environment has affected the type of fish caught in Egypt's four coastal lakes. Dominated by Lake Manzala, which produces 58 000 t/yr, and Lake Burullus, which yields 52 000 t/yr, these lakes used to be saline, but became less saline. Harvesting between 1.0-1.8 t/ha, these four lakes produce 60% of the country's inland catch, and make a significant contribution to the coastal fisheries and local economy. Following the construction of the Aswan High Dam, freshwater tilapias and catfish were the dominant species. However, the fish species spectrum in Lake Manzala, the largest lagoon in the delta, is changing back from carp to mullet (FAO, 1997a). This is due to drainage water discharge making the freshwater lake brackish again.

Marine fisheries

Marine fisheries in the Nile marine catchment basin derive from the Mediterranean Sea. The regulated and reduced flow of the Nile after the construction of the Aswan High Dam altered the flow of nutrients into the already nutrient-poor Mediterranean Sea. In recent years, however, an increase in nutrient flow has been observed, and is attributed to sewage discharge from Cairo and the coastal cities (Caddy, Refk and Do-Chi, 1995). This has resulted in marine catch sizes increasing, though not to pre-dam levels. Egypt is supporting a fish-rearing programme, with hatcheries for sea-bream and sea-bass to provide income and employment for fishermen in the Delta and other coastal regions. As can be seen from Table 10, marine catches do not constitute a major portion of the total fisheries catch in the Nile Basin.

LIVESTOCK

The Nile Basin contains various systems of livestock production, ranging from subsistence crop-livestock to intensive commercial production (World Bank, 1993b). To improve productivity, issues such as animal health, stock quality and balanced stocking will have to be addressed. Higher levels of productivity will also require subsector deregulation, and policies that provide incentives to farmers and allow free markets to exist. Livestock production in the Nile basin for the consumption of meat is concentrated in the Lower Nile sub-basin, as can be seen from the offtake rates in Table 12 (and Annex Table A6). Elsewhere in the Nile Basin, livestock are maintained for their socio-economic importance in ensuring food and income security. An exception is the production of poultry which has high offtake rates throughout the Nile Basin. Cattle production dominates the livestock sector, followed by small ruminants, and poultry, a

TABLE 12
Offtake rate of livestock in the Nile Basin

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Cattle				
Stock ('000s)	28 633	26 056	33 457	**88 146**
Offtake (%)	7.3	19.1	13.4	**13.1**
Production animals ('000s)	2 099	4 984	4 494	**11 577**
Carcass weight (kg/beast)	109.5	138.1	127.8	**128.9**
Meat production ('000 t)	229.2	688.2	574.3	**1 492.4**
Poultry				
Stock ('000s)	57 267	78 565	84 508	**220 340**
Offtake (%)	165.0	245.0	123.6	**177.6**
Production animals ('000s)	94 486	192 483	104 465	**391 434**
Carcass weight (kg/bird)	0.8	1.1	1.1	**1.0**
Meat production ('000 t)	75.6	218.4	111.2	**405.2**

Notes: Indigenous Production of Animals (IPA) = slaughtered + live animals exported. Offtake rate = (IPA/stock numbers)*100. Indigenous Production of Meat = IPA*carcass weight.
Source: Alexandratos, 1995

TABLE 13
National herd size and size of herd within the Nile Basin

	NUMBER OF CATTLE	
	Country	In Nile basin
Burundi	449 000	281 000
D R Congo	1 576 000	101 000
Eritrea	1 773 000	248 000
Ethiopia	26 871 000	9 872 000
Egypt	NA	NA
Kenya	11 031 000	2 891 000
Rwanda	757 000	623 000
Sudan	19 604 000	17 903 000
Tanzania	13 817 000	3 993 000
Uganda	5 393 000	5 342 000

Note: The GIS database of the Animal Health Service covers only sub-Saharan Africa, and therefore has no figures on Egypt.
Source: From FAO Animal Health Service GIS.

TABLE 14
Historic and projected livestock production in the Nile Basin(1) ('000 ton)

		EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Cattle	historic	229.9	688.2	574.3	**1 492.4**
	2010	370.0	1 103.0	1 150.8	**2 623.8**
Sheep & goats	historic	149.9	188.8	127.4	**466.1**
	2010	262.0	312.0	254.9	**828.9**
Pigs	historic	0.9	2.2	80.0	**83.1**
	2010	1.8	4.2	179.5	**185.5**
Poultry	historic	75.6	218.4	111.2	**405.2**
	2010	150.0	493.0	341.6	**984.6**
Total	historic	456.3	1 097.6	892.9	**2 446.9**
	2010	783.8	1 912.2	1 926.8	**4 622.8**

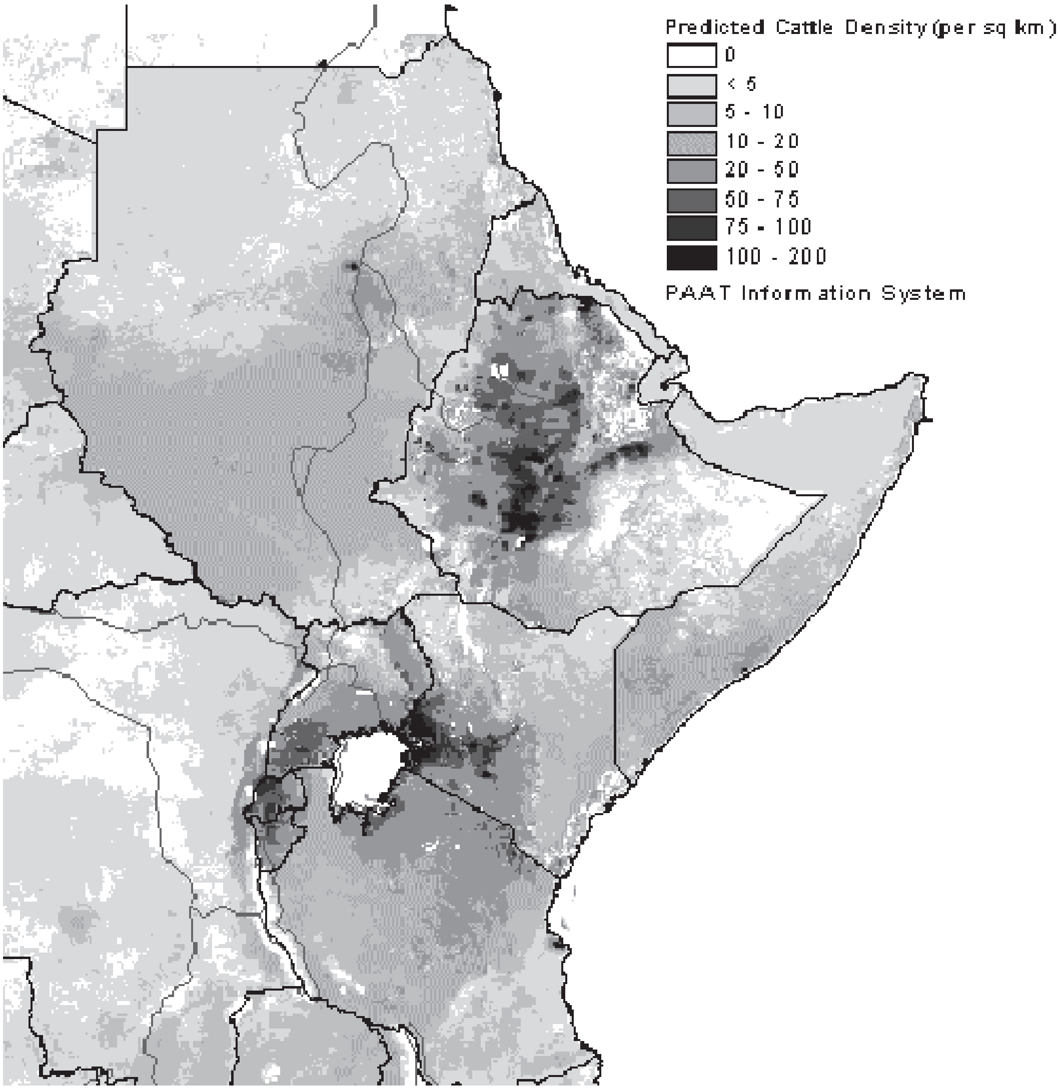
Notes: Livestock production is live + slaughtered animals (including exports of live animals), minus any imports.
Source: Alexandratos, 1995.

sector which is growing rapidly (see Table 14 and Annex Table A7). Livestock production overall is projected to double: from 2.5 million t in 1989, to 4.6 million t in 2010. The small deficit in production may be met through trade.

There are an estimated 88 million units of cattle and a similar number of smaller ruminants, such as sheep and goats (see Table 13). Livestock production is concentrated in the arid and semi-arid areas of the Nile Basin. Ethiopia, Kenya, the Sudan and Tanzania are the main livestock producers, principally because they have large grazing areas free of tsetse fly. Where small pockets of tsetse fly do exist in the Nile Basin, livestock production is absent, with the result that the local wildlife and biodiversity have been sustained (see Figure2).

Raising cattle in transhumance flocks is probably one of the most effective ways of using limited "green" water resources (soil moisture) in arid and semi-arid conditions. However, intensifying production under this method is difficult, since there are socio-economic and cultural factors reinforcing low offtake levels, and overgrazing limits the availability of natural grasslands. Therefore it is assumed that production increases will be achieved with confined livestock using dry feed produced by rainfed or irrigated agriculture. Increasing population pressures and land constraints combine to make a case for intensification. However, the process will take time, as

FIGURE 2
Predicted cattle density (Source: Programme Against African Trypanosomiasis (PAAT) Information System)



agricultural practices change to mixed farming systems that maintain soil fertility (Winrock International, 1992). Individual Nile countries are at different stages in this process of evolution, which ranges from nomadic grazing, through small-holder farming based on animal traction, and ultimately to growing legumes and forage to enhance livestock production and to increase soil fertility and crop yields.

Forestry

Reports estimating the size of forest plantations in the Nile Basin as a region remain problematic, due to data discrepancies, and are subject to inaccurate estimations. Nonetheless, the figures used do give an estimate of the magnitude. Tables 15 and 16 present data that specific to the geographic make up of the Nile Basin, rather than aggregated country data. Six of the ten

TABLE 15
Reported plantation area ('000 ha)

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Land area	110 100	62 730	397 262	**570 092**
Plantations				
Industrial	25	43	384	**452**
Non-industrial	245	247	349	**841**
Total	270	290	733	**1 293**

Source: Lorenzini and Marzoli, 1990.

TABLE 16
Annual adjusted total fuelwood production and demand in the Nile Basin ($\times 10^6$ m^3)

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Production	15.05	49.31	93.91	**158.27**
Demand	14.64	23.75	45.89	**84.28**
Balance	0.41	25.56	48.02	**73.99**

Source: Lorenzini and Marzoli, 1990.

countries in the Nile Basin (Burundi, Ethiopia, Kenya, Rwanda, the Sudan and Tanzania) are among the twelve countries in Africa that account for 80% of reported plantations, with each country having more than 100 000 ha. Similarly, Burundi, DRC, Kenya, Rwanda, the Sudan and Tanzania account for 90% of the industrial plantations, and each has over 30 000 ha of industrial plantations (FAO, 1995c).

The total area of reported plantations in the Nile Basin doubled – from 639 900 ha to 1.3 million ha –between 1980 and 1990. In 1980, industrial plantations comprised 46% of the total plantation area; ten years later (see Table 15 and Annex Table A8) this percentage had fallen to 35%, with non-industrial plantations growing from 54 to 65% of the total (FAO, 1995c). The most common species are the eucalypts, with acacias and pines following. However, certain species are preferred in some of the sub-basins. In the Lower Nile sub-basin, gum arabic (*Acacia senegal*) – which has no wooden by-products – dominates 79% of the plantations, and is used to earn foreign exchange. In 1989, production was estimated to be 23 000 t from 50 000 ha, and earned $US 52 million (FAO, 1995c). In the Eastern Nile sub-basin, eucalyptus is the dominant genus, comprising 83% of the plantations.

Forest regeneration depends primarily upon the extent to which the land is grazed once the trees have been cleared. If grazing is prevented, then 500-1000 mm/yr of rainfall may be sufficient to grow a plantation. The rate of growth will not, however, be spectacular, and will also depend upon the species being grown. In the Lower Nile sub-basin wastewater (irrigation and sewage) is being used to grow trees, either to protect the fields or as plantations. In the Southern Nile sub-basin, commercial plantations provide most of the timber, but natural forests remain the primary source of fuelwood (James Ball, FAO, *pers. comm.*, 1998).

Basin-wide data on fuelwood demand and production indicates production far exceeds demand. This suggests that approximately 75 million m^3 of fuelwood is exported (informally) out of the basin (see Table 16 and Annex Table A8). However, as this data is basin-specific, it could imply a trade between provinces within a country, and not necessarily international trade between countries. The Democratic Republic of the Congo dominates the Southern Nile sub-basin's exports, with 57 million m^3, followed by Uganda (9 million m^3). Other countries in the sub-basin are primarily fuelwood importers. Production and demand are fairly balanced in the Eastern

Nile sub-basin. In the Southern Nile sub-basin, the Sudan exports 26 million m^3 annually, and it is believed that 88% of actual production is, on average, produced sustainably (Miguel Trossero, FAO, *pers. comm.,* 1998).

Post-harvest management

Post-harvest management is concerned with the process of getting agricultural products from the field to the table. Waste is considered to be not only quantitative losses but also other losses, such as economic and qualitative. Table 5 outlines for cereals the supply utilization in the Nile Basin and includes waste. Calculating reported waste as a percentage of demand and production suggests that it was less than 10% for both categories in 1989, and projected to remain at these levels in 2010. However, this estimate is believed to represent only part of the total post-harvest loss. Estimates put total post-harvest losses at an average of 30-40% of production (FAO, 1996d; Francois Mazaud, FAO, *pers. comm.*, 1999).

Agro-processing

Agro-processing, which transforms agricultural, forestry and fisheries products, has a high degree of interdependence with forward and backward (pre- and post-processing) activities. This sector could, therefore, catalyse economic activities in the agricultural sector. At present, the Nile economies have low agro-industrial productivity. The profile of this industry is characterized by low wages, low value-added and limited operating margins and profits, but high shares of raw materials. For example, internationally, in 1993, the maximum reported level of cost share of raw materials was 93.1% in Kenya. In order for this industry to develop, it has to establish forward-backward economic linkages and increasingly consume other industrial products. In Egypt, primary agriculture accounts for approximately 90% of the immediate purchases by the agro-industry, and it is only for livestock-related products that longer chains of links exist. Looking to a developing country beyond the Nile Basin, in Morocco, the food industry purchases less than 70% of its raw material from agriculture, with more than 45% of the final product comprising non-agricultural products.

Agricultural institutions

Land management

Security of land tenure is a basic requirement for sustainable agricultural development and resource conservation in the Nile Basin. The extent and effectiveness of land management schemes, some of which are relics of colonial rule, vary throughout the Basin. Where traditional systems have collapsed and not been replaced with ‘better’ schemes, land management obstructs good agricultural planning and husbandry. Under such circumstances, it is harder to introduce modern technology, techniques and conservation of land and water resources.

Agricultural land in Egypt is either worked by the owners, or leased to tenant farmers and share-croppers. Egyptian land registration dates back to the cadastre system of 1925. Though it was modified during the 1950 land reforms, it is not geared up to deal with land sales under a free market system. In anticipation of the South Valley development, a new registration system is being introduced, but there remains a large backlog of land registration. In the absence of active regulation, and despite legal restrictions, land is being speculated in by urban-based landlords.

A further development threatening production was the removal of agricultural land tenancy ceilings in 1997. Approximately one million farmers can now be expelled from land they have farmed for decades. Egypt recognizes the current system's shortcomings and acknowledges the need for a new registration system, or even complete land reform. At present, farmers are unable to buy the land they farm, nor can a land certificate be given that would act as collateral for credit.

In the 1970s, the Sudan established an excellent land register, which focused on the drylands. However, the system became outdated and politicized, with the consequence that only very large land deals justified the high registration costs. The original objective, which was to protect the smallholders, has led to those same smallholders now becoming absentee landholders. They, in turn, lease the land to other, smaller farmers. Given the size of the Sudan, land management probably needs to be implemented on a project by project basis, rather than through a national land administration scheme.

Northern Arab and southern Nilotic nomadic herders have a long tradition of sustainably managing grazing lands in the Sudan. Established councils of chiefs regulated grazing rights and resolved conflicts. They also accommodated the interests of villages using spate irrigation, which formed an integral part of the agricultural system. These institutions developed in recognition of the importance of local production and consumption in these remote areas. Unfortunately, these institutions have suffered under the Sudan's civil conflict.

Ethiopia, following the transition from collective farming, is implementing a cost-effective approach to supporting small-scale farming. Land administration is being effected through local, decentralized management.

Uganda, with a new Land Act in 1997, is decentralizing its land management too. There remain, however, features that could discourage agriculture and sustainable water use. Diminishing farm sizes and land fragmentation – which is considered to constrain productivity and is an efficient use of resources – remains a major issue.

Cooperative lake management

Kenya, Tanzania and Uganda are cooperating in order to jointly manage Lake Victoria. They aim to safeguard both the lake's environmental integrity and their use of its resources. The Lake Victoria Fisheries Organization (LVFO), established in May 1996, aims to foster cooperation, harmonize national sustainable use of resources, and to develop and implement conservation and management policies. The Lake Victoria Water Resources Project (LVWRP) is aimed at better management by understanding and monitoring the lake's water resources and use. Establishment of an institutional arrangement under the Treaty of East African Cooperation is under consideration.

The Lake Victoria Environmental Management Program (LVEMP), supported by the Global Environment Facility (GEF), assists rehabilitation of the lake's ecosystems. The national secretariats of Kenya, Tanzania and Uganda, together with LVEMP, have prioritized fisheries management and control of water hyacinth. The projects are coordinated by the governments, in collaboration with LVFO.

The countries are also trying to harmonize their environmental laws, with particular focus on Lake Victoria. The onus is upon determining policies that are consistent with national legislative procedures and policies, but remain within the sub-regional framework. The collaboration aims to cooperate on research, pollution, pest control and fisheries management. In October 1998, a Memorandum of Understanding was signed by all three governments as an interim measure until a protocol – which is currently under negotiation – can be adopted under the Treaty for East African Cooperation.

Irrigation management

Water management, through organized traditional systems, has long existed in the Fayoum depression in Egypt. Informal organizations also exist for pumping systems (*sakia*), which are owned, operated and managed by groups of farmers. The micro-system (*mesqa*), which includes the offtakes (*marwas*), has 30-60 farmers working 20-60 ha. The system is owned by the farmers, who are responsible for the water lift's operation and maintenance. A policy aimed at forming private water user associations and irrigation advisory services at *mesqa* level is being implemented. The aim is to address legal rights and responsibilities of the participants. Participatory management appears promising, and can be expected to improve as the farmers continue to respond to the free market system (Abdel Aziz, 1995).

In the Sudan irrigation has, traditionally, been subject to top-down management. The State regulated every aspect of this sector: the tenant farmers, cropping patterns, inputs, services, marketing and pricing of produce. The system of "livelihood pump schemes" dates back to the construction of the Jebel Aulia Dam, and the transfer of the Gezira Scheme to the Government of the Sudan in 1950. The schemes were administered as a "triple partnership" between the Government, public corporations operating under the Ministry of Agriculture, and the tenants. The irrigation works themselves fell under the Ministry of Irrigation's mandate.

The system has long been a source of contention, with adverse impacts on production. Problems emerged as tenancy contracts were changed from sharecropping to individual accounts. Under sharecropping, costs and proceeds were shared equally; however, under the changed system, individual tenants incurred the full costs of all inputs, including land and water charges. A privatization process was started over 30 years ago, driven by deteriorating cotton production in the pumped schemes. The public corporations were dissolved, and some pumped schemes were handed over to cooperatives and private individuals. More recently, participation of tenants in scheme management has been extended, and the ancillary units privatized. There is a growing recognition of the need to privatize irrigation facilities and services, particularly the ownership and operation of pumps. Another sign of privatization has been the evolution of unofficial lease land markets in government-owned schemes (Samad, Dingle and Shafique, 1995).

AGRICULTURAL TRADE

Total trade in the Nile Basin is believed to be more than the reported trade figures would suggest, since there is informal intra-basin trade. For formal trade, apart from Kenya which conducts significant intra-basin trade, the Nile Basin economies' primary trading partners lie outside the basin (see Table 17). However, recent developments in intra-basin trade, such as Ugandan exports, are not reflected in the data quoted in Table 17. Of approximately 10 million t of commodity imports into the Basin, cereals represent over 90% (Alexandratos, 1995).

TABLE 17
Intra-regional agricultural commodity trade ($US million)

COUNTRY	YEAR	EXPORTS TO		IMPORTS FROM	
		World	Nile Basin	World	Nile Basin
Egypt	1997	269.59	7.48	2 698.59	83.25
Sudan	1995	114.83	1.76	216.16	22.15
Ethiopia	1995	294.89	0.18	132.53	0.25
Kenya	1996	1 042.70	171.04	184.91	7.69

Source: UNCTAD

TABLE 18
Historic and projected supply utilization of commodities ('000 ton)

		EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Demand	historic	9 542	25 591	61 296	**96 429**
	2010	17 222	41 361	119 047	**177 630**
Production	historic	8 632	16 511	60 486	**85 629**
	2010	14 718	28 503	116 074	**159 294**
Trade	historic	-738	-8 736	-544	**-10 017**
	2010	-2 504	-12 858	-2 973	**-18 336**
SSR(1)	historic	0.90	0.65	0.99	**0.89**
	2010	0.85	0.69	0.98	**0.90**

Notes: (1) SSR = self-sufficiency ratio = production/demand
Source: Alexandratos, 1995.

Table 18 (and Annex Table A9) compares demand (which includes waste and uses such as animal feed) with national production and imports, to provide a self-sufficiency ratio (SSR) for the Nile economies and sub-basins. From the table, it can be observed that, firstly, almost 10% of demand is imported. Secondly, SSRs for the Nile Basin overall imply production will closely follow demand. Sub-basin self-sufficiency will vary, however, from 0.65 to 0.98. Areas that are self-sufficient could engage in trade with deficient areas.

Continued use of imports, basin-wide, to close the gap between domestic demand and production assumes that commodities are available and can be financed in international markets. Projected imports for 2010 estimate that, of a total 18.3 million t of commodities, approximately 18.1 million t of cereals – costing $US 2 700 million – and 350 000 t of meat – costing $US 900 million – would be required (Alexandratos, 1995). Such high levels of dependence upon external sources implies regional vulnerability, and illustrates the need to improve the Nile Basin's internal food supply.

Policies to expand intra-basin trade may be risky since trade barriers for agricultural commodities persist in the region, despite trading blocs such as COMESA. Where trading blocs are in place, they promote trade through low or preferential tariffs, investments and payments between the signatories. Yet, as Table 19 indicates, agricultural export earnings have been in steady decline over the past three decades in the Nile economies, as elsewhere in Africa (UNCED, 1992). The main cause has been a fall in international agricultural prices, which in turn is the result of global overproduction, export subsidies, and the industrialized countries dumping their agricultural surplus on the market.

TABLE 19
Annual percentage change in agricultural exports

	1975-80	1980-85	1986-92
Burundi	13.2	9.5	-15.9
DR Congo	0.3	2.8	-19.3
Ethiopia	13.7	-2.9	-11.2
Kenya	15.2	1.7	-4.6
Rwanda	10.3	1.6	-11.4
Sudan	4.2	-4.1	13.4
Tanzania	4.2	-10.0	-3.1
Uganda	4.8	5.1	-18.8

Source: UNCED, 1992.

Chapter 4
Agricultural water use and conservation

.

The management of water for agricultural use involves an array of economic (Keith, 1998: Winpenny, 1997) and environmental considerations over the allocation of raw water and the disposal of return flows. Agricultural water use is consumptive to the extent that it induces evaportative losses over and above the previous use in the same landscape or degrades water quality to the extent that it is rendered unusable by others. These considerations are most apparent in irrigated agriculture, but also to rainfed agriculture which may also significantly impact downstream water availability[1]. The relative 'efficiences' of agricultural water use are often cited as reasons for promoting conservation and the matrix in Figure 3 illustrates the various categories of agricultural water and their use in the Nile Basin in the crop (irrigated and rainfed), livestock, fisheries and forestry sub-sectors. Clearly if the overall economic efficiency of agriculutre is low, alternative use of resources (natural and human) may be considered so long as the agricultural production can be substituted (by importing food, for instances) and the freed resources put to more effective use. This 'macro' approach to food production begs many questions about the structure and function of agricultural systems, particularly in poor countries with high rural populations and limited scope to assure alternative sources of agricultural produce and alternative employment (FAO, 2000). Some of these questions that apply to agricutural water use in the Nile basin are discussed in this Section.

Agricultural water use

The broad definition given to "agricultural water use" is inclusive of all uses related to the agricultural sector, from labour force to crop production to food processing to the disposal of drainage and effluent water.

Most of the water is consumed as evapotranspiration in rainfed cropped and forested areas. The major share of the abstracted consumptive uses is for irrigated cropping, together with limited rural and livestock water supplies. Agricultural and environmental in-stream water uses, such as fisheries, which depend on maintenance of water surface area – with associated water evaporation losses – are indirectly consumptive. Crop production utilizes rainfall either directly or through abstraction of water from surface and groundwater bodies. In contrast, fisheries and biodiversity maintenance both rely upon the continual maintenance of seepage zones and wetlands and surface water bodies, including dams while evaporation from the surface of artificially impouned water bodies represents a consumptive loss. However, irrigation uses require a secure supply of water that meets appropriate quality criteria, but that is on demand and 'just-in-time' and it is this requirement that continues to determine the bulk of infrastructure investment in surface and groundwater development for agriculture.

1 For example, measures to conserve soil and water in the upper catchments in Eritrea have been so successful that reservoirs downstream in the catchments do not fill.

FIGURE 3
Matrix of the various water uses and impacts in the Nile Basin

Agricultural sub-sector	ABSTRACTIONS FROM RIVERS AND GROUNDWATER USE	RAINWATER AND SOIL MOISTURE USE	IN-STREAM USE AND IMPACTS	VIRTUAL WATER TRADE, CHANGES IN STOCK, ENVIRONMENTAL DEGRADATION
IRRI-GATION	12% of cultivated area in Nile Basin	supplementary irrigation/-water harvesting; non-rival uses	non-point source river pollution	food trade; food aid
RAINFED CROPS	supplementary irrigation/water harvesting; rural water supplies	88% of cultivated basin area; cash export crop production	non-point source river pollution	food trade; food aid; land degradation
LIVESTOCK	livestock watering supplies; production based on irrigated fodder	range; grazing land management	grazing of seasonally flooded lowland	reduction and expansion in stock; food trade; food aid; land degradation
FISHERIES	pond aquaculture	n/a	capture fisheries; farming in natural waterbodies	food trade; food aid
FORESTRY	forest irrigation is limited within basin	annual consumptive use (500-1500 mm) reduced runoff, improved low-inflows	impact on sedimentation and floods	reduction in stock, export/import of timber and fuelwood

Land use

Current cultivation in the Nile Basin extends to 72 million ha, which is reduced to 58 million ha when adjusted for production potential (Alexandratos, 1995). The availability of land per caput varies considerably throughout the Basin, from high (1.6- 2.2[1] ha per caput), through to adequate (0.2-0.4 ha per caput) and limited (>0.1 ha per caput) down to zero or even negative[2]. Overall it is thought that five times the land area currently being cropped could be cultivated. However, this estimate includes areas of drylands and marginal land with high desertification risk, and which would not sustain repeated cropping.[3]

Land degradation and soil constraints vary across the Basin. In the Eastern and Southern Nile sub-basins, erosion, caused by overgrazing and crop production, is coupled with shallow soils and low fertility. In the Lower Nile sub-basin, chemical degradation through salinization is coupled with shallow soils. For optimal use of available resources, an accurate assessment of

1 The high land availability figure of 2.2 ha/caput applies to DRC, which lies 99% outside of the Nile basin.

2 Land potentials are already exceeded, with use of marginal and environmentally vulnerable land categories.

3 Classification of drylands is based upon the length of the rainfed growing period. Thus, the hyper-arid zone has zero days in the growing period; the dry semi-arid zone has 60-119 days; and the moist semi-arid zone has 120-178 days. Desertification risk is measured by the portion of the agriculturally productive land located in drylands. In the upstream humid regions, in the south of the basin, the growing period extends beyond 270 days, and two rainfed crops are possible. Downstream, the growing period diminishes and with it the reliability of cropping. Thus, the period lasts less than 60 days in the semi-arid zone and zero days in the arid zone.

TABLE 20
Historic and potential irrigation in the Nile Basin

		Eastern Nile	Lower Nile	Southern Nile	Nile Basin
Historic					
Area	(ha)	38 284	5 013 200	27 120	**5 078 604**
Need	(m^3/ha)	9 000	13 000	10 000	**––**
GIWR(1)	(km^3)	0.4	67.1	0.3	**67.7**
Potential					
Area	(ha)	2 370 000	7 170 000	652 000	**10 192 000**
Need	(m^3/ha)	9 000	13 000	10 000	**––**
GIWR(1)	(km^3)	21.6	96.0	6.5	**124.1**

Notes: (1) GIWR = gross irrigation water requirement
Source: FAO, 1997b.

TABLE 21
Overview of water use for irrigation in the Nile Basin

	Irrigated area(1) (ha)		Water used for irrigation per country(2) (10^6 m^3)	Water used for irrigation in the Nile basin(3) ($10^6 m^3$)	Total land suitable for irrigation within the Nile Basin(4) (ha)
	Country	In Nile-basin			
Burundi	14 400	50	64	0.2	80 000
D R Congo	10 500	80	83	0.6	10 000
Eritrea	28 124	5 800	?	?	150 000
Ethiopia	160 785	32 100	?	?	2 220 000
Eritrea + Ethiopia	188 909	37 900	1 892	3 808	4 570 000
Egypt	3 245 700	2 923 200	47 400	42 690	4 420 000
Kenya	66 600	9 800	1 570	230	180 000
Rwanda	4 000	3 300	720	594	150 000
Sudan	1 946 200	1 930 300	16 800	16 663	2 750 000
Tanzania	150 000	14 100	1 040	98	30 000
Uganda	9 100	9 100	120	120	202 000

Note:: Due to the recent independence of Eritrea, no distinction can be made between water use for irrigation in Ethiopia and in Eritrea.
Sources: (1) FAO Land and Water Information System. (2): AQUASTAT. (3) Calculated (Irrigated area in the Nile basin / Irrigated area per country) * water used per country for irrigation. (4) FAO, 1997b.

irrigation potentials is necessary. Currently, however, assessments are based upon aggregated country data, which leads to discrepancies. Harmonized data on the Basin's water resources is believed to be essential for a data-supported dialogue on agricultural development.

Tables 20 and 21 (and Annex Table A10) details current and potential irrigation water uses in the Nile Basin, based on data in the FAO AQUASTAT database. The data indicates that the Lower Nile sub-basin dominates irrigation, with 99% of the use, as estimated by individual countries in 1997, though this is forecast to drop to 91% by 2010. Mobilising the full irrigation potential of the Nile Basin is estimated to exceed water availability. An option of increasing production within the limits of water available is proposed in the Section *Supplementary irrigation*. Table 20 is derived from a GIS-based database currently being complied by FAO, covering water resources and their use in the major river basins of Africa. Such information is expected to be useful in planning future water use.

Crops

Different crop types (food and fibre) are produced in the various agro-climatic conditions of the Nile Basin, with cereal production dominating overall cultivated area (see Table 7). Table 22 details actual and projected cultivated area in the Nile Basin. It can be seen that: (a) non-irrigated cultivation is 10 times the irrigated cultivated area and is expected to remain so in 2010; (b) non-irrigated areas are expected to increase by 11 million ha, whereas irrigated areas are expected to increase by 2 million ha; and (c) projected increases in cultivated areas are high for the Southern Nile sub-basin.

The cropping intensities for the Nile Basin's total cultivated area, including irrigated areas, provide indications of actual and potential levels of intensification, pressure on rainfed agricultural land, and utilization efficiency of existing irrigation investments (see Table 23). The data indicate high cropping intensities for irrigated cultivation in the Lower Nile sub-basin, with lower cropping intensities in the semi-arid rainfed regions.

TABLE 22
Historic and projected irrigated and non-irrigated land in the Nile Basin ('000 ha)

	Eastern Nile	Lower Nile	Southern Nile	Nile Basin
		Historic – 1989		
Non-irrigated	15 246	13 058	38 686	**66 690**
Irrigated	162	4 480	298	**4 940**
Irrigated cultivated(1)	165	5 013	276	**5 454**
		Projected – 2010		
Non-irrigated	16 604	14 218	47 575	**78 397**
Irrigated	280	5 448	423	**6 151**
Irrigated cultivated(1)	289	6 699	503	**7 491**

Note: (1) "Irrigated cultivated" refers to the calculated area (irrigation area × cropping intensity)
Source: FAO-AGLW, 1999

TABLE 23
Historic and projected cropping intensities in the Nile Basin

	1989		**2010**	
	Irrigated	**Total**	**Irrigated**	**Total**
Ethiopia	1.0	0.5	1.0	0.6
Egypt	1.5	1.5	1.7	1.7
Sudan	0.6	0.5	0.7	0.6
Burundi	0.9	0.9	1.0	1.2
DR Congo	1.4	0.4	1.4	0.5
Kenya	1.0	0.7	1.2	0.8
Rwanda	0.8	1.3	1.4	1.5
Tanzania	0.9	0.6	1.2	0.7
Uganda	1.3	0.9	1.4	0.9
Nile Basin	1.3	0.7	1.4	0.8

Source: FAO data

Increased cropping intensities in irrigated areas are expected to lead to corresponding increases in irrigation water use. The actual cropping intensity and utilization of existing irrigation infrastructure is low in the semi-arid southern parts of the Lower Nile sub-basin. Improved utilization, from a cropping intensity of 0.6 to one of 1.6, represents a cost-efficient means of improving agricultural production with limited investment and within a short period. Improved efficiencies would also answer an urgent need for improved food security. This would, however, lead to an increase in actual irrigation water use, of approximately 12 km^3 per year, primarily as a result of enhanced cropping intensity in the Sudan. The total cropping intensities in the higher rainfall areas of the Southern Nile sub-basin are already high, especially in areas with high population pressures and a shortage of arable land.

Projected cropping intensities indicate even higher cropping intensities in irrigated agriculture in the Lower Nile sub-basin, reaching practical and theoretical limits. The cropping intensities in the semi-arid rainfed regions are also expected to increase, possibly through rainfall harvesting and supplementary irrigation (FAO, 1991). In some areas in the Southern Nile sub-basin, cropping intensities are expected to increase to high levels for rainfed cultivation.

Fisheries

Inland fisheries resources and production potentials are proportional to the surface area of lakes and streams, and categorized as a non-consumptive in-stream water use. In-stream water uses that maintain flooded lands and water bodies are also generally non-exclusive (see Section *Water equivalents of food*). Estimates of wetlands' and lakes' consumptive use, such as evaporation, are only relevant when compared with other competing uses for water. Coastal lakes and fish ponds in the Nile Delta yield 1.0-1.8 t/ha/yr, with a consumptive use of about 13 000 m^3/ha/yr. Priced as a mean of import and export prices, the harvest is valued at $US 1.0/kg of fish, indicating a high water value-in-use of $US 0.08-0.14/$m^3$ of water (FAO, 1997a)[1].

Rural water use

The estimates of water consumption by the rural population in 1989 and projected for 2010 is given in Table 24 and expected to increase from 5.8 km^3 to 9.1 km^3. Average per caput consumption is estimated as 36.5 m^3 per year or 100 litres per day.

TABLE 24
Historic and projected rural water supplies in the Nile Basin

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
		1989		
Rural population ($\times10^6$)	36	36	88	**160**
Demand (km^3/yr)	1.3	1.3	3.2	**5.8**
		2010		
Rural population ($\times10^6$)	55	40	154	**249**
Demand (km^3/yr)	2.0	1.5	5.6	**9.1**

Source: FAO-AGLW, 1999

Livestock

About 250 million units of cattle, goats and sheep are estimated to exist within the Nile Basin, with large and small ruminants roughly equal in number. Cattle are estimated to consume 18.7 m^3 of water per head per year (50 litres per day), and small ruminants consuming approximately

[1] With an annual catch of about 500 000 t/yr, valued at some $US 250 million, an annual evaporation loss of about 100 km^3 in Lake Victoria, the consequent value of water-in-use for fisheries is of the order of $US 0.003/$m^3$.

20% of this (10 l/day; 3.7 m^3/yr). Livestock water supply is estimated to require 3.04 km^3/yr (see Table 25). This of course represents only a fraction of livestock production's total equivalent water consumption in systems based on irrigated fodder.

Meat consumption is expected to increase by 2010 (see Table 6). If all this meat is produced from the larger ruminants feeding off irrigated fodder, this could strain water availability in the Basin. Water savings can be made by increasing the production and consumption of poultry at the expense, in part, of cattle and other ruminants. Increased poultry availability may also aid food security. Table 26 (and Annex Table A11) outlines the water savings to be made (the water difference) if meat consumption in the Nile Basin shifted by 10% from beef to poultry. Calculations are based upon estimates of water use requirements of 10 000 m^3 per ton of beef and 3 000 m^3 per ton of poultry.

TABLE 25
Livestock water demands in the Nile Basin

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Cattle population ($\times 10^6$)	31	26	58	**116**
Water demand (km^3)				
cattle	0.68	0.57	1.27	**2.53**
small ruminants(1)	0.14	0.12	0.25	**0.51**
Total water demand (km^3)	0.82	0.51	1.53	**3.04**

Notes: (1) at 20% of cattle demand.
Source: Alexandratos, 1995

TABLE 26
Water savings from a 10% shift in meat consumption

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Total meat consumption ('000 ton)				
current	455	1 273	928	**2 656**
2010	782	2 514	2 040	**5 336**
Water equivalents (km^3)				
100% beef				
current	4.6	12.7	9.3	**26.6**
2010	7.8	25.1	20.4	**53.4**
90% beef + 10% poultry				
current	4.1	11.5	8.4	**24.0**
2010	7.0	22.6	18.4	**48.0**
Water difference (km^3)				
Current	0.5	1.3	0.9	**2.7**
2010	0.8	2.5	2.0	**5.3**

Source: Alexandratos, 1995

Forestry

The incremental water use of forest plantations (see Section *Post-harvest management*, Chapter 3) compared to grassland or savannah forest areas, especially in semi-arid regions, is sometimes recognized as a consumptive use (see Section *Water cost and values*). Forest production, and maintenance, can consume considerable amounts of water. The reported plantation area of the Eastern and Lower Nile sub-basins is 560 000 ha. A conservative estimate of the plantation's net effect on river runoff, when utilizing 500 mm/yr of rainfall (5 000 m^3/ha), is a modest 2 to 3 km^3 annually. Some of this water use falls outside the Nile basin. The example in Section 4.3 indicates a low water-in-use value of \$US 0.01/m^3.

Using basin-specific data, consumptive use estimates for maintaining a large fuelwood area in the basin, including net fuelwood exports, are substantial. However, estimates of the net water values-in-use for fuelwood production, including social values and negative environmental externalities, are not available. Forest and water for fuelwood production represent an example of a “combination” resource. The rapid reduction of forests in the upper catchments of the Eastern and Southern Nile sub-basins represents a mining of resources with high water equivalents.

Water equivalents of food

A commodity’s consumptive use of water per ton of product, whether provided by rainfall or irrigation can be estimated and expressed as a water equivalent. If this water equivalent is derived for imported food commodities, for instance (FAO, 1997c), the flow of water in and out of the Basin through agricultural imports and exports can be estimated.

Table 27 (and Annex Table A12) provides estimates of historic (1989) and projected (2010) water equivalents for food production and demand. The estimates are based on the accepted average virtual water equivalents of different commodities (1 000 m^3/t for cereals; 500 m^3/t for roots and tubers; and 10 000 m^3/t for meat). The data, based on FAO crop production country data, provide a basis for a broader discussion of agricultural water use as a combination of flow and stock resources. If focus continues on expanding production through improved rainfall water management, then the figures presented indicate that both current and projected production represent but a small share of the total water resource. This water is believed to be linked to a rapid reduction of natural forest, which is compensated by plantations, and to exports of live animals and meat out of the basin.

Water cost and values

TABLE 27
Historic and projected water equivalents of food production and consumption (km^3/year)

	Eastern Nile	Lower Nile	Southern Nile	Nile Basin
		Production		
Historic	11.8	25.4	43.9	**81.0**
2010	20.3	44.1	87.0	**151.4**
		Consumption		
Historic	14.5	35.1	41.4	**90.9**
2010	21.6	47.6	76.2	**145.4**

Source: FAO-AGLW, 1998

There is a need for consistent cost and benefit data for irrigation investment costs and other water uses in the Nile Basin, as only limited data are currently available (FAO, 1997b). In the Lower Nile sub-basin, intensive irrigation provides a net farm revenue[1] of $US 600/ha and consumes on average 12 000 m^3/ha annually (World Bank, 1993b). This corresponds to a water value-in-use of $US 0.05/$m^3$. However, irrigation margins are expected to increase with more favourable fiscal policies. Not including the main system, capital investment in irrigation is

[1] Different crops yield different net farm revenues: short berseem - $US 232/ha; wheat - $US 531/ha; potato - $US 803/ha; sugar cane - $US 1 248/ha; and tomato - $US 1 676/ha (World Bank, 1993b).

$US 2 000 to 3 000/ha, and is recovered as irrigation water charges. The operating margin at the farm level is 10 to 15%.

Table 28 details the range of costs – from $US 1 000 to 25 000/ha – in the Basin. With the exception of Egypt, operating costs, especially pumping costs, dominate the total cost. Subsidized fuel is, in effect, a subsidy for water use, and can lead to a pricing distortion and non-sustainable patterns of water appropriation. There are discrepancies between projected and actual costs, where the latter are extremely high when compared to other sub-regions in Africa, such as South Africa. The high cost represents a major constraint to the development of large irrigation schemes. It does, however, represent a realistic condition that dictates that irrigation expansion in the Eastern and Southern Nile sub-basins will take place over a relatively longer time period. It is expected that this will allow for structural adjustments in the national and regional economies of the Nile Basin. Table 29 details an example of South African investment costs with ceilings for maximum achievable irrigation, which appears to be more realistic.

TABLE 28
Irrigation capital investment cost per unit ($US/ha)

	Micro/sprinkler	Small scale/pump	Large scale	Drainage/spate
Eritrea		750 - 4 000	16 000	2 000
Ethiopia		2 300 - 3 400	18 000 - 25 000	2 000
Egypt	1 600 - 3 200			
DR Congo			1 000 - 6 000	400
Kenya (project cost)		1 000	5 800	
Tanzania			10 000 - 15 000	6 000 - 15 000

Source: FAO, 1997b

TABLE 29
Irrigation investment cost and efficiency in the Republic of South Africa

Operator	Government	Irrigation Boards	Private schemes	Small farmers
Unit cost ($US/ha)	4 300	3 950	2 140	6 500
Notes	1994 average	1994 average	maximum subsidy	1-10 ha gardens
Irrigation technique	surface irrigation	sprinkler	micro-irrigation	
Cost ($US/ha)	100 - 1 400	500 - 2 000	1 300 - 2 800	
Application efficiency	55 - 65%	75 - 80%	85 - 95%	

Source: FAO, 1997b

Basin water balance

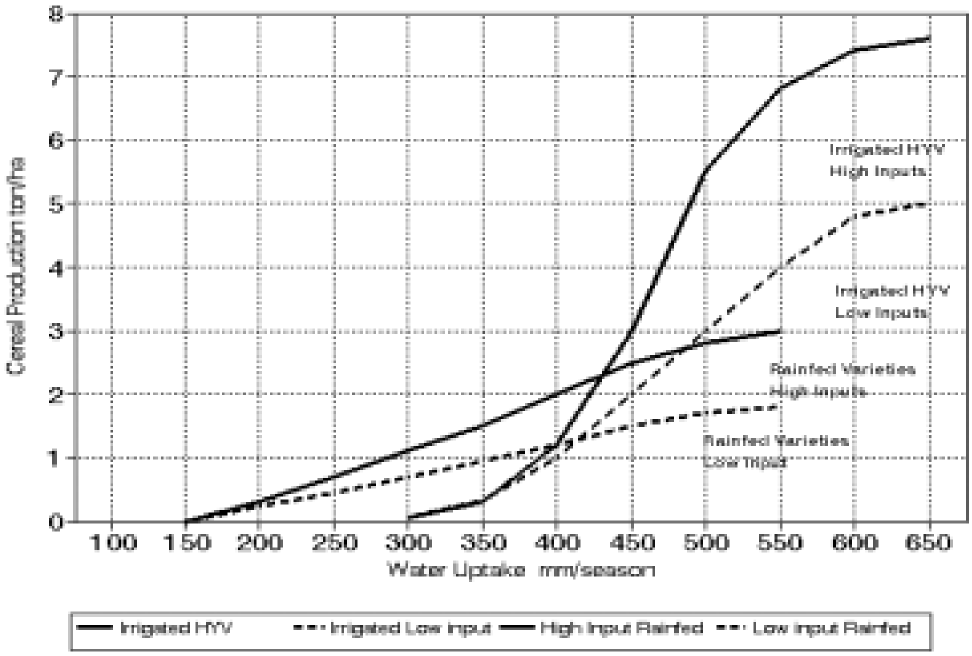
Water consumption figures are not known for the entire Nile basin, although it is estimated that irrigated areas as the highest net consumers. The total net water consumption is high in the Lower Nile sub-basin where irrigation is concentrated. For example, in Egypt, out of the annual releases from the Aswan, averaging 55.4 km^3, a total of 42.1 km^3 is consumed or lost in conveyance, with the balance, 13.3 km^3, flowing into the Mediterranean Sea. This corresponds to a consumption/conveyance loss rate of 76%. However, current water management initiatives aim to increase consumption to 99%. If successful, such efforts would reduce water flow to the Mediterranean Sea to 0.3 km^3 per annum. This will have significant impacts on the delata and linked marine environments, as the reduction in outflow to the sea will result in a reduced nutrient and sediment flow into the Mediterranean. There is a need to balance and establish trade-offs between economic and environmental costs and benefits. The overall environmental benefits of guaranteeing a minimum fresh water flow to the sea are such that it could well be regarded as an ecological obligation, both local and global. This should be reflected in allocation discussions.

Supplementary irrigation

Under rainfed agriculture, erratic rainfall forces farmers to prioritize risk reduction over increasing productivity. Lack of soil moisture control is a major cause of the low performance of rainfed subsistence farming in the Nile basin. In response to frequent stress periods, crop types and cropping systems are adapted to minimize risks and to maintain minimum but assured production levels, even under unreliable rainfall conditions. As a result, yields, water use efficiency and farmer income remain low, even during periods of favourable rainfall or ample water control and improved soil fertility.

A strategy to increase production based on secure water supply would encourage the introduction of high yielding varieties and consistent plant nutrition. However, this will only be successful if allied to assured availability of the necessary inputs, including credit. In this way, supplementary irrigation and water harvesting with improved soil management can intensify production and reduce risk in rainfed areas. Figure 4 shows that supplementary irrigation of 150-200 mm, together with improved agronomic inputs, could result in significantly higher average yields. These yields are comparable to those from full irrigation, which would require 500-600 mm, or 3 to 4 times more irrigation water, in areas with no rainfall.

FIGURE 5
Water use efficiency of irrigated and rainfed crops (Source: Smith, 1999)



Similar improvements could be achieved through higher flexibility with different cultivated areas during periods of high and low rainfall. Spate irrigation – which uses water harvesting principles – makes use of additional water when it is available to grow additional crops (FAO, 1991). When additional water is not available, production returns to the core area and core crops. This is expected to ensure a minimal supply of food, which can be supplemented with additional crops that can generate income.

The potential for agricultural expansion, whether irrigated or rainfed, has already been summarized in Table 20. Were the total potential area to be utilized, it is estimated that it would exceed total water availability in the Basin. An alternative option is outlined in Table 30, one that maintains the level of irrigation in the Lower Nile, but expands to meet the full potential of supplementary irrigation in the Eastern and Southern Nile sub-basins. Since the purpose is to supplement rainfall, supplementary irrigation uses less water per hectare than full irrigation of areas without rainfall. The amount of water needed for this option is within available limits. For example, supplementary irrigation in the Eastern Nile sub-basin would use, on average, between 3 000 and 6 000 m^3/ha. In the Southern Nile sub-basin, higher rainfall areas would use between 4 000 and 6 000 m^3/ha. It is recognized, however, that such an assessment is a technical, rather than a politico-socio-economic, measure of water use in Nilotic agriculture. Overall, vertical measures, such as rainfall harvesting, increased inputs and better agronomic practices, are thought to be the primary means of improving agricultural production, rather than horizontal expansion.

Projects under the World Bank's Special Country Programme aim to supply supplementary irrigation which can produce market surplus in normal rainfall years, and ensure at least subsistence

TABLE 30
Supplementary irrigation in the Nile Basin

	EASTERN NILE	LOWER NILE	SOUTHERN NILE	NILE BASIN
Area (ha)	2 370 000	5 013 200	652 000	**8 035 200**
Rate (m^3/ha)	5 000	12 000	4 000	––
GIWR[(1)]	11.9	60.1	2.6	**74.6**

Notes: (1) GIWR = gross irrigation water requirement (km^3/yr)
Source: FAO, 1997b

BOX 2: REGIONAL IRRIGATION INITIATIVE – COMESA

With recurrent droughts threatening agricultural production and food security in the region, COMESA (1998) has emphasized the need to reduce dependence on rainfed agriculture by expanding irrigation. Based on the observation that irrigated agriculture is underdeveloped in the region, the proposed action plan includes a framework with identified measures for regional cooperation on irrigation. Firstly, to mitigate the impact of drought. Secondly, to ensure the optimal regional use of shared water resources. Thirdly, to draw from economies of scale for irrigation research and training, for example, and standardization of inputs and irrigation equipment. Fourthly, to enhance intra-regional cooperation in skilled manpower, design and construction capacities through exchange of technical and management experience.

The importance of the regional dimension was emphasized. COMESA, under the Action Programme for a Unified Food Security Strategy, in cooperation with IGAD and SADC, will: (a) coordinate joint programmes and exchange of monitoring information; (b) promote and build regional capacity in irrigated agriculture; (c) facilitate the use of regional manpower resources; and (d) support, promote and catalyse the flow of investments and resources for irrigation development.

levels in drought years (World Bank, 1996). In the Eastern Nile sub-basin, small-scale irrigation schemes benefiting from small-scale dams are underway (UNDP *et al*., 1994). In the Ethiopian province of Tigray, after some initial problems building small dams, the SAER (Sustainable Agriculture and Environmental Rehabilitation) programme has found some success.

FAO is supporting feasibility studies for small dams only, under the South-South Cooperation Programme, using Indian and Chinese expertise (Fernando Chanduvi, FAO, *pers. comm.,* 1998). A World Bank programme targeted some 20 000-35 000 ha in the Ethiopian highlands that met the hydrological, economic, agricultural and technical criteria for small-scale irrigation. In 1994-95, the project was on target, with the irrigated land amounting to 2 000 ha (World Bank, 1996). Other sub-basin areas in the Nile would also benefit from small-scale supplementary irrigation.

In-stream water requirements

In-stream agricultural water requirements in the Nile Basin are closely related to fisheries resources and sustainability of wildlife and biodiversity. The requirements vary for lakes, river channels or wetlands freshwater life and use throughout the basin, and depend principally upon flow regimes and the consequent water quality and flow volumes. Of particular importance is the surface area of the linked water bodies whose biodiversity – measured by different types of species within a class – is rich (WCMC, 1998). Another distinctive aspect of freshwater bodies is that the water quality varies over short distances, according to catchment geology, land cover, climate and – increasingly – as a result of anthropogenic influence.

The greatest threat to aquatic biodiversity in the Nile Basin comes from environmental degradation, whether biological or chemical pollution, or stemming from land use issues, such as sedimentation (FAO, 1995d). An additional problem linked to biological pollution is the proliferation of aquatic weed. The weed clogs up waterways and increases evaporation losses from water bodies (e.g. Lake Kyoga) and impedes transportation by water. The intricate balance of the Nile Basin is also affected by the wetlands in the basin – of which the most significant is the Sudd. This vast wetland is subject to extensive seasonal and annual variation (FAO, 1995a). The seasonal floodplains (*toiches*) provide essential grazing pastures for nomadic groups, and nutrient-rich nursery grounds for many fish and bird species.

Upper catchment management and conservation

Long-term sustainability and mountain conservation

In the Nile Basin, the mountainous areas and wetlands have high 'non-use' environmental value. The economic service provided to humans by wetlands, lakes and rivers and coastal regions is estimated to be $US 15 000, $US 8 500 and $US 23 000/ha, respectively (UNEP, 1999). Denniston (1995) stated:

> "Reflecting only the present costs of extraction and distribution, today's prices for natural resources do not even come close to telling the ecological truth; they ignore the full cost of denuded forest, eroded hillsides or dammed or polluted rivers – not to mention the incalculable social costs of uprooting people living atop the resource."

In the Southern Nile sub-basin, some countries (Burundi, Democratic Republic of the Congo, Rwanda and Uganda) have large forested mountain areas with important wildlife, and related

Box 3: Mountain conservation in the Southern Nile sub-basin

In the Akagera Hunting Preserve of Rwanda, hunting and trophy fees represent an important income to the local people. The local population also have a right to the meat of the hunted animals. In Rwanda and in Democratic Republic of the Congo, even during periods of civil strife when the unique montane areas were threatened, the significance of the mountain gorilla population was highlighted. The $US 200 per day fee to visit the gorillas were a major contribution to the preservation of the region and its wildlife by supporting staffing facilities and salaries.

The Bwindi Impenetrable National Park and the Mgahinga Gorilla National Park in Uganda represent some of the last remaining montane ecosystems in Africa. The forested mountains, which serve as critical water catchments, and contain most of the world's gorilla population, are amongst Africa's most densely populated areas. A trust has been set up, owned jointly by the Government, local and international NGOs, and the local community. GEF provided $US 4 million capital to generate income for the trust, to be used to manage the park, conduct research, and support the local communities' economic activities.

tourism, resources (see Box 3). These areas are coming under increasing pressure from agriculture, threatening sustainable environmental services and potential income generation.

Mountain degradation affects downstream water resources. Conservation of the mountainous areas is a priority within the Nile basin cooperation effort, and to preserve biodiversity (UNCED, 1992; FAO-Mountain Institute, 1997). Success of conservation efforts will depend upon the involvement of the upland populations. These populations are amongst the poorest in the region, and have not benefited from economic activities downstream. To redress this inequity and engage the populations in conservation efforts, more effective institutional mechanisms are required. These include: well-defined property rights (to provide incentives to local mountain communities for sound resource management); tax and fee collection to assign the resources' full value and cover the cost of their sustainable use (such as Rwanda's Gorilla Viewing and Hunting Fees); and appropriately channelling of external financial support (such as Uganda's Forest Conservation Trust).

Forestry, water and land conservation

Forests in the upland areas play an important role in erosion control and water resource enhancement. Visible and quantitative socio-economic benefits, such as reduced reservoir siltation and extended dry-season river flows, are mainly confined to the local sub-basin. Only forest cover of an appropriate quality (good lower canopy and ground litter) is beneficial for conservation of the uplands. As more land is being cultivated, alternative means of erosion control are being found, such as terracing. These measures involve the upland communities directly. Water conservation in the upland catchments is affected by forests, which even out river flows, reduce flood flows, and enhance dry-season flows. However, evapotranspiration from afforested areas is high, and can be considered in some instances a consumptive water use, reducing river runoff, as demonstrated by the Komati River Basin (see Box 4).

Sustainable use of existing forest is the economic base for communities that depend on fuelwood and other non-wood products. As already mentioned, fuelwood and construction materials for local use are on an average produced sustainably. The balance that is not sustainably produced may contribute to local environmental degradation. In such cases, although high water consumers, forest plantations for local use may be required. Highland-lowland links are important. The uplands supply the majority of the basin's water resources. However, degradation and

Box 4: Water demand and values of afforestation in Southern Africa

The 1992 Komati River Basin Treaty, between Swaziland and South Africa, not only allocates water but also assigns consumptive water use value to afforested areas. The Treaty delimits the maximum area for future afforestation within the basin vis-à-vis a reduction in mean annual runoff. According to the Treaty, Swaziland can afforest a total of 90 000 ha using 33 km^3. The basin has a semi-arid climate with natural grassland, where afforestation has evapotranspiration costs. Under this Treaty, evapotranspiration by forested areas is translated into additional consumptive water use. It is estimated that the mean annual runoff is reduced by 1100-1300 mm/ha. In addition, this reduction comprises 45-65% (500-850 mm) of high assurance demands, which compete for scarce dry season flows (FAO-TCP, 1998).

The trees being grown (Eucalyptus, Pine, Gum and Wattle) yield 12-20 m^3 for timber uses such as pit props, which are mainly exported. Timber exports are regarded as exporting virtual water. The average water demand for forestry annually is 1000 m^3/m^3, but 500 m^3/m^3 in terms of dry season flow. The gross margin for timber is only $US 100 /ha, with an additional $US 200 from pulp processing. The corresponding gross margin water values for annual and low flow supplies (in US cents) are ¢ 0.8/m^3 for timbering, and ¢ 22.5/m^3 for timbering and processing. These values correspond to water values for low intensity rather than intensive irrigated agricultural water use.

deforestation in the upper catchment – often a result of rural poverty, population pressure and inappropriate practices in subsistence agriculture – result in loss of water resources locally and increased sedimentation and floods (see Box 5). The impact of natural or anthropogenic activity upon the Nile Basin's environment and irrigation systems is not fully known.

Geographic scale is important in seeing the impact of human activities on the environment. While large-scale natural disasters are easily visible, anthropogenic changes are only visible, in

Box 5: Soil erosion and conservation in the Nile Basin

Forest coverage is low in the Eastern Nile sub-basin: 30% in Akobo and Baro, 10% in Abeya, and only 5% in Atbarah. There is rampant upstream degradation in these two sub-basins. The Amhara plateau is recognized as "one of the most erosion prone areas on earth" with forest cover comprising less than 2.7%. Further depletion is proceeding at a rate of 100 000 to 200 000 ha/yr, with annual sediment loss as high as 200 t/ha. The average sediment loss for cropland is 40 t/ha. Annually, serious erosion is affecting 16 000 000 ha of cropland, 62 300 000 ha of grazing land, and 5 000 000 ha of already degraded badland. The average annual reduction in soil productivity is 1-2%, with locally observed losses, especially in western Ethiopia, of up to 10%. In contrast, sediment yields from conserved upland areas can be as low as 1 to 3 t/ha.

The economic value of nutrient losses from soil erosion remain substantial, with estimates as high as $US 500 million due to soil erosion and $US 1 200 million due to nutrition losses as a result of biomass removal. Historically high sediment loads in the Nile tributaries have accelerated recently. There is some evidence that the Atbara River's average sediment load increased from 5 mg/l in 1969 to 6.5 mg/l in 1972, and to 8.0 mg/l in 1993. This may be linked to increasing population pressures. Agriculture in the Lower Nile sub-basin no longer depends upon sediment supply.

The impact of sedimentation on the reservoirs of the Nile Basin is the primary concern now. Of particular long-term concern is the extent to which extensive sedimentation would, in conjunction with a large flood event, affect the river bed and potentially divert river flow. Such an event would render even the largest reservoir useless. The Atbara and the Blue Nile, which together represent 80% of total Nile discharge, carry over 90% of the sediment load. As a result, there is significant sedimentation in the Lower Nile sub-basin, which also affects land productivity and constrains water resources development. In 1998, the second largest recorded flood on the Atbara, discharging over 2 000 m^3/s of water, resulted in larger than average sediment flow towards the High Dam at Aswan (SNCID, 1998).

the short term, at the local level. To see human-activity-induced changes at the larger scales would require larger time scales. Similarly, though forest cover in the highlands of the Nile Basin might reduce flood risks, and augment dry season flows locally, there would be limited effects farther downstream. Single, large-scale natural events, such as floods or high rainfall, occur independent of forest cover and are usually underestimated. The effect, therefore, upon river sedimentation cannot be predicted. Highland-lowland issues remain significant, particularly, for large irrigation and hydropower reservoirs located in the mountain-to-plain transition areas.

Environmental threats to production

Agricultural and industrial chemical use

Agricultural and industrial chemical use is limited overall in the Nile Basin, except for fertilizer use in the Lower Nile sub-basin, as shown in Table 8. Egyptian irrigation water re-use raises some issues regarding contamination through a concentration of these chemicals. Return flows are 4.7 km^3 in the Nile Valley and 12.4 km^3 in the Delta. In 1995, re-use in the Delta was officially 4.27 $km^{3,}$ and is expected to increase to 7 km^3 by 2000. Total re-use includes an additional 3-4 km^3 of informal water re-use. With rapid urbanization, industrial development and increasing wastewater discharges, the drainage water has become contaminated with toxic chemicals and pathogens.

Drainage water monitoring at summer (rice) and winter (berseem) irrigation sites showed:

- pathogens in both the water and the crops during the summer;
- traces of heavy metals (Cu, Pb, Fe, Zn and Cd) during the summer; and
- evidence of herbicides (Altrazine) in the groundwater, with residues in the upper soils.

The monitoring underlined the need to review water re-use policy and address issues of domestic and industrial pollution impacts on human health, ecological effects and the need for appropriate mitigation measures (Abdel-Gawad, 1998).

Residents near Lake Manzala have a life expectancy drastically below the national average, and fish catches have declined 90% over a decade; mercury levels in fish in Lake Maryut exceeded the WHO limits 1000 times. Removing harmful affects upon humans from agricultural practices does not have to be at the cost of profit. Recent studies have shown that switching to ‘clean’ agriculture, including bio-fertilization, is practical not only because it would address the pollution issues but also because it would lead to increased economic benefits (Khouzam, 1996).

Water weed

Water hyacinth (*Eichhornia crassipes*) is a spreading problem. Concentrated in Lake Victoria, but existing in both the Southern and Lower Nile sub-basins, water hyacinth is a problem that threatens biodiversity and the economies of the sub-region. Rapid encroachment of water weed is causing major operational constraints throughout the Nile Basin, threatening fisheries, freshwater life and the irrigation systems of the Lower Nile.

The socio-economic aspects of the water hyacinth invasion are substantial, as demonstrated clearly in the Lake Victoria region, where nearly 90% of the shoreline is already infested, with the weed spreading to open waters (FAO, 1996a). Water hyacinth degrades water quality, impedes fishing and navigation, blocks water intakes and reduces the flow of water in irrigation channels. It also increases water loss through evapotranspiration, chokes communities of indigenous plant and animal life, and acts as a habitat for vectors of diseases such as malaria and bilharzia.

In Lake Victoria, and Lake Kyoga in Uganda, water hyacinth affects the activities of fishermen and transporters of goods. When fish landing places are severely infested, boats have sometimes to be hauled to the shore across mats of weed. In the Owen Falls Hydroelectric station, power generation is often interrupted by lumps of water hyacinth mat blocking the intakes, and machinery has been damaged. The problem posed by water hyacinth can only be solved in the long-term, and for this there is a need to develop a sustainable programme consisting of site-specific integrated control measures applied according to the prevailing level of infestation. Integrated control should rely on a combination of biological, chemical and physical control methods. In this context, regulatory measures backed up by effective monitoring should be essential components of the foreseen programme.

Salinization and waterlogging

There is little salinity data available for sections upstream of Aswan, but estimates are given in Table 31. As can be seen from that table, the Nile becomes more saline as it flows towards the Mediterranean Sea. The biggest jump happens between Cairo and the Delta. This is attributed to irrigation water re-use. The Nile Valley and Delta are, in general, well drained through an extensive system of open drains. This system has recently been improved, with the installation of pipe draining serving approximately 1.8 million ha. With the extensive re-use of water, control of salinity and other pollutants is becoming increasingly important.

TABLE 31
Salinity along the Nile and its main tributaries (mg/l)

SITE	WHITE NILE	BLUE NILE	MAIN NILE
Lake Victoria	50		
Lake Kyoga	60		
Lake Albert	400		
Before the Sudd	100		
Khartoum	200-250	150	av. 150-175
Aswan outflow			175-200
Cairo outflow			350
Outflow to the sea			1000

Source: Smedena, 1999.

There is a difference in annual net salt inflow to the Nile Valley (2 200 kg/ha/yr) and to the Delta (10 800 kg/ha/yr) (see Table 32). This is due to a combination of factors: agro-chemical residues and other pollutants, fossil marine salts, saline seepage and influx from recently developed desert areas upstream of the Delta. The Mediterranean Sea annually

TABLE 32
Annual salt balance in the Nile Valley and Delta (million ton)

	IN	OUT	BALANCE
Valley	10.9	13.3	-2.4
Delta	12.6	34.1	-21.5
Total area	10.9	34.1	-23.2

Source: Smedena, 1999.

receives 13.3 km^3 of water from the Nile, made up of 2.1 km^3 from the Nile river branches and 11.2 km^3 from the pumped and gravity drainage outfalls. However, while consideration of minimum flows for ecological requirements to maintain or re-establish the coastal water systems is beyond the remit of this paper, some discharge to the sea is generally considered to be essential.

The total drainage volume in the Nile Valley and Delta could be reduced further through even more irrigation re-use and by limiting over-drainage, especially of rice fields. Re-using water may prove to be a cost-effective means of increasing supply without requiring additional withdrawals from Aswan. However, as mentioned already, some outflow to the Mediterranean Sea is essential. Though there are environmental considerations, there are also other issues, such as maintaining the salt balance in the Valley and the Delta, controlling water quality, and providing a minimum waterway draught for navigation.

Chapter 5
Scenarios for progress

OVERVIEW OF OPTIONS

With increasing water scarcity becoming an overall critical issue in the Nile Basin, a series of opportunities for water savings have been identified, either directly in terms of efficient agricultural water use[1], or through changes in cropping patterns and alternative economic activities. The report identifies and assesses transboundary options for water saving, considering both benefits and costs, to establish viable tradeoffs for win-win solutions. Within the frame of total water balance, the options aim for an overall equilibrium between agricultural production and demand.

The scenarios presented here identify and combine a number of readily implementable options for additional water gains and benefits from joint measures in the basin- and sub-basins. Substantial water savings together with overall efficient utilization can only happen as the result of transboundary, river basin cooperation. The potential for substantial transboundary water savings and efficient agricultural use in the basin are discussed. In many cases these contrast to national- and scheme-level proposals for water savings and use efficiency measures that are narrow, often costly, conflicting and not sustainable.

In the long term, it is concluded that substantial water savings coupled with sustainable, overall efficient utilization of the scarce Nile water resources can only be achieved at joint basin and sub-basin level.

Water scarcity is essentially the result of demographic growth and environmental degradation of the water resource base. Addressing water efficiency in the river basin needs to focus on two key elements:

- in the immediate term, aim to reduce losses due to evaporation or other sinks in sub-basins and river sections, which offers substantial water saving potential; and
- in the longer term, allocate water to specific uses, or to sub-basin areas with higher economic water use efficiency due to favourable climatic conditions or other comparative advantages. A critical parameter would be considerations of multi-purpose use benefits per unit of water. Real water savings could be achieved with improved technology, and result in increase in agricultural output per unit of water applied. The decrease of water and land used per unit produced would help to save on total area under irrigation in the basin. This is important as it has implications for the potential to save on scarce investment resources and maintain future flexibility of water resources utilization and development.

TWIN OBJECTIVES: WATER SAVING AND EFFICIENT USE

In the context of shrinking per caput availability of water, facilitating desirable welfare improvement is a double challenge, namely to:

[1] A strategic framework for improved water use for agriculture production forms the first priority under the socio-economic, environmental and sectoral analysis component of the Shared Vision Program, Nile Basin Initiative (TAC-NILE; Sodere, Ethiopia Workshop, May 1999).

- ➢ safeguard life-supporting ecosystems, for productivity and diversity ; and
- ➢ secure welfare while meeting development expectations.

Water resources management in the Nile basin must not only pay attention to direct demands for goods in society, but must also recognize that water in the basin as a whole is effectively non-substitutional. The consumptive use of raw water in irrigated agriculture and the role of instream flows in maintaining a set of linked ecosystems upon which socio-economic development depends are critical. This less obvious goal – good stewardship of the whole aquatic environment – need not be regarded as a simple trade-off between increased production and ecological concerns. Reserving certain fractions of natural water flows in streams and lakes to maintain intricate webs in the environmental fabric are as important for the overall development and stability of society as are more immediate decisions concerning how to share and use the water that is withdrawn from natural courses.

The usual first stage of adaptation – namely traditional engineering efforts attempting to "get more water" – is now recognized as shortsighted and insufficient. Water needs of ecosystems and the interests of stakeholders in downstream areas will make further large withdrawals of water a risky strategy. Later stages of adaptation to water scarcity can include, *improved end-use efficiency* through demand management measures (producing more with less water), and, to a degree, *improved allocative efficiency* (producing higher economic values from available water resources).

Re-allocation, i.e. releasing water from agriculture and replacing local agricultural production with imports, would carry considerable political cost. Imports of "virtual" water, through food imports, could have negative social and economic consequences, and might not be acceptable or even financially viable to the Nile basin economies in the light of widening trade deficits and food distribution constraints. There are also problems of income, employment, food and social security, which, to a large extent, depend on the considerable national subsistence farming sectors. Rapidly growing food import is commonly seen as a warning signal to national economies concerned at their heavy reliance on world markets, and perceived vulnerability to external pressures. The institutional prerequisites, such as stable and transferable water rights, however, are rarely in place to allow for re-allocation and related compensations. Hence the lack of appropriately structured water rights could, in some cases, limit future economic development and induce out-migration.

In the perspective of increased global food trade driven by the growing demands from developing countries, it is highly unlikely that the increased imports could be financed internally, especially in the sub-Saharan countries. In general, the Nile Basin economies do not have the economic capacity to restrain local agricultural production, and, with agriculture as the only base for transition into urban economies based on service and manufacturing sectors, as a general trend for development and structural change in the region, such change would carry high social and political costs. Such a significant change would require major institutional modifications to mitigate social impact and ensure that benefits are internalized and remain with or accrue to local populations. Possible means, appropriate for national-level implementation, include[1]:

- establishment of stable and transferable water rights;
- incremental and generalized transfer of water use, to encourage conservation rather than land abandonment;

[1] This section draws heavily on Rosegrant, M., & Ringler, C. 1998. Impact of re-allocating water from agriculture for other uses on food security and rural development. Paper presented at *Expert Group meeting on Strategic Approaches to Freshwater Management*. Harare, January 1998.

- re-investment in the rural communities of gains from higher-value uses elsewhere; and
- adequate compensation to sellers and affected third parties.

Positive externalities from water efficiency measures, in the form of benefits accruing to other users in the basin as a result of local measures, need to be reflected in fair cost sharing. While benefits to, and sharing of, costs for water resource enhancement by downstream economic users might be straightforward, this concept should also apply to traditional free-rider benefits, which also form part of integrated measures to save water and secure agricultural production, such as flood mitigation. Measures to improve water use efficiency have implications for internal and as well as external benefits and costs. The proposed scenarios aim at equitable social impact. Nevertheless, as impacts will not be the same for all, the costs and benefits should be distributed proportionally.

In a transboundary context, agriculture, as the main consumptive user, is critical to the conservation of land and water, and the key to saving and releasing water for actual and future potential and alternative demands in all sectors. The options to improve water use efficiency and save water include long-term, as well as immediate, measures. For the options and scenarios to be accepted and implemented, they need to be framed with clear and agreed objectives that are consistent at basin and sub-basin levels. The measures need to be critically adapted to social, institutional and economic limitations and realities at national level.

Basin-wide Objectives

Within the shared Nile Basin vision of *sustainable socio-economic development through equitable utilization of, and benefit from, the common Nile Basin water resources*, the following **basin-wide objectives** are proposed, either for or in support of water savings and water efficiency in agriculture:

- To enhance flows and stocks of water resources to ensure quantity, quality and reliability of water related services. The major options for water savings[3] in the five sub-basins selected for the present discussion - Upper Eastern Nile, Lake Victoria, White Nile, Main Nile and Lower Nile, with the main flow of saved water to downstream users and reciprocal flow of economic compensation, cost-sharing in different forms, including investment, increased trade etc., are indicated in Figure 5.

- To control environmental degradation, including water pollution, sedimentation and wetland degradation.

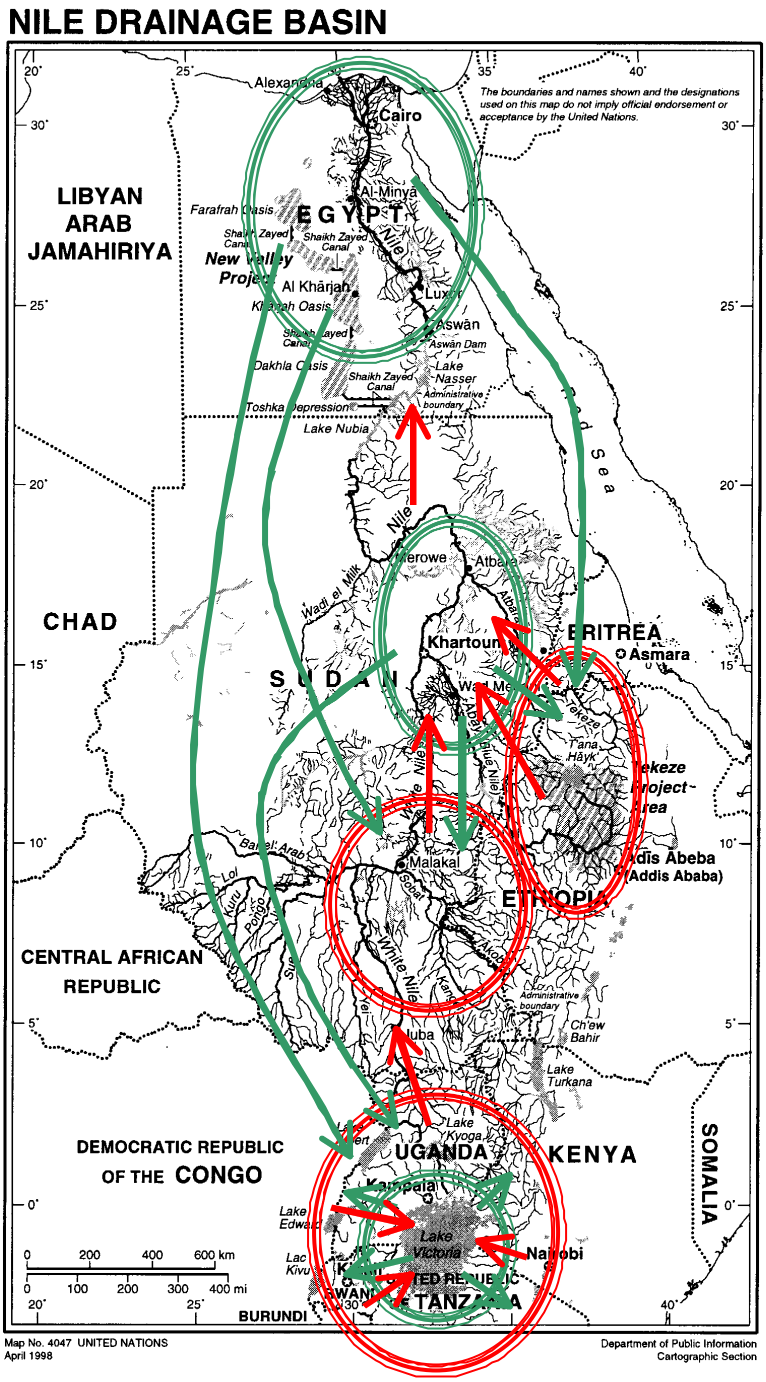
- To control and mitigate basin-wide impacts of natural disasters, especially flood and drought.

Based on information in Tables 1, 2, 10 and 20, Table 33 highlights differences in potential and actual development and the focus of agriculture in the sub-basins, relative to the climate,

---

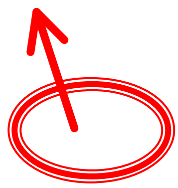
[3] Potential water savings are likely to represent significant portions of the total available water resources in each sub-basin, and therefore substantial and cost-efficient savings should be focused on the main contributors to the Nile flows, namely Baro-Akobo-Sobat, Blue Nile and – possibly at higher cost – Atbara. The total flow and the possible water savings in the While Nile are considered more limited and imply higher costs. Water savings in the main watercourses, which might require costly major projects, need to be balanced with limited measures in smaller tributaries and upper catchments, that would be more manageable and affordable for implementation at local level.

FIGURE 5
Areas for potential water saving through better management, and reciprocal flows of goods and finance

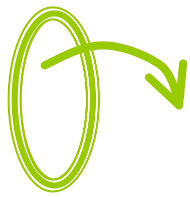


Map No. 4047 UNITED NATIONS
April 1998

Department of Public Information
Cartographic Section



Areas of water saving and flow of benefits to areas downstream



Areas benefiting from improved water supply, and reciprocal flow of goods and finance

TABLE 33
Sub-basin management areas: strategic indicators for agriculture, water use and water demand

FACTOR	EASTERN NILE	LAKE VICTORIA	WHITE NILE	MAIN NILE	LOWER NILE
Climate	humid & semi-arid	humid	humid & semi-arid	humid & semi-arid	semi-arid
Actual irrigation area (ha)	38 000	36 000	limited	1 930 000	2 923 000
Actual irrigation water demand (km^3)	0.5	0.9	limited	16.7	42.7
Potential irrigation area (ha)	4 570 000	660 000	limited	2 220 000	4 420 000
Potential irrigation water demand (km^3)	high	moderate - high	moderate	high	high
Actual inland fisheries	low	high	high	limited	high
Livestock population	high		high	high	

present and potential irrigated areas, estimates of present and potential irrigation water demands, and also fisheries production and livestock populations.

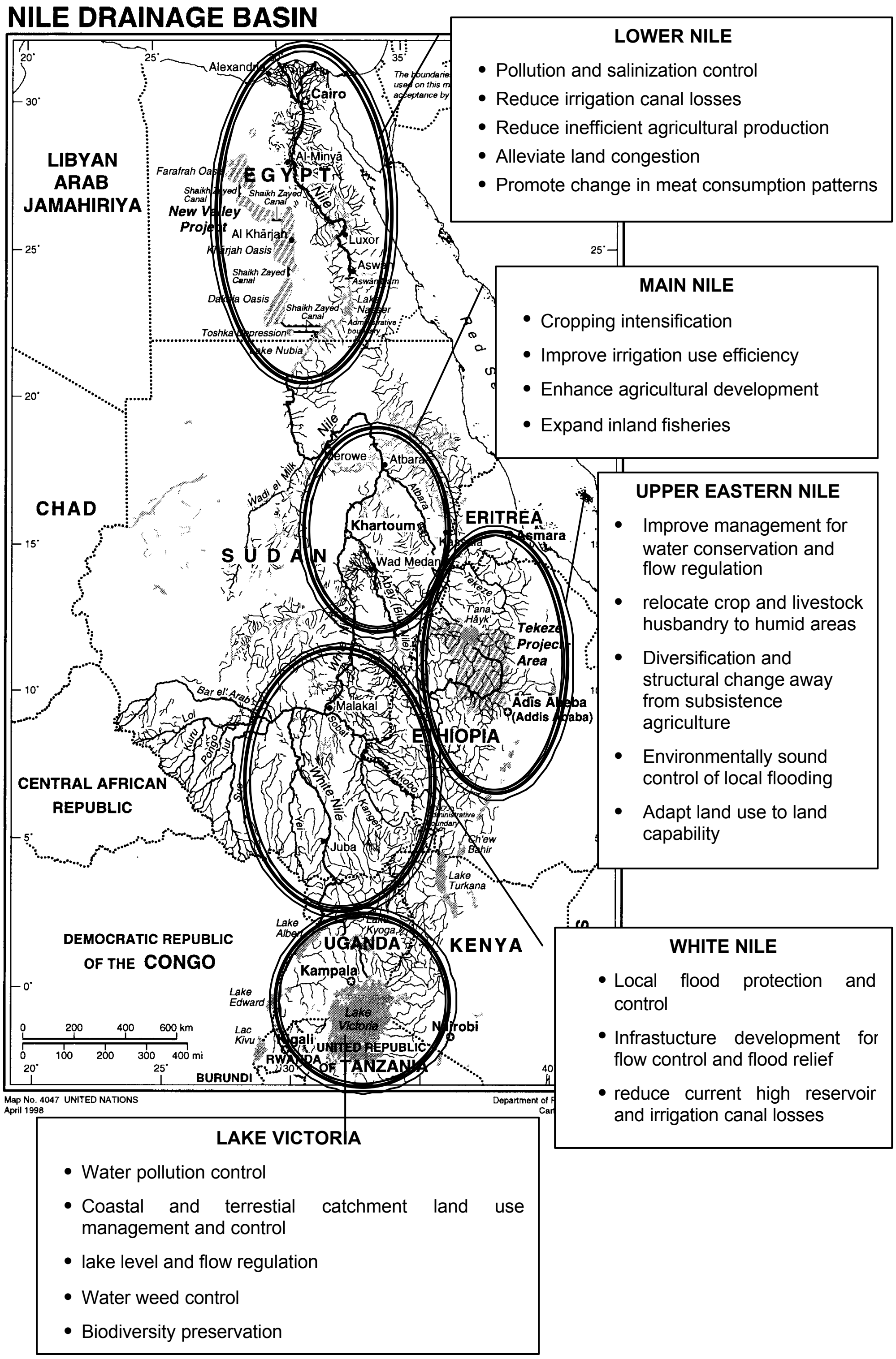
The table provides a summary of known information, of importance for formulation of a strategic framework for water saving and improved agricultural water use. A number of conclusions could be drawn.

- The option of *improved end-use efficiency* is of immediate interest in sub-basins with substantial actual and also potential irrigation area and water demand. Major expansion of irrigation area in the immediate term is, however, unlikely, due to financial and economic constraints. Improved end-use remains an important option in the Main Nile and, potentially, also in the Upper Eastern Nile. On a basin-wide scale, the main longer-term water saving option is to move agriculture from the semi-arid areas to the humid sub-regions in the Nile Basin.
- The option of *improved allocative efficiency* is applicable in:

  (a) sub-basins where the economy could support re-allocation, of substantial present or potential uses, to other sub-sectors or to more efficient agricultural use for higher economic efficiency per unit of water used. The option is applicable particularly in the more wealthy economies of the Lower Nile. However, the option also indicates the importance and urgency of improving rural incomes and promoting urban development in the less wealthy economies in the Upper Eastern Nile, in order to address poverty as the underlying cause of rapid environmental degradation of the upper catchments; and

  (b) in areas where actual or potential low-yielding irrigation water use in subsistence farming could be brought to more efficient use, such as for inland fisheries, environmental and biodiversity conservation, combined with support to the urban, processing and service sectors.
- The options of *improved end-use efficiency* and *improved allocative efficiency* carry high social, economic and even political cost, and require continuous support and investments over considerable time, while the waters saved remain relatively limited. The two options need to be supplemented with short-term, pragmatic and readily implementable measures for substantial water savings in a basin-wide context. These measures focus on watershed conservation and flood control in the upper catchments, especially in the Eastern and the

FIGURE 6
Water savings in agricultural sub-basins: management areas and major options



White Niles. These options, which carry costs and benefits, need to be beneficial to all parties. The options are feasible only in a transboundary context, and need to be addressed as international measures undertaken in specific locations with costs shared in proportion to the benefits of the parties. As a consequence they need to be based on international agreements, including legal treaties and appropriate institutional arrangements.

Sub-basin focus and options

These objectives translate into a number of priority objectives specific to individual sub-basins as detailed below. The options in the individual sub-basins are summarized in Figure 6.

Upper Eastern Nile (upper catchments of Blue Nile and Atbara)

Due to the degraded upper watersheds, the catchment is subject to frequent local floods, resulting in very high evaporation losses from stagnant water on flooded land. The priority is therefore for watershed management, especially in the Abbay[4] (Blue Nile) river, and construction of small- to medium-sized reservoirs in the upper tributaries in order to reduce floods and resulting water losses. The conservation issues are closely related to rural poverty, and the priority strategy is to encourage investment in support of development to enable transfer out the purely subsistence economy. The sub-basin has several potential hydropower dam sites, which, if developed, could also improve water conservation and flow regulation. In addition, improved flood protection would have a major positive impact on rainfed agricultural production. Efficient water use and irrigation applied to reclaimed high capability land implies transfer out of the Nile Basin proper, for use in adjacent areas with land but no water. Within-basin small-scale irrigation based on water harvesting, small reservoirs and shallow groundwaters (which are still underutilized) based on community work and labour intensive approaches, has considerable potential. The trade-offs are between, on the one hand, the costs of watershed management, as a long-term undertaking, including necessary structural change, and, on the other hand, the social and economic benefits from hydropower generation and consumptive water uses, both of additional water in neighbouring basins or further downstream in the basin.

The options identified are:

- Relocation of parts of intensive and water-consuming agricultural and livestock production from the drier arid areas to higher rainfall areas the upstream parts in the basin and with transfer to improved rainfed cultivation. The option includes crop management, and agricultural and crop prising policy and is supplemented with macro-policy measures and structural change, supporting development towards service and manufacturing in drier areas, including promotion of high-yielding commercial agricultural production and promoting intra-basin and external agricultural trade for a sustainable regional food balance. The economies of rainfed and irrigated cropping are compared in Table 34, based on information from the Baro-Akobo-Sobat river basin.
- National and regional diversification and structural change of national and local economies out from subsistence agriculture into service and manufacturing. In the context of basin water efficiency, the priority attention - to reduce the negative impacts from subsistence

1 The Abbay is considered to be still recoverable, while the Tekezo (Atbara) upper catchment areas are almost fully degraded.

farming and deforestation, by poor populations especially in the sensitive upper watersheds of the Eastern Nile.

- Selective reduced and controlled flooding, in tributary water-courses in annually flooded areas not contributing to groundwater recharge or with high environ-mental or biodiversity values. This options is seen as a major opportunity to save substantial volumes of water now lost by evaporation, at low costs and providing development, income and employment as well as flood protection of agricultural land to the most poor areas in the upper catchments. While the option remains to be studied further[1], the potential for water savings is highly significant.
- Balanced and optimal allocation of land resources based on land capability for agriculture, catchment protection and forest protection.

TABLE 34

Benefit per unit area of rainfed versus irrigated cropping in the Baro-Akobo-Sobat River basin (Ethiopia)

Crop	Rainfed Cropping Benefit ($US/ha)	Irrigated Cropping Benefit ($US/ha)
Maize	783	783
Sorghum	513	403
Wheat	310	569
Vegetables	221	346
Rice	227	1574
Pulses	196	512
Oil Seeds	93	550
Cotton	1080	989
Sugar	253	2094
Fodder	13	1355

Note: Irrigation capital development cost is in the range of: $US 8 200 to $US 9 200/ha. The irrigation returns are feasibly high for fodder, and – if the opportunity values of the water are disregarded – also for sugar cane and rice. However, as long as no alternative sources of livelihood are available, the social irrigation benefits for rural poverty alleviation are considerable.

Source: Ministry of Water Resources, Ethiopia, 1996. TAMS-ULG Baro-Akobo-Sobat River Basin Integrated Development Master Plan.

Lake Victoria Catchment, to the outlet of Lake Albert into the While Nile

The large water bodies of the upper White Nile are subject to pollution, mainly from the terrestrial part of the catchment, but also from water weed infestation. Recognizing the dominant economic role of inland fisheries, the primary focus must be on water quality control and protection of the water bodies to maintain and improve freshwater biodiversity. Therefore lake management issues focus on sustainable coastal development of the littoral countries, including lake level and outflow control. Particular attention has to be paid to preserving the natural ecologies in the montane parts of the catchment. The trade-offs are between, on the one hand, socio-economic benefits from economic and agricultural development, both in the terrestrial catchment and along the lake banks, and, on the other hand, environmental losses and costs from degradation of the Lake water body, and the consequent longer-term negative effects on the fisheries sector. In the upper catchment areas, local communities, characterized by rural poverty and civil strife, should be appropriately motivated and compensated to maintain the catchment and montane environments, and be mobilized in catchment rehabilitation and reforestation. A uniform, common environmental protection policy for the Lake should to be adopted and enforced by the littoral states. In a transboundary context, a simplistic win-win solution would be to maintain the lakes at maximum levels to optimize non-consumptive benefits, including hydropower generation, and make maximum use of the Lake system's high capacity for regulating White Nile flows and managing flooding and related evaporation losses. The options are:

[1] A remote sensing assessment of actually flooded areas would provide a safer estimate of the actual water saving potential. There are, however, indications that the savings could amount to 25% of the total run-off, which indicates total potential water savings in the Nile Basin of 10 to 20 km^3 .

- Environmental conservation to ensure water conservation and soil erosion and water quality control and preserve biodiversity, fisheries resources and other environmental values, with institutional measures for international and within country re-distribution of social benefits from preservation.
- Sustainable, optimal regulation of Lake Victoria, considering social, economic and environmental costs and benefits.

White Nile

In view of the ecological importance of the Sudd, it should not be tampered with, but preserved.

A lot of water could be conserved by low-cost interventions along the Sobat-Baro-Akobu river system. This area is subject to frequent inundation due to flash-type floods, resulting in loss of agricultural production and high evaporation losses.

The Sobat floods often, and this normally occurs during periods of White Nile low flows. Blocked by the natural barrier of the Malakal cataracts, the Sobat floodwater backs up along the White Nile, and floods. The backing up can affect flow as far upstream as the Sudd, and is associated with significant evaporation losses. One option to reduce the effects of these floods is to plan and build a multipurpose control structure at the Malakal cataract, that would combine run-of-the-river hydropower generation with flood-relief by-pass structures. There would also be the potential for a navigation lock to allow shipping to pass from Khartoum to Juba, thus avoiding the current transhipment requirement. This option should be reinforced by two related works: firstly, small- to medium sized dams in the upper Sobat tributaries for local power production and flood mitigation, and, secondly, dykes or levees along the course of the Sobat-Baro-Akobu river system. The dykes would be low-cost and should be constructed by local labour using local material. This option, in whole or in part, provides a low-cost and minimum-risk alternative to major drainage projects (e.g. the Jonglei canal).

The implementation of flood-relief bypasses at Malakal would also assist in reducing the flood intensity of the White Nile in season.

The water efficiency of Jebal Aulia reservoir for regulation of White Nile flows needs to be reviewed. There are high evaporation losses that are not compensated for by the benefits from current irrigation uses.

In essence, the tradeoffs are between, on the one hand, high-value in-stream environmental water values in wetlands for inland fisheries, biodiversity, tourism and seasonal grazing for local populations, and, on the other hand, the demand for increased downstream flows for various agricultural uses. The options are:

- Flood protection dykes along the Sobat- Baro-Akobo-Sobat with buffer storage in the tributaries. The reduction in flooded area has to be traded against resulting reduction in grazing area, biodiversity and inland fisheries including related the social impact.
- Development of inland fisheries and tourism values.
- Planning a major flow control and flood release structure at the level of Malakal.

Main Nile

Currently, irrigation in the Main Nile is characterized by low economic efficiency, low infrastructure utilization levels and very low cropping intensities. The immediate option is therefore to intensify cultivation through rehabilitation and improved management in existing, and future, irrigation schemes. However the main constraint here is insecurity of water supplies, due to sedimentation and consequent reduced storage capacity in the Blue Nile reservoirs and hydropower dams (Sennar and Roseires).

From the national point of view, it has been proposed that this be addressed by raising the dams to create additional storage and to secure year-round electricity generation. There is also a need to replace ageing pumping equipment and rehabilitate irrigation canals, and to take further steps towards participatory irrigation management. These solutions may not be sustainable.

In the transboundary context, an alternative sustainable, win-win, solution is to control floods and erosion, and also to regulate flows in catchments further upstream in the Nile Basin. It is proposed here that measures in the Main Nile should focus on improved efficiency of use. This would facilitate more effective use of any additional supply that might become available, including through reducing flooding risk.

The long-term measures in the sub-basin should concentrate on moving agriculture southwards, towards higher rainfall zones as rainfed farming, and livestock production supported by supplementary irrigation.

Priority should be given to development of the highly under-used inland fisheries potential.

These options are complementary, on the one hand, to maintain and expand commercial irrigated agriculture, to produce tradable export commodities, and, on the other hand, to expand and improve the rainfed subsistence farming and livestock sectors, to improve food and social security.

Lower Nile

Available options for measures to ensure efficient agricultural water use in the downstream parts and the coastal sub-basin of the Nile, in the Nile valley and the Nile Delta, are becoming increasingly constrained. Emerging constraining issues are land scarcity, congestion and environmental pollution, and salinization due to re-use of irrigation water and minimal releases to the sea. In an increasingly congested Lower Nile sub-basin, the challenge is to identify and ensure sustainable and efficient alternative water uses. In the transboundary context, the measures need to justify – both economically and financially – support for any possible additional water that could be made available as the result of upstream water conservation and enhancement measures.

Within the perspective of a national water policy, a number of problems and the policies and specific strategies to address them have been identified. The potential problems relate to:

- supply:demand imbalance;
- rapid deterioration of the water quality in irrigation and drainage canals and coastal lagoons; and, in particular,
- increasing national dependence on Nile waters, with the need to advance, and benefit from international cooperation on Nile waters. However, this has to be done in the perspective of the present situation, namely:
  - ➢ inefficient use of water, with high per unit water use, including high conveyance losses. Agriculture, in the Nile valley and the delta, uses 80% of the water while contributing only 20% of GDP and providing about 40% of all employment; and

- ➢ ineffective use of water, with cropping patterns oriented towards water-intensive crops[1] with large amounts of re-useable drainage water, together with seemingly wasteful releases for navigation, spilled to the sea.

The national options at the lower end of the Nile basin are established in the context of integrated, multi-purpose water utilization for water supply, agriculture, energy and navigation, together with increasingly critical environmental issues of pollution and salinization. With congestion and land scarcity in the Nile valley and the Delta, recent national strategies have been directed towards reclamation of new arid land, including the New Valley-Toshka and the New Sinai Projects, based on groundwater supply and out-of-basin water transfers. Transboundary strategies might coincide with the national strategies, at least toward improved water use efficiency. This would affect crop management, and even shifts in dietary patterns, as well as reduced reservoir evaporation losses in the Aswan Dam. The long-term structural transboundary option of moving agriculture to higher rainfall areas further up in the Nile Basin, and increasing reliance on food imports, might not be acceptable at the national policy level. The tradeoffs are therefore to balance national policy and security against the evident water saving and economic benefits deriving from available transboundary options. This implies a policy adjustment, involving:

- establishing the capacity and political acceptance to support upstream water conservation measures;
- reducing the within-sub-basin storage loss; and
- implementing a number of integrated longer-term agricultural policy adjustments to reduce water demands in the sub-basin, including:
  - ➢ reducing inefficient agricultural irrigated production while supporting agricultural development and supporting increased – mainly rainfed – production in the upper basins of the Nile; and
  - ➢ changing meat production and consumption pattern, combining investment in and import of livestock products from the upstream sub-basins, with support for a shift in meat consumption from beef to poultry.

Scenarios at different levels of cooperation

Different scenarios for agricultural-based cooperation are envisaged, and entail differing levels, namely moderate, medium and high, of cooperation to facilitate them. The scenarios also provide an indication of institutional and human resources needs for management, administration and monitoring at different levels. Also, three areas for independent side studies have been identified.

Moderate level of cooperation – basin-wide coalition

- Information and research programmes looking to eventually develop a basin-wide agricultural and food security strategy, covering issues such as production stability under extreme conditions, and irrigation potentials.

---

[1] Including plans for increased production of sugar cane, where recent trade liberation had exposed the local production to imports of 2.3 million tons in 1997-98, with import prices dwindling from $US 435 to $US 160/t. With total imports of $US 17.5 million, of which about 10-15 % are food imports, and a trade deficit of about $US 12 400 million, increasing agricultural imports to save water carries high political importance. At the same time, with the focus on modern, commercial development of the Toshka and New Sinai projects based on out-of-basin water transfers, these developments need to be traded off by reduced irrigation uses for basic food production in less efficient sectors.

- Basin- and sub-basin land utilization and development planning.
- Exchange programme for technology and expertise through mobilization of intra-basin expertise and the creation or use of centres of excellence.
- Exchange programme for priority institutional development, such as land management and irrigation pricing.
- Economic, trade and investment-cooperation programme to establish or exploit links with existing economic and development blocks (COMESA, SADC, IGAD) within and outside the African region.
- Social enhancement and welfare programme that address the appropriate gender and grass-roots elements of society

Medium level of cooperation – sub-basin or bi/tri-lateral coalitions

- Planning for sub-basin agriculture and water resources development, looking at, for example, irrigation development, catchment area management and basic infrastructure.
- Enhancing rangeland, livestock and wildlife management (health, stock improvement, grazing, settlement, processing, marketing and export of livestock products).
- Sub-basin programme(s) on intensification (technology, diversification, constraints analysis) and improved water management in subsistence farming
- Sub-basin cooperation programme on enhancing inland fisheries production and conservation.
- Sub-basin programme on forestry, with a focus on fuelwood production and plantation forest development and management.
- Sub-basin cooperation on soil conservation.
- Review of land management policies.
- Promotion of private sector capital and partnership investments in Nile Basin agriculture.
- Coordination of exchanges on nature conservation and eco-tourism.

High level of cooperation - sub-basin or bi-lateral coalitions

- Cooperation programme on upstream-downstream water saving, conservation and use, including institutional and legal arrangements for sharing of cost and benefits of water saving measures.
- Joint government-private sector development of agriculture (cropping, livestock, agro-processing) and water resources (irrigation, reservoirs, wetlands management, upper catchment management).

Side studies

- Review the regional and national ramifications of income diversification away from subsistence agricultural production.
- Water use efficiency and criteria for assessment of value-in-use in the agricultural production sectors (crop, livestock, fisheries and forestry) and ecological use for nature conservation and biodiversity preservation.
- A time-factor study of Nile Basin development to project the impact of developing national agricultural sectors on national and cumulated basin agricultural water demands in the immediate, medium and long terms.

Chapter 6
Conclusions and recommendations

The Nile sub-regions encompass a variety of climatic, land and socio-economic conditions. Agricultural development continues to underpin socio-economic development in the Nile Basin. Agriculture is needed to maintain food security and anchor rural livelihood for the rapidly growing Nile populations. An increase in food availability of 40% is thought to be necessary just to meet the minimum acceptable level of food security in the basin. A combined approach of increasing production with improved post-harvest management and value added processing is considered necessary. Since the agricultural production sectors (crops, livestock, forestry and fisheries) are subject to national policies, regional improvements will depend on substantial coordination and cooperation between the riparian countries.

Development of the subsistence sector, which in places represents as much as 80% of production, needs to be emphasized. The Basin also sustains important pastoral groups, with the largest livestock population in Africa. Alongside liberalization of the agricultural sector, which in some of the Nile economies has enhanced growth, there is a concurrent need to protect the most vulnerable groups, who unless they receive assistance are unable to benefit from the change.

Under condtions of poverty and a shortage of agricultural land, current agriculture practices are resulting in degradation of the soil and water resources of the Basin. These negative impacts need to be assessed and managed within the context of the Basin as a whole. For example, the important Nile fisheries resources are under threat from point and non-point sources of pollution and intensive water use in the Lower Nile sub-basin is resulting in salinization.

The land potential for agricultural expansion is estimated to be five times the area currently cropped in the Nile Basin. However, the suitability of land in terms of supportable cropping intensities and population densities varies throughout the basin. A necessary condition to drive agricultural development and improve rural incomes is to add local value and enhance productivity in agro-processing to add value. This is expected to require increased integration with the manufacturing sector and the economy of each of the Nile countries.

With increasing water scarcity an immediate issue in the basin, major water saving opportunities include re-locating intensive agricultural production to higher rainfall areas, and promoting agricultural trade.

Agriculture and natural resources conservation in the basin needs to be focused upon a range of issues throughout the basin at various scales, notably;

- immediate water savings through reduction of local flooding;
- a basin-wide exchange on subjects of regional significance (such as regional agricultural trade and production, food security and environmental conservation policy) and specific social issues (such as subsistence farming and gender issues);

- at the meso-basin level, focusing on agricultural development planning (see Figure 1 for the hydrological meso-basins rather than the sub-basins defined for this paper); and
- at the project level, focusing on joint agricultural development projects.

Enhanced interaction is expected to lead eventually to increased and closer cooperation among the Nile Basin economies, to their joint benefit.

Bibliography

Abate, Zewdie, 1994. *Water Resources Development in Ethiopia: An Evaluation of Present Experience and Future Planning Concepts*. Reading: Ithaca Press.

Abdel-Gawad, 1998. Environmental concerns, health risks and mitigation measures of irrigation pollution. Paper presented at the *Intl. Workshop on Drainage Re-use in Irrigation.* Sharm El-Sheikh, Egypt, May 1998.

Abdel Aziz, Y. 1995. Irrigation management transfer: Development and turnover to private water user associations in Egypt. IMI/FAO *International Conference on Irrigation Management Transfer.* Rome.

Alexandratos, N. (ed). 1995. *World Agriculture: Towards 2010. An FAO Study.* Chichester: Wiley.

American Chamber of Commerce in Egypt. 1998. *The South Valley Development Project: Toshka and East Oweinat*.

Attia, B.B. 1997. A Framework for the Development of Egypt's National Water Policy. In: *Proceedings of the Expert Consultation on National Water Policy Reform in the Near East.* Beirut, Lebanon, 9-10 December 1996. Cairo: FAO Regional Office for the Near East.

Brismar, A. 1997. *Comprehensive Assessment of the Freshwater Resources of the World: Freshwater and Gender, A Policy Assessment*. Stockholm: SEI.

Caddy, J.F., Refk, R., & Do-Chi, T. 1995. Productivity estimates for the Mediterranean: Evidence of accelerating ecological change. *Ocean and Coastal Management*, **26**(1): 1-18.

Coates, D. 1995. Paper presented at the *Intl. Conference on Sustainable Contribution of Fisheries to Food Security.* Kyoto, Japan, 4-9 December 1995.

COMESA. 1998. *Irrigation Development Study in the COMESA Region*. COMESA Irrigation Development Workshop, Lusaka, 1998.

Denniston, D. 1995. High Priorities: Conserving Mountain Ecosystems and Cultures. *World Watch Paper*, No.123. Washington DC: World Watch Institute.

FAO. No date. *Aquaculture Development in Africa*. Rome.

FAO. 1991. *Water Harvesting.* Doc. No. AGL/MISC/17/91. Rome.

FAO. 1994a. Aquaculture Development and Research in Sub-Saharan Africa: National Reviews. *CIFA Technical Paper*, No.23, Suppl. Rome.

FAO. 1994b. *Programme Thrust on the Developments of Inland Fisheries and Aquaculture in Africa*. The Inland Water Resources and Aquaculture Service, Fishery Resources Division, Fisheries Department. Rome.

FAO. 1994c. Studies for Integrated Irrigation Systems. Terminal Report of UNDP/FAO project ETH/88/001. Roe.

FAO. 1994d. *Fishery Country Profile: Sudan.* FID/CP/SUD/Rev.3. Rome.

FAO. 1995a. Sudan Fisheries: An Assessment of the Situation and Proposals for the Future, with Emphasis on the Inland Fisheries. *Fisheries Circular,* No.901. Rome.

FAO. 1995b. Effects of Riverine Inputs on Coastal Ecosystems and Fisheries Resources. *Fisheries Technical Paper*, No.349. Rome.

FAO. 1995c. *Forest Resources Assessment 1990: Tropical Forest Plantation Resources.* Rome.

FAO. 1995d. *Management of African Inland Fisheries for Sustainable Production: An Overview*. Prepared by J.M. Kapetsky. Rome.

FAO. 1996a. *Strategies for Water Hyacinth Control*. Report of a Panel of Experts Meeting, 11-14 September 1995, Fort Lauderdale, Florida, USA.

FAO. 1996b. Fisheries and Aquaculture in the Near East and North Africa: Situation and Outlook in 1996. *Fisheries Circular*, No.919. Rome.

FAO. 1996c. Fisheries and Aquaculture in Sub-Saharan Africa: Situation and Outlook in 1996. *Fisheries Circular*, No.922. Rome.

FAO. 1996d. [Report of the] *World Food Summit.* 13-17 November 1996, Rome.

FAO. 1997a. *Fishery Country Profile: Arab Republic of Egypt*. Rome.

FAO. 1997b. Irrigation potential in Africa - A basin approach. *FAO Land and Water Bulletin*, No. 4.Rome.

FAO. 1997c. *Water Resources of the Near East Region: A Review*. Rome.

FAO. 1998a. *The State of Food and Agriculture 1998*. Rome.

FAO. 1998b. Aquaculture Production Statistics – 1987-1996. *FAO Fisheries Circular,* No.815, Revision 10 [FIDI/C815 (Rev.10]. Rome.

FAO. 1999. Integrated Resource Management for Sustainable Inland Fish Production. 23rd Session, Committee on Fisheries, Rome, Italy, 15-19 February 1999. Doc.No.COFI/99/2. Rome.

FAO. 2000. Crops and Drops: making the best use of land and water. Advance edition. Rome.

FAO/IFA/IFDC. 1996. *Fertilizer Use by Crop. No 3.* Doc. No. ESS/MISC/1966/1. Rome.

FAO-Mountain Institute. 1997. *Investing in Mountains: Innovative Mechanisms and Promising Examples for Financing Conservation and Sustainable Development.* Synthesis of a Mountain Forum Electronic Conference in Support of the Mountain Agenda. The Mountain Institute, Franklin, WV, USA

FAO-TCP. 1998. *Analysis of Compensation Options in Connection with the Driekoppeis Dam Project*. Terminal Statement of TCP/SWA/4555. Rome.

Fernandez, A.P. 1998. *The Myrada Experience: Alternate Management Systems for Savings and Credit of the Rural Poor*. From Internet site http://www.myrada.com.

Grenney, Assiouti, & Hekmat. 1998. Cost allocation for multi-purpose water systems in Egypt. *Journal of Irrigation and Drainage Engineering,* **124**(4).

Hvidt, M. 1998. *Water, Technology and Development: Upgrading Egypt's Irrigation System*. London: Tauris Academic Studies.

IGADD/FAO. 1994. *Crop Production System Zones in the IGADD Sub-Region*.

Keith, J. 1998. *Economic Options for Managing Water Scarcity.* Discussion Paper prepared for the Second FAO Electronic Conference on Managing Water Scarcity – WATSCAR2. 29 May - 23 October 1998.

Khouzam, R. 1996. A Water Quality Management Strategy Study Case: The Nile River. pp. 120-127, *in:* Howsam, P., and Carter, C. (eds), *Water Policy: Allocation and Management in Practice*. Proc. the Intl. Conf. on Water Policy. Cranfield University, England, 23-24 September 1996.

Lorenzini, M., & Marzoli, W. 1990. *Report on Forest and Biomass in the Framework of the African Energy Program*. FAO: Rome.

Messerli, B., & Hurni, H. (eds) 1990. *African Mountains and Highlands: Problems and Perspectives*. African Mountains Association.

Morgan, D. 1997. Directions in Development. *African Farming,* September-October.

Nile Basin Initiative. 1998. *Nile River Basin Action Plan Review: Towards a Priority Action Plan.* Revised Draft Report, February 1998.

Samad, M., Dingle, M., & Shafique, M. 1995. Political and economic dimensions of privatization and turnover of irrigation schemes in the Sudan. IMI/FAO *International Conference on Irrigation Management Transfer*. Rome, 1995.

Shehadeh, Feidi. 1996. Aquaculture and Resource Limitations in Egypt. *Aquaculture Newsletter* FAO Fisheries Department; 14 December 1996.

Smedema, L.K. 1999. *Comparative Study of the River Salinity Conditions in Five Major Irrigated Basins in the Arid Zone*. International Irrigation Management Institute.

Smith, M. 1999. The Application of Climatic Data for Planning and Management of Sustainable Rainfed and Irrigated Crop Production. Paper prepared for the *International Workshop on Agrometeorology in the 21st Century*, Accra, February 1999.

SNCID [Sudan National Committee on Irrigation and Drainage] 1998. *Sudan Irrigation and Drainage Newsletter*. Nos. 10-11, June-September.

Swaziland-South Africa. 1992. *Treaty on the Development and Utilization of the Water Resources of the Komati River Basin*. Signed by the Kingdom of Swaziland and the Republic of South Africa, 13 March 1992.

UNCED. 1992. *Managing Fragile Ecosystem: Sustainable Mountain Development*. UNDP/World Bank.

UNDP *et al*. 1994. *Sustainable Agriculture and Environmental Rehabilitation in Tigray.* Prepared by UNDP, ECA, FAO, The Regional Government of Tigray, and TDA.

UNEP. 1999. Freshwater Issues: Progress in the Implementaion of the Governing Council Decisions SS. V/4 and Environmental Issues Arising from the Decision. Report of the Executive Director.

Winpenny, J.T. 1997. Managing Water Scarcity for Water Security. A discussion paper prepared for the first FAO email Conference on Managing Water Scarcity

Winrock International. 1992. *Assessment of Animal Agriculture in Sub-Saharan Africa*. Winrock International Institute for Agricultural Development, Arkansas, USA.

World Bank. 1990a. *Population Growth, Wood Fuels, and Resource Problems in Sub-Saharan Africa*. Industry and Energy Department Working Paper. Energy Series Paper No. 26. Washington DC.

World Bank. 1990a. *Sudan: Toward an Action Plan for Food Security*. Washington, DC.

World Bank. 1990b. *Kenya: Agricultural Growth Prospects and Strategy Options.* Washington, DC.

World Bank. 1993a. *Uganda Agricultural Sector Memorandum*. Washington DC.

World Bank. 1993b. *Arab Republic of Egypt: An Agricultural Strategy for the 1990s.* Washington, DC.

World Bank. 1996. *African Water Resources: Challenges and Opportunities for Sustainable Development*. World Bank Technical Paper No.331. Washington, DC.

WCMC [World Conservation Monitoring Centre]. 1998. *Freshwater Biodiversity: A Preliminary Global Assessment*. Prepared by WCMC for UNEP.

AGL MISCELLANEOUS PAPERS

1. Exploitation de Résultats d'Essais Agronomiques: Fixation Symbiotique de l'Azote. Analyse de la variance. G. Caraux, 1985 (F)*
2. A Review of Small-scale Irrigation Schemes in Kenya. J.H. Van Doorne. 1985 (E)*
3. Exploiting Agronomic Test Results. Symbiotic Nitrogen Fixation User's Manual: Analysis of variance on Apple II computer. G. Caraux. 1985 (E)*
4. Water for Animals. Ph. Pallas. 1985 (E)*
5. Landscape-guided Climatic Inventory Using Remote-sensing Imagery. F. van der Laan. 1985 (E)*
6. Biogas in Africa: Current Status and Strategies to Enhance its Diffusion. D.C. Stuckey. 1985 (E)*
7. Status Report on Plant Nutrition in Fertilizer Programme Countries in Asia and the Pacific Region. 1986 (E)*
8. Hydraulique pastorale. Ph. Pallas. 1986 (E)
9. Levels of Fertilizer Use in the Asia and Pacific Region. 1986 (E)*
10. Status Report on Plant Nutrition in Fertilizer Programme Countries in Africa. 1986 (E)*
11. Irrigation and Water Resources Potential for Africa. 1987 (E)
12. Effects of Agricultural Development on Vector-borne Diseases. 1987 (E)
13. Irrigated Areas in Africa. E/F. 1987 (E)
14. Manpower Planning for Irrigation. R. Carter, D. Mason and M. Kay. AGL/ESH. 1988 (E, F)*
15. NGO Casebook on Small-scale Irrigation in Africa. R. Carter. 1989 (E)
16. Water, Soil and Crop Management Relating to the Use of Saline Water. 1990 (E)
17. Water Harvesting. 1991.
18. Improved Irrigation System Performance for Sustainable Agriculture. 1991 (E)
19. Fertigation/Chemigation. 1991 (E)
20. Secondary Nutrients. 1992 (E)
21. Le travail du sol pour une agriculture durable. 1997 (F)
22. Planning Sustainable Management of Land Resources: The Sri Lankan example. 1999 (E)
23. Integrated Soil Management for Sustainable Agriculture and Food Security in Southern and East Africa. 1999 (E)
24. Soil Physical Constraints to Plant Growth and Crop Production. 1999 (E)
25. New Dimensions in Water Security. 2000 (E)
26. Guidelines for On-farm Plant Nutrition and Soil Management Trials and Demonstrations. 2000 (E, S)
27. Guidelines and Reference Material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools. 2000 (E)
28. Simple Soil, Water and Plant Testing Techniques for Soil Resource Management. 2000 (E)
29. Water and Agriculture in the Nile Basin. 2000 (E)

Availability: March 2002

E - English
F - French
S - Spanish
** Out of print*