Farming Systems Report

Information Products for Nile Basin Water Resources Management

Farming Systems Report

Synthesis of the Country Reports at the level of the Nile Basin

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Background

FAO project GCP/INT/945/ITA aims to develop information products for decisions on water policy and water resources management in the Nile Basin. One important element of the project is a basin-wide analysis of agricultural water productivity.

Acknowledgements

This report was compiled by FAO consultant Anne Woodfine together with inputs from FAO staff, Jacob Burke, Jean-Marc Faurès, Jippe Hoogeveen and Dorit Gross. Overall design of the reports and information products was managed by Nicoletta Forlano, James Morgan and Gabriele Zanolli.

List of acronyms

AIPs	Alien Invasive Plants
asl	Above Sea Level
AU	Animal Unit (1 000 lb/454 kg)
BMU	Beach Management Unit
C	Centigrade
CA	Conservation Agriculture
DAP	Diammonium phosphate
FAO	Food and Agriculture Organization
fed	Feddan (see Annex 2)
ha	Hectare
hh	Household
K	Kantar (see Annex 2)
kg	Kilogram
km	Kilometre
l	Litre
lb	Pound
m	Metre
mm	Millimetre
MoA	Ministry of Agriculture
N	Nitrogen
NBI	Nile Basin Initiative
NWFP	Non-Wood Forest Product
PET	Potential Evapotranspiration
Q	Quintal
SGB	The Sudan Gezira Board
SLM	Sustainable Land Management
SWC	Soil and Water Conservation
SPFS	Special Programme for Food Security
t	Tonnes (see Annex 2)
TLU	Tropical Livestock Unit
UPA	Urban and Peri-urban Agriculture
USD	United States Dollars
yr	Year

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Summary

Yields of the main crops in most of the rainfed and traditional irrigated farming systems of the Nile Basin are still very low – well below potential yields. Clearly individual farmers, particularly those working at the subsistence level, are unlikely to achieve the yields obtainable under optimal field and management conditions (Type II yield gaps). However, this review of the 14 major farming systems of the basin has uncovered a range of common issues in each system which currently limits productivity.

Once fundamental issues of land tenure and resource access are overcome, the management of soil moisture for rainfed production and water storage for livestock and irrigated production are perceived as the primary requisites for improved performance. Technologies and approaches to help close the large Type II yield gaps across the farming systems can also help land users to adapt to the anticipated impacts of climate change.

The enhanced availability and use of water, including soil water conservation and rainwater harvesting methods, is not the only requirement to close Type II yield gaps (see details in Chapters 3 and 5). However, it is a necessary prerequisite to maximize the benefits of other improvements such as better seeds, fertilizers, improved tools and infrastructure. Even in equatorial farming systems, additional water can still make a significant difference.

Certain areas of some farming systems in the basin show promise, achieving reasonable and consistent crop yields – notably in Egypt and the Sudan. These can act as models to help guide improvements in the poorly performing systems. Elsewhere yields are not only low but also show high levels of variation from one year to the next and cannot even be relied upon to provide subsistence – hence the periodic need for emergency food aid. Investment to enable land users to achieve a level of stability across all farming systems would make expensive and disruptive food aid unnecessary.

The national studies used to compile this report (FAO Nile Country Reports, 2008) emphasize the need to extend irrigation to meet current and future demand for food and fibre. However, since the total rainfall over the course of a season in rainfed systems is frequently sufficient, the high risk of water deficits in such systems usually refers to quite short, albeit critical, periods. But to ensure that short-term dry periods do not reduce crop yields requires widespread scaling-up of soil moisture conservation and rainwater harvesting methods which can be both small-scale and low-cost – or the adoption of supplementary irrigation which is not cheap and would only be applied to high-margin crops, not necessarily food staples.

The national studies have demonstrated that rural communities in the Nile Basin. have the proven capacity to assimilate low-cost water management technologies. But an information push will be required in order to realize any benefits upgrading currently volatile and unpredictable farming systems with more secure climate-proof approaches. However, the channels

for dissemination of information are still limited where they would have the potential for greatest impact. It is important that all available channels are used to help communicate with difficult-to-reach farmers and livestock keepers, including formal education, adult education, extension services, farmer field schools, posters, rural radio and newspapers.

Irrigation remains very important for overall food production in the Nile Basin and contributes to local and national food security in the countries of the lower basin. While irrigation can reduce poverty through higher yields and raise incomes for some farmers it is also crucial for society in general through increased employment, both direct and indirect, and through its impact in terms of lower food prices. By lifting crop production, irrigation development has also saved millions of hectares of forest land from conversion to agriculture. Irrigated agriculture also plays a significant macroeconomic role in many countries since, among other things, it generates foreign exchange.

A major factor limiting the food security of households in many faming systems is shortage of land for cultivation – households farm plots which are simply too small to support them with current production practices. Closing the yield gap will increase food production and security.

The potential exists to boost both crop and livestock production within all the farming systems of the Nile Basin to meet food demand in 2050. It is particularly high in currently very low-yielding farming systems usually found where poor people live. Realising the yield growth potential of existing rainfed areas will thus not only avoid resorting to emergency food aid but also reduce the need for new, large-scale irrigation developments, which have high environmental and financial costs.

1. Introduction

The River Nile flows 6 800 km south to north from equatorial Africa, finally discharging into the Mediterranean Sea (Figure 1). Throughout history, the Nile Basin has supported an array of ecosystems, nourished livelihoods and been the focus for the development of a rich diversity of cultures and agroecosystems in the ten countries which share its basin - Burundi, the Democratic Republic of the Congo (DRC), Egypt, Ethiopia, Eritrea, Kenya, Rwanda, the Sudan, the United Republic of Tanzania and Uganda. The Nile Basin encompasses an area of 3.1 million km^2 - one tenth of Africa's total land mass - and the countries of the Nile are home to an estimated 300 million people. The hydrology of the Nile exhibits high spatial variability (Sutcliffe and Parks, 1999), but essentially progresses from an equatorial gaining regime in the Lake Victoria Basin to the Sudd wetlands, then a losing regime downstream of the Sudd to the Mediterranean.

Figure 1: Map of the Nile Basin

The Nile Basin is not only a very large area but includes a wide range of geologies, geomorphological settings, altitudes, climates and as a consequence soil and vegetation systems. Accordingly, it features many different agroecosystems, where a varying range of crops, livestock, forests and fisheries form the foundation of the subsistence economies upon which the majority of the basin's human population depend. To varying degrees in different parts of the basin, commercial agriculture is increasingly being pursued to supply urban areas and for export.

Taken in its widest context, the agricultural sector including fisheries, livestock and forestry, has profound effects on water use and is linked to a range of social and environmental factors such as food security, poverty alleviation, conservation of the natural environment and biodiversity, all of prime importance for national and basin-wide development policies. However, despite the basin's natural endowments, its people face considerable challenges. Today the region is characterised by environmental degradation, food insecurity and poverty – too frequently linked to poor management of water resources.

A renewed focus is required on agricultural water management, as appropriate crop and land management can improve agricultural production by converting non-beneficial evaporation of rainwater from soil surfaces into beneficial transpiration through crops. In addition, many sustainable land management practices can increase the proportion of rain which infiltrates the surface to become soil moisture for plant growth. Improved agricultural water management can contribute to increasing food production[1], thereby alleviating poverty and hunger in an environmentally sustainable manner.

While the Nile Basin holds significant opportunities for cooperative management and development, some of its farming systems have evolved while others have stagnated. Understanding the present performance of the farming systems in

Table 1: Basin-Wide Distribution of Farming System Areas

Farming system	Area (ha) in Nile Basin
Agro-pastoral	18 400 051
Dryland farming	64 745 370
Forest-based	13 393 767
Highland cold	3 650 464
Highland temperate	13 224 484
Highland tropical	8 169 690
Irrigated (large scale + small scale traditional)	7 312 675
Lowland tropical	17 986 563
Pastoral	29 673 966
Woodland/Forest	18 429 032
Subtotal	**194 986 062**
Protected areas	7 773 025
Swamps	3 787 863
Water	9 362 152
Cities	196 790
Desert	100 935 908
Subtotal	**122 055 738**
Grand Total	**317 041 800**

[1] Food demand in sub-Saharan Africa is expected to triple in the coming 50 years

the basin and their environmental and social constraints can help to give a clearer indication of the opportunities for improved productivity. This report outlines the agricultural productivity and water management issues and opportunities in the main farming systems.

A basin-wide differentiation of farming systems in the Nile Basin is given in Table 1 as derived from the farming systems analysis presented in Figure 2.

Within the Nile Basin, the full spectrum of systems of water management for agriculture is found: from purely rainfed (dominantly in the south), through the continuum of practices including rainwater harvesting and other supplementary irrigation, to purely irrigated (from groundwater and/or surface water sources). In the past, attention has focused on agricultural water use for irrigation, with varying interest in rainfed systems. But overall, the sites at which available water can be applied to available land have been taken or are already planned. Hence a larger question is posed as to the future of rainfed production in the basin.

Acute poverty tends to be concentrated in communities of smallholders practicing rainfed farming, where the unpredictability of rainfall hampers agricultural yields and constrains wider rural development. Smallholders have long been very vulnerable to the impacts of short-term dry periods, seasonal droughts and also floods – all of which are expected to increase in frequency with climate change. Improved management of water in smallholder agriculture offers promising opportunities to increase crop yields, thus reducing hunger and poverty and contributing to development goals. Improved water management through soil water conservation (SWC) in combination with other sustainable land management (SLM) approaches also offer low-cost opportunities for both adaptation to, and mitigation of, climate change.

This report begins with a review and analysis of crop yield differences between the ten countries of the basin – which is the level for which comprehensive recent data is available.

The report then synthesizes the reports prepared by national consultants for each Nile Basin country (FAO Nile Country Reports, 2008), analysing agricultural production by farming system and contrasting productivity in the different systems between countries and the implications of water resources management. Agricultural productivity is commonly quantified as the crop yield per unit area (t/ha). However, as this report concerns a basin where water is already becoming limited in many places and is likely to become more so in future[2], water productivity is also considered where possible. In particular, the report attempts to highlight productivity gaps (both in yield /ha and /m^3 of water) in rainfed and irrigated systems, identifying the main causes of these gaps and offering options to address them.

The report then summarises other constraints to agricultural productivity enhancement, discusses opportunities for improvement and briefly outlines the hydrological consequences of such improvements.

[2] Due *inter alia* to population growth, urbanization, changing diets, industrial demand and climate change.

2. National Level Analysis of Agricultural Yields

Although the prime focus of this analysis is to consider agricultural production in the different farming systems of the Nile Basin, it is essential to start with a review of agricultural production at national level for the ten basin countries as the national level is the lowest level of disaggregation for which comprehensive recent data on agricultural crop yields and harvested areas is available[3]. Use of national-level data is necessary but not ideal, as they do not necessarily reflect conditions in the basin. National data is most useful in the countries which have a high proportion of their area within the basin (notably Uganda, Rwanda and the Sudan, 98%, 83% and 78% respectively – see Table 2), but less useful in those with very small such proportions (notably the Democratic Republic of the Congo). An additional problem arises in drawing conclusions, for example, as both the Democratic Republic of the Congo and Rwanda have 0.7% of the basin in their country – yet this is 83 percent of Rwanda and only one percent of the Democratic Republic of the Congo. Accordingly, the following information must be used judiciously.

Table 2 indicates the area of the country within the Nile Basin in km^2, the percentage of each country within the basin, the percentage of the basin in each of the ten basin countries, the UNDP Human Development Index ranking (2007), the most recent population data and also the projected population figures for 2015.

Table 3 demonstrates the huge differences in crop yields achieved between the countries of the Nile Basin, as it presents not absolute yields but the average yield of each country as a percentage of the yield of the highest yielding country (per ha, averaged over 1998-2007). Full details of the FAOSTAT data used in these analyses are presented in Annex 1, including annual yield and harvested area figures for each crop in each country and a figure which represents the global average yield (Bruinsma, 2009).

Table 3 clearly demonstrates that Egypt achieves the highest yields in eight of the thirteen crops analysed. This was predictable, as these crops are grown under irrigated conditions in Egypt, where there is also high usage of other inputs such as fertilizers and pesticides.

The analysis in Table 3 shows that Uganda has the highest yields of both millet and cassava, with Kenya achieving the highest yields of tea and Ethiopia the highest levels of coffee yields. None of these crops are recorded as growing in Egypt and all are grown under rainfed conditions.

[3] Some data disaggregated to lower (sub-national) levels is available on the FAO internet site Agro-MAPS (http://www.fao.org/landandwater/agll/agromaps/interactive/page.jspx), but is less up-to-date and does not cover all basin countries.

Table 2: National-Level Statistics of the Nile Basin Countries						
Country	Area in basin (km²)*	Percentage of total country area in Nile Basin*	Percentage of the Nile Basin in each country	Human Development Index (2008) (ranking out of 179 countries)	Population (millions)	
					2005	2015 (medium-variant projections)
Burundi	13 000	46	0.4	172	7.9	11.2
Dem. Rep. of the Congo	22 300	1	0.7	177	58.7	80.6
Eritrea	25 700	21	0.8	164	4.5	6.2
Ethiopia	366 000	32	11.8	169	79.0	101.0
Egypt	307 900	33	9.9	116	72.8	86.2
Kenya	52 100	9	1.7	144	35.6	46.2
Rwanda	20 400	83	0.7	165	9.2	12.1
Sudan	1 943 100	78	62.5	146	36.9	45.6
United Rep. of Tanzania	118 400	13	3.8	152	38.5	49.0
Uganda	238 700	98	7.7	156	28.9	40.0
Total	**3 107 600**		**100**		**372.0**	**478.1**

Sources: FAO (2000) and United Nations (2007).

Considering major grain crops, Table 3 shows that Ethiopia's *maize* yield is closest to Egypt's – but only 24 percent, while Eritrea's maize yield is the lowest in the basin, at only 5 percent of Egypt's (n.b. maize is only harvested from a very small area in Eritrea, on average around 18 300 ha – see Annex 1). In the case of *sorghum*, Uganda, Ethiopia and Burundi achieve yields of 22-25 percent of Egypt's, while Eritrea, the Sudan and the Democratic Republic of the Congo have much lower yields. There is no data for *millet* in Egypt, however, so that for this notably drought-tolerant crop Uganda achieves the highest yields and thus is the "base" for calculations, followed by Burundi (70%) and Ethiopia (65%). Rwanda and the United Republic of Tanzania, both countries geographically close to Uganda, achieve only 51 percent of Uganda's yields, and again the lowest yields are achieved in Eritrea (20%). In the case of *wheat*, Kenya and the Sudan achieve 35 percent and 38 percent respectively of Egyptian yields, with the Democratic Republic of the Congo, Ethiopia, the United Republic of Tanzania and Uganda in the range 20 percent to 30 percent. The three lowest-yielding countries (Burundi at 13 percent, Rwanda at 12 percent and Eritrea at six percent) all have only small areas of wheat harvested (as does Uganda). Barley growing is predominantly concentrated in Ethiopia (on average over 1 million ha harvested per year) – contrasting with the Democratic Republic of the Congo, which has an average of only 759 ha across its enormous land area. Kenya achieves highest yields in barley, followed closely by Egypt (86%) and the United Republic of Tanzania (78%).

Table 3: Yield Gaps for Major Nile Basin Crops (a) [calculated using the average yield per ha for each country (1998–2007) from FAOSTAT. The figures are percentages achieved by each country of the basin, compared with the highest yield, (highlighted)]

Country	Grains					Roots And Tubers			Others					
	Maize	Sorghum	Millet	Wheat	Barley	Potatoes	Sweet Potatoes	Cassava	Bananas	Sunflower Seed	Tea	Coffee	Sugar-cane	Cotton
Burundi	14	22	70	13	n/a	11	24	68	13	n/a	38	87	59	
Dem. Rep. of the Congo	10	12	42	20	23	19	18	63	9	n/a	24	46	35	
Egypt	100	100	n/a	100	86	100	100	n/a	100	100	n/a	n/a	100	
Eritrea	5	9	20	6	17	28	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	24	23	65	22	40	35	33	n/a	18	n/a	42	100	81	
Kenya	21	14	37	35	100	33	35	67	36	39	100	41	71	
Rwanda	10	17	51	12	0	34	21	45	n/a	n/a	56	84	23	
Sudan	11	11	17	38	0	70	49	14	82	37	n/a	n/a	78	
United Republic of Tanzania	22	15	51	22	78	26	8	60	13	14	63	48	88	
Uganda	21	25	100	27	n/a	29	16	100	12	41	78	84	74	

Evaluating the results for roots and tubers is important for this study as they form a major part of diets in Nile Basin countries. There is a wide range of potato yields across the basin, with the Sudan achieving 70 percent of Egypt's yield (likely under irrigation). While most countries achieve 25-40 percent of Egypt's yield Burundi notably achieves only 11 percent. Again, Egypt shows the highest results for sweet potatoes with the Sudan in second place with 49 percent, possibly under irrigation. Yields are moderate for Kenya (35%) and Ethiopia (33%), but low for the remaining countries – notably the United Republic of Tanzania (eight %). Uganda achieves highest yields for cassava – for which there is no data for Egypt, Eritrea and Ethiopia. Other basin countries mostly achieve 60-70 percent of Uganda's yield, with the notable exception of Rwanda (45%) and the Sudan (14%) – however, it should be noted that very little cassava is harvested in the Sudan (under 6 000 ha).

As with roots and tubers, bananas form a vital component of diets in many southern countries of the Nile Basin, although again the highest yields are obtained (under irrigation) in Egypt. The Sudan achieves bananas yields of 82 percent of Egypt's (probably also under irrigation/in oases and only in a very small area – 2 250 ha). Kenya is third but far behind with 36 percent followed by the other countries at 9-18 percent of Egypt's performance. Sunflower seeds are an important (and possibly increasingly valuable crop, as potential feedstock for biodiesel), grown in five basin countries. Again, highest yields are obtained in Egypt, with Uganda, Kenya and the Sudan getting around 40 percent and the United Republic of Tanzania much less – 14 percent. Tea is grown in seven of the ten basin countries, with highest yields obtained in Kenya, followed by Uganda (78 percent), the United Republic of Tanzania (63 percent - but not in the Nile Basin area). Rwanda comes next at 56 percent, followed by Ethiopia (42 percent), Burundi (38 percent) and the Democratic Republic of the Congo (24 percent). The same seven countries also grow coffee – with Ethiopia achieving the highest yields, closely followed by Burundi (87percent), Rwanda and Uganda (both 84 percent) and the remaining three returning considerably lower yields (the United Republic of Tanzania 48 percent, the Democratic Republic of the Congo 46 percent and Kenya 41percent).

Reviewing yields of sugar cane at national level is problematic. The large range of values supports the notion that this encompasses both irrigated and rainfed cane, including statistics from estates with high usage of agrochemicals and smallholder farms with limited availability of inputs; thus variations between countries may reflect differing proportions of cane grown under the different conditions. Egypt again achieves the highest yields, probably because all cane in that country is grown under irrigated conditions. Five countries achieve average yields of between 70 and 90 percent of Egypt's (the United Republic of Tanzania 88percent, Ethiopia 81 percent, the Sudan 78 percent, Uganda 74 percent and Kenya 71 percent). The Democratic Republic of the Congo and Rwanda have much lower average yields (35 and 23 percent respectively).

Table 4 has been derived from the same statistics as used in Table 3. However, in calculating the yields gaps Egypt has been excluded from the calculations, on the basis that all agriculture in Egypt is irrigated, whereas most of production in other countries is rainfed.

Table 4: Yield Gaps for Major Nile Basin Crops (b) [calculated using the average yield per ha for each country (1998–2007) from FAOSTAT. The figures are percentages achieved by each country of the basin, compared with the highest yield excluding Egypt, (highlighted)]

Country	Grains				Roots And Tubers			Others					
	Maize	Sorghum	Millet	Wheat	Barley	Potatoes	Sweet Potatoes	Cassava	Bananas	Sunflower Seed	Tea	Coffee	Sugarcane	Cotton
Burundi	59	87		34		16	49		16	n/a				
Dem. Rep. of the Congo	43	45		53		27	37		11	n/a				
Eritrea	21	36		17		40	n/a		n/a	n/a				
Ethiopia	100	91		59		49	67		22	n/a				
Kenya	90	57		93		47	71		44	95				
Rwanda	43	68		32		49	43		n/a	n/a				
Sudan	45	43		100		100	100		100	91				
United Republic of Tanzania	93	60		58		37	16		15	33				
Uganda	89	100		72		41	33		14	100				

[Millet and cassava excluded from this table as data n/a for Egypt; barley yields are not highest in Egypt; tea and coffee not grown in Egypt and sugarcane, presumed irrigated, in all countries.]

In the context of this study, the differences in yields shown in Table 4 are of greater significance than those in Table 3 as they more closely reflect the gap in yields which could feasibly be reduced, for example by rainwater harvesting.

Ethiopia has the highest average maize yield of the nine basin countries, with the United Republic of Tanzania, Kenya and Uganda all achieving around 90 percent of Ethiopia's level. The other basin countries achieve notably lower yields with Burundi at (59percent), the Sudan (45 percent), both Rwanda and the Democratic Republic of the Congo at 43 percent and Eritrea at only 21 percent. Uganda achieves the highest sorghum yields, followed by Ethiopia (91 percent), Burundi (87 percent) and Rwanda (68 percent). the United Republic of Tanzania (60 percent), Kenya (57 percent) and the Democratic Republic of the Congo (45 percent) are modest, with the Sudan (43 percent) and Eritrea once more lowest at 36 percent. Wheat yields vary more widely across the basin, with the Sudan achieving highest yields and Eritrea only 17 percent of its neighbour. Of the other countries, Kenya achieves 93 percent, Uganda 58 percent, Ethiopia, the United Republic of Tanzania and the Democratic Republic of the Congo all 50-60 percent, Burundi 34 percent and neighbouring Rwanda 32 percent.

The Sudan returns the highest yields of the three other crops in Table 4 (potatoes, sweet potatoes and bananas) – possibly all also under irrigated agriculture and all on very small areas of harvested land. Considering potatoes yields, no other country manages to achieve 50 percent of the Sudan's average yield, with Ethiopia, and Rwanda on 49 percent, Kenya 47 percent, Uganda 41 percent, Eritrea 40 percent and the United Republic of Tanzania at 37 percent - then the Democratic Republic of the Congo and Burundi with much lower yields (27 percent and 16 percent respectively). Kenya achieves 71 percent and Ethiopia 67 percent of the Sudan's average yield of sweet potatoes, followed by Burundi (49 percent), neighbouring Rwanda (43 percent), the Democratic Republic of the Congo (37 percent), Uganda at 33 percent and the United Republic of Tanzania at only 16 percent. Banana yields across the basin are all much lower than in the Sudan – with Kenya achieving only 44 percent of the Sudan's average yield and all other countries in the range of 22 to 11 percent. (N.B: there is no data for Eritrea – probably as the crop is not grown).

3. Major Farming Systems of the Nile Basin

"A farming system ….. is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households." (FAO and WB, 2001)

The following criteria are used as the basis for any classification of farming systems:

- available natural resource base, including water, land, grazing areas and forest; climate, of which altitude is one important determinant; landscape, including slope; farm size, tenure and organization; and dominant pattern of farm activities and household livelihoods, including field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities. In addition, account is taken of the main technologies used, as they determine the intensity of production and integration of crops, livestock and other activities.

Based on these criteria, the following 14 main farming systems have been distinguished in the Nile Basin:

- irrigated (large-scale, traditional);
- irrigated (small scale, traditional);
- irrigated (commercial);
- pastoral;
- agro-pastoral - dry and hot (millet);
- dryland farming;
- highland - tropical;
- highland - temperate (wheat);
- highland - cold (barley, sheep);
- lowlands - tropical;
- forest-based;
- woodland.

These 12 systems are mapped in Figure 2. In addition two other farming systems whose spatial occurrence cannot be mapped at this general scale are included in the analysis. These are;

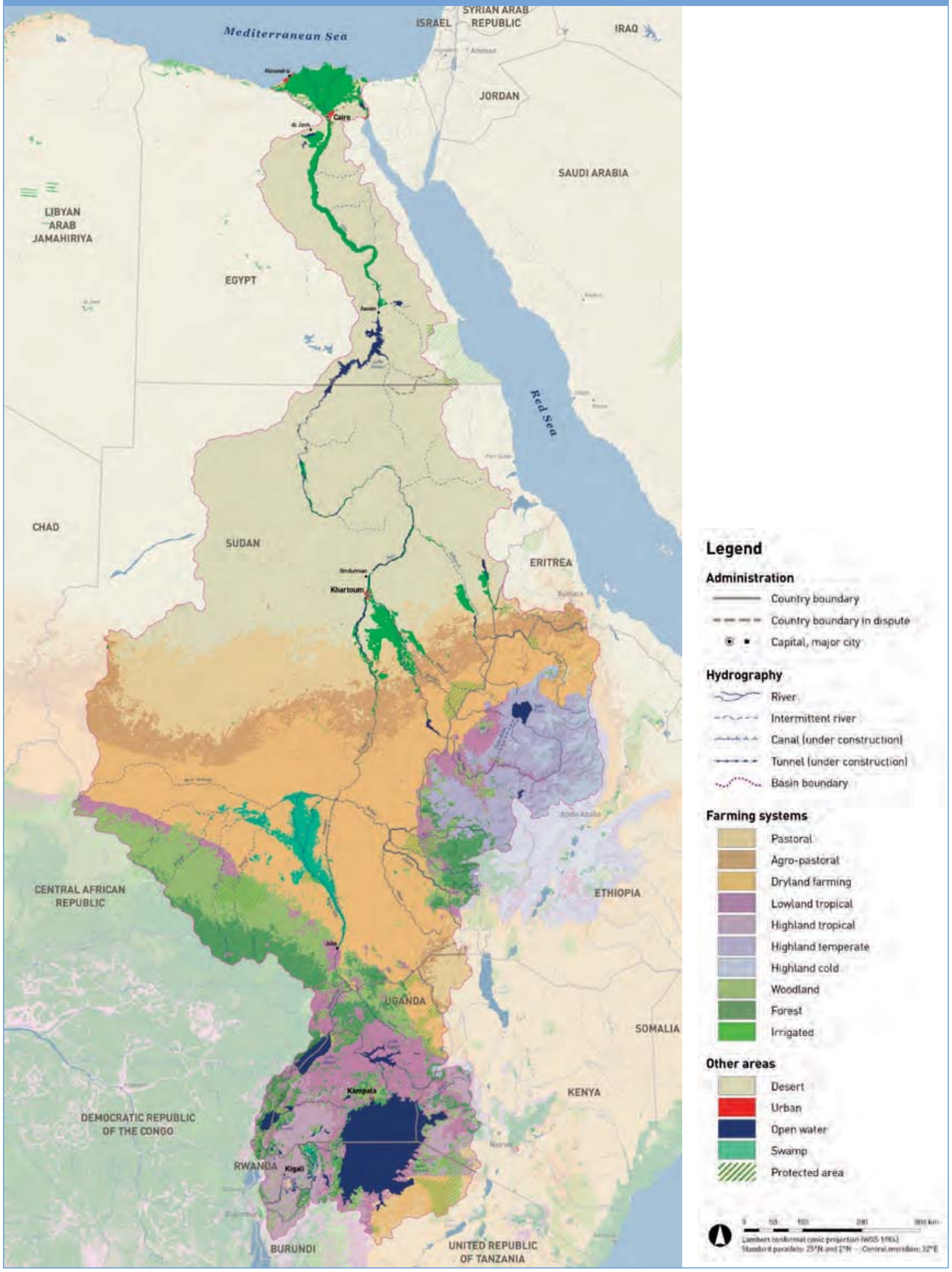
- Market-oriented agriculture (urban, peri-urban and commercial);
- Riverside.

The farming system is considered an appropriate criterion for the zonation of the basin for this synthesis as:

- It is the result of the interaction between cultural, agro-biological and socio-economic factors and the farmer's own priorities and resource capabilities. It reflects, better than any single criterion, the balance of factors important to identifying homogeneous zones.
- Farmers operating a similar system have, generally speaking, the same priorities and resource endowments and thus similar problems and development opportunities.
- It is the starting point for development; the foundation on which productivity improvements must be constructed.

A map showing the spatial distribution of the farming systems is presented in Figure 2; their occurrence in the basin countries is outlined in Tables 5 and general statistics are provided in Table 6.

Figure 2: Map of the Farming Systems of the Nile Basin



Irrigated (large-scale, traditional)

General Description

Large-scale traditional irrigated agriculture is practiced throughout the Nile Basin, excepting Burundi, Rwanda and the Democratic Republic of the Congo, with the major large-scale traditional systems located in Egypt and the Sudan (Figure 2 and Tables 5 & 6). Together with the small scale traditional irrigation categories, it covers 7.3 million ha or two percent of the basin, an area inhabited by over 56 million people (34 percent of the total) The average population density is 770/ha, with over 4.2 million ha of cropland, thus 0.08 ha cropland/person. This farming system is highly dependent on the availability of stored water and irrigation services.

The system is complex and, like any large-scale irrigation system, is centrally managed and generally mechanized. It is designed to use high levels of agrochemicals to maximize production, with full or partial water control. Crop failure is generally not a problem; consequently the incidence of poverty is lower than in other farming systems and the absolute numbers of poor are small. However, livelihoods are vulnerable to water shortages, breakdowns and higher input prices. In many cases, the crops grown on large-scale commercial traditional irrigated cropping areas are now supplemented by rainfed cropping and/or animal husbandry, added in recognition of the need to ensure local food security.

An emphasis on rehabilitation of existing schemes in the early 1980s has seen a reduction in the rate of expansion of these schemes, but rehabilitation has not been universally successful and still many state-run schemes remain in crisis. However, if the institutional problems can be solved, future agricultural growth through increasing yields and cropping intensities (with emphasis on avoiding widespread horizontal extension) would appear good given the state of global commodity markets.

Agricultural Productivity

The large-scale traditional irrigated farming system occupies about 1.86 million ha in the Sudan (Table 7), where five schemes (Gezira/ Managil, New Halfa, Rahad, Kenana Sugar, and Es Suki), totalling 1.2 million ha, dominate. The majority of the systems are gravity-supply schemes[4], which were originally owned and managed by the public sector [except for the Kenana sugar scheme]. The schemes are cultivated by thousands of tenant farmers, who grow almost all the country's cotton, most of its wheat, 35 percent of the groundnuts and 10 percent of the sorghum. The typical farm extends between six and 17 ha. Rotation requirements, the necessity to organize water distribution and the need to consolidate small plots under one crop into large areas, have led to the establishment of central management boards, who make the major production decisions, prescribe the cropping pattern and provide the necessary inputs.

Pump irrigation accounts for about 25 percent of the irrigated area. The range of crops grown on the bigger pump schemes on the White and Blue Niles are similar to

[4] The proportion of the irrigation sourced from surface waters, as opposed to groundwater (wells), was 96 percent in 1995. In 2000, 11 percent of the cultivated area in the Sudan was equipped for irrigation. However, between 1995 and 2000, the area with full or partial control fell at a rate of 0.9 %/year.

Table 5: Area of the Farming Systems in the Nile Basin Countries

Farming system	Area (ha) in Nile Basin	Egypt	the Sudan	Eritrea	Ethiopia	Kenya	Uganda	Dem. Rep. of the Congo	United Republic of Tanzania	Rwanda	Burundi
Irrigated (3 typologies)	7 312 675	3 884 949	2 774 226	21 404	438 976	107 865	15 895	0	2 125	50 660	16 575
Pastoral	29 673 966	237 043	25 459 986	676 745	229 907	1 875 865	63 070	11 815	1 085 535	34 000	0
Agro-pastoral	18 400 051	0	15 885 661	1 470 526	718 144	322 830	2 890	0	0	0	0
Dryland farming	64 745 370	0	52 868 341	153 859	8 669 630	66 555	1 627 580	765	1 358 640	0	0
Highland tropical	8 169 690	0	0	0	0	1 734 425	2 496 195	136 765	1 225 105	1 572 330	1 004 870
Highland cold	3 650 464	0	0	0	3 489 899	101 150	40 290	6 715	0	12 325	85
Highland temperate	13 224 484	0	2 614	0	13 221 870	0	0	0	0	0	0
Lowland tropical	17 986 563	0	2 915 301	0	3 763 967	1 189 490	8 467 190	294 440	1 355 750	0	425
Forest based	13 393 767	0	5 693 060	0	2 892 682	529 125	2 939 130	539 155	762 875	32 045	5 695
Woodland	18 429 032	64 268	12 360 950	0	1 749 479	400 945	2 592 670	36 890	854 165	154 360	21 5305
Market-Oriented Agriculture	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
River- or Lake-side	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Other land-use categories											
Protected areas	7 773 025	162 622	2 480 903	84 904	739 176	199 325	1 735 700	573 835	1 592 390	150 025	54 145
Swamps	3 787 863	0	3 568 818	0	0	14 110	60 775	0	125 545	17 595	1 020
Water	9 362 152	586 517	309 118	0	315 357	437 920	3 662 140	402 050	3 597 455	32 385	19 210
Cities	196 790	107 312	67 973	0	0	3 400	18 105	0	0	0	0
Desert	98 240 828	2 4817 829	73 354 310	48 134	18 260	0	0	0	340	1 955	0
Grand Total	**314 346 720**	**29 860 540**	**197 741 261**	**2 455 572**	**36 247 347**	**6 983 005**	**23 721 630**	**2 002 430**	**11 959 925**	**2 057 680**	**1 317 330**

Table 6: General Statistics by Farming System within the Nile Basin

Farming System	Area (ha)	Area (% of total)	Population (1000's)	Population density (per km^2)	Population (% of total)	Cropland (ha)	Cropland (% of total)	Cropland (% of area)	Cropland per inhabitant (ha/pers.)
Irrigated (sub-divided into 3 levels)	7 312 675	2	56 315	770	34	4 274 212	12	58	0.08
Pastoral	29 673 966	9	7 189	24	4	1 415 280	4	5	0.20
Agro-pastoral	18 400 051	6	3 119	17	2	6 613 428	18	36	2.12
Dryland Farming	64 745 370	21	9 169	14	6	7 971 337	22	12	0.87
Highland Tropical	8 169 690	3	18 289	224	11	3 085 776	9	38	0.17
Highland Temperate	13 224 484	4	12 473	94	8	3 588 573	10	27	0.29
Highland Cold	3 650 464	1	4 489	123	3	1 254 426	3	34	0.28
Forest	13 393 767	4	6 283	47	4	900 507	3	7	0.14
Woodland	18 429 032	6	5 323	29	3	769 724	2	4	0.14
Lowland Tropical	17 986 563	6	18 019	100	11	4 264 893	12	24	0.24
Market-Oriented Agriculture	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
River- or Lake-side	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Protected Areas	7 773 025	2	2 026	26	1	1 060 061	3	14	0.52
Swamps	3 787 863	1	672	18	0	37 986	0	1	0.06
Water	9 362 152	3	1 506	16	1	144 141	0	2	0.10
Cities	196 790	0	11 222	5703	7	35 753	0	18	0.00
Desert	98 240 828	31	7 860	8	5	554 713	2	1	0.07
Total	**314 346 720**	**100**	**163 954**	**52**	**100**	**35 970 810**	**100**	**11**	**0.22**

Note: Land-use highlighted in pink are not included in this review; farming systems in turquoise are too small and dispersed to appear on the map (Figure 2).

Table 7: Irrigation Systems, the Sudan		
Irrigation System	**Year**	**'000 ha**
Full or partial control	2000	1 731
Spate	2000	132
Area equipped for irrigation	2000	1 863
Area salinized	1999	199

Source: FAO AQUASTAT

Table 8: Areas of Irrigated Crops, the Sudan		
Crop	**Year**	**'000 ha**
Cotton	2000	167
Fodder	2000	142
Groundnuts	1989	91
Maize	2000	68
Other roots and tubers	2000	16
Potatoes	2000	16
Rice	2000	4
Sorghum	1989	355
Sugar cane	2000	70
Sunflower	2000	21
Vegetables	2000	97
Wheat	2000	103

Source: FAO AQUASTAT

those gravity irrigation systems, although the few big schemes in Khartoum, Nile and Northern States produce most of the Sudan's fruits, vegetables, winter legumes and spices.

There are small areas under flood/ spate irrigation in the two river deltas in eastern Sudan, which grown cotton, sorghum, millet and castor.

The combined Gezira/Managil gravity scheme, located between the Blue and the White Niles, constitutes one of the largest irrigation complexes in the world under single management (around 900 000 ha), with around 120 000 tenant farmers. The cropping patterns on the Gezira (and other) schemes must be consistent with the design of the irrigation system, specifically to ensure efficient water use. The present cropping pattern is the result of a rigidly set crop rotation over a five-year period. The current "five-course" crop rotation sequence in the Gezira has been used since the 1991/92 crop year and is as follows: cotton - sorghum - groundnuts - wheat (or winter fallow) – fallow. It is used Gezira-wide; while farmers can make a choice of which summer and winter crops they grow, they must grow cotton in designated areas in the summer, as decided by the Sudan Gezira Board (SGB).

In technical terms, the current rotation is regarded as a major advance on previous rotations, because:

- Following cotton with sorghum forces farmers to clean their fields quickly of disease-harbouring cotton plants in order to make timely preparations for planting sorghum.
- Following wheat with cotton (with a fallow year in between) allows cotton to benefit from the residual phosphorous and nitrogen fertilizers used for the wheat crop. [Only one crop is grown per year on a given area.]

In addition, fodder and grain crops, always secondary in such schemes, are irrigated irregularly with unscheduled deliveries of surplus water in the system, perhaps the result of rainfall.

In recent years, sorghum has become the main crop in terms of area in the Gezira Scheme with an average of 35 percent of total area planted, followed by wheat (25-30percent) but tending sharply downward, cotton (under 25 percent) and groundnuts (about 20 percent). Sorghum has occupied the largest area because it is both a fodder and a subsistence grain crop. However, cotton is the dominant crop due to its high value and hence returns for the SGB, as well as its importance to farmers for cash income and to the national economy for the foreign exchange it generates.

In contrast to the Sudan, only a small proportion of agricultural land in Uganda is irrigated; formal irrigated agriculture occupies a total area of only 6 500 ha, which is 0.1 percent of the total cultivated land area However, reports suggest that as the internally and externally generated water resources are currently underutilized, there are opportunities to increase this significantly (FAO Country Report: Uganda, 2008). The irrigation potential has been estimated by different consultants (1955–1997), but with figures ranging between 200 000 – 400 000 ha. The review under the Agricultural Water Use Survey by Mr. J.M. Ogwang revealed a potential of approximately 1 million ha comprising 350 000 ha of upland crops and 580 000 ha in wetlands. Accordingly, the total net irrigation requirement for crop production (paddy and upland crops) was 16.0 billion m^3/year. It is predicted that this could be tapped and utilized without impinging upon the water rights of other riparian countries in the Nile Basin given that the total amount of internally and externally generated water resources is 66 billion m^3/year.

About 70 percent of the formally planned irrigated area in Uganda is under lowland rice production, 23 percent under sugar cane, while the remaining seven percent is under vegetables, fruit trees (mangoes and citrus) and clonal coffee. Irrigation schemes range in size between 500 and 1 200 ha, large according to Ugandan standards. With rice the average paddy yield is 9 t/ ha but it has been noted that poor water management impacts substantially on lowland rice production, limiting yields to between 3.5 t/ha and 7.5-9.0 t/ha in the Doho Rice Scheme, and 2.4 t/ha to 6.2-7.0 t/ha in various smallholder schemes of eastern Uganda. Appropriate use of fertilizers (basal and top dressing) is much more effective when coupled with recommended water management practices and yields of 9 t/ha-12 t/ha are reportedly achievable under such treatment. In the Doho Rice Scheme, Thai advisors introduced rice-aquaculture three to four years ago and farmers are benefiting from both rice and fish farming, thereby improving local diets and increasing the range of produce for sale.

In Uganda under the FAO Technical Cooperation Programme, it has been demonstrated that clonal coffee yields could be increased threefold under irrigated agriculture, with similar results for fruit, leafy vegetables and green maize. These statistics exemplify the importance of this farming system in the country's economy. In total the system employs about 3.2 million people directly plus over two million indirectly (i.e. about 18 percent of the total population). The incidence of poverty, among these people is limited to moderate and with appropriate interventions the potential for growth is very high.

Water Management

Management of water in large-scale traditional irrigation schemes is critical to their productivity. Tables 9 and 10

Table 9: Field Water Requirements (m^3/ha/month) Gezira, the Sudan

Month	Cotton LS	Cotton MS	Groundnut	Wheat	Sorghum	Fruit & Veg.	Fodder	Monthly Total
Jan	1 723					1 768		3 491
Feb	1 399			555		1 887		3 841
Mar	250					2 368		2 618
Apr						2 559		2 559
May						2 801		2 801
Jun			2 873		1 904	2 818		7 595
Jul			885		643	1 664	2 637	5 829
Aug	445	328	1 166		1 266	1 157	923	5 286
Sep	864	1 645	1 759		1 787	1 621	1 047	8 723
Oct	2 104	2 813	962	612	1 035	2 044	1 202	10 772
Nov	2 116	2 535		1 564		1 799	1 081	9 094
Dec	1 956	1 480		1 754		1 699		6 890
Annual Total	**10 858**	**8 801**	**7 645**	**4 484**	**6 635**	**24 186**	**6 890**	**69 498**

Source: FAO Nile Country Report: the Sudan (2008)

Table 10: Peak Daily Water Requirements (m^3/ha/day), Gezira, the Sudan

Month	Cotton LS	Cotton MS	Groundnut	Wheat	Sorghum	Fruit & Veg.	Fodder	Monthly Total
Jan	55.7					57.1		112.8
Feb	50.0			19.8		67.4		137.1
Mar	8.1					76.4		84.5
Apr						85.2		85.2
May						90.4		90.4
Jun			95.7		63.5	94.0	87.8	341.1
Jul			28.6		20.7	53.6	29.8	132.6
Aug	14.3	10.7	37.6		40.9	37.4	33.8	174.7
Sep	28.8	54.7	58.5		59.5	54.0	40.0	295.6
Oct	67.8	90.7	30.9	19.8	33.3	65.9	34.7	343.2
Nov	70.4	86.9		52.1		60.0		269.4
Dec	63.1	50.9		56.6		54.7		225.4
Annual Total	**358.2**	**293.9**	**251.3**	**148.3**	**218.0**	**796.1**	**226.1**	**2 291.9**

Source: FAO Nile Country Report: the Sudan (2008)

demonstrate the complexities of the different monthly and daily water requirements for different crops, using the example of the Sudan. Table 9 shows that monthly requirements vary greatly (from 2 559 m^3/ha/month in April to 10 772 m^3/ha/month in October, that some crops only need some months of irrigation (cotton MS 5 months) while others need large amounts of water each month (fruit and vegetables).

Problems in water management are blamed for widespread underperformance in many schemes across the basin. For example, in the Sudan in 2000, the total area equipped for irrigation was 1 863 000 ha (Table 7). However, only about 801 000 ha (43 percent) of the total area was actually irrigated, owing to deterioration of infrastructures. In the Gezira Scheme, a complex mix of financial, technical and institutional problems resulted in a serious fall in the productivity of the scheme and a corresponding drop in farm incomes in the late 1990s, resulting in a drop of cropping intensity from 80 percent in 1991/92 to only 40 percent in 1998/99. About 126 000 ha were taken out of production owing to siltation Due also to poor management, water supply was reported to be about 12 percent below crop water requirements at crucial stages in the growth cycle, while at the same time as much as 30 percent of the water delivered was not used by crops. In some cases, the number of actual irrigations made available to farmers was less than recommended (Table 11). This has serious repercussions in all large-scale schemes, as it limits the uptake of other inputs (e.g. fertilizer) and directly reduces crop yields. Yet it could be resolved through improved maintenance of equipment.

Another important water supply constraint on crop yields in large-scale systems is the "head to tail" effect, where yields of all crops are lower at the tail of the system (Table 12). Again this is attributable to problems in the water delivery system, which are technically

Table 11: Actual and Recommended Number of Irrigations by Crop, Gezira, the Sudan

Crop	Actual	Recommended
Cotton	10-12	16
Wheat	5	8
Groundnut	5	8

Source: FAO Nile Country Report: the Sudan (2008)

Table 12: Yield Effects on Crops due to Distance from Water Source, the Sudan

Crop	Gezira Main		Managil	
	head	tail	head	tail
Cotton (k seed cotton/fed)	5.14	2.99	4.48	2.20
Wheat (t/fed)	0.57	0.39	0.41	0.30
Groundnut (t/fed)	0.40	0.31	0.45	0.27
Sorghum (t/fed)	0.51	0.35	0.47	0.39

Source: FAO Nile Country Report: the Sudan (2008)

resolvable and could result in major improvements in crop yields.

Increasingly, large-scale schemes (exemplified in Uganda) are attempting to better target precious irrigation water to maximize benefits. For example, supplementary irrigation using modern gun sprinklers and centre pivot irrigation systems is carried out on sugar cane seed material to enhance sprouting and take-off before the onset of the rains in the Kakira estate. Occasionally management applies supplementary irrigation in other stressed parts of the estate using the same technologies. Currently, for economic reasons, this is not used as widely in the 10 000-ha sugar cane estate as could have been expected on agronomic/water supply grounds as the incremental yield (30 percent) is not worth the effort when sugar prices remain stagnant.

Issues

All the riparian countries face the challenge of ensuring the utilization of their shares from the Nile water and securing their rights to satisfy their needs in expanding the irrigated sector. It is vital that attention is given to rationalizing and raising the efficiency of the use of water in irrigated agricultural production. The information already presented in this section demonstrates that the yield gap could be closed by improving the efficiency of the water delivery system.

Taking the Gezira scheme in the Sudan as an example, in the past cultivation was totally organized by the irrigation authority and the main responsibilities of the tenant farmers were to maintain bunds and control water distribution within their fields, while managing all aspects of groundnut production and organizing manual picking (often using hired labour). The cropping patterns in the Gezira scheme were adapted in 1990 to integrate livestock into the system by introducing growing fodder. But the desired integration was not achieved as the plan simply introduced fodder into the crop rotation without consideration of other production and marketing requirements for livestock.

In 1992, the Gezira scheme operation was profoundly affected by economic liberalization including withdrawal of the public sector from direct financing of agriculture, elimination of subsidies on crop production inputs and devolution of support services to the private sector. The prices of inputs to farmers rose sharply, especially for imported chemicals, but without a corresponding increase in product prices. Consequently, cropping areas and the general level of operations declined, while substantial financial deficits developed together with growing deterioration of operations. Shortage of water and lack of financial resources represented poor incentives, and the scheme suffered. In 1999, the Government embarked on a rehabilitation programme intended to reverse declining trends and restore production. This programme included much needed mechanisms to involve farmers in land and water management.

Theoretically, crop yields within an irrigation system should be much higher than in rainfed systems as water availability should be dependable, water stress eliminated and growth maximized through higher usage of other inputs. However, Table 13 clearly demonstrates that yields vary greatly from one year to the next on the Gezira scheme. Factors held to be responsible include: water shortages due to poor maintenance; inadequate and late application of fertilizers

Table 13: Actual Crop Yields (1997–2007) in the Gezira Scheme, the Sudan												
Crop	1997 - 1998	1998 - 1999	1999 - 2000	2000 - 2001	2001 - 2002	2002 - 2003	2003 - 2004	2004 - 2005	2005 - 2006	2006 - 2007	Ave. yield (per fed)	Ave. yield (per ha)
Groundnut (t/fed)	1.04	0.50	0.65	0.66	0.73	0.80	0.81	0.92	0.82	0.90	0.78	1.86
Cotton (k/fed)	4.48	4.42	2.57	4.47	5.25	5.05	3.51	4.30	4.09	3.20	4.13	9.84
Sorghum (t/fed)	1.04	0.79	0.67	0.95	0.98	0.98	0.83	1.06	0.90	1.02	0.92	2.19
Wheat (t/fed)	0.70	0.31	0.50	0.80	0.80	0.85	0.85	0.73	0.65	0.99	0.72	1.71

Source: FAO Nile Country Report: the Sudan (2008)

and pesticides; declining efficiency of farm machinery services; lack of information and technical guidance for farmers; insufficient financial resources and low farmgate prices. Comparison between the yields in Gezira in Tables 13 and 14 shows that although the yields for both sorghum and wheat are slightly above the national average yields for irrigated crops (2.19 and 1.71 t/ha respectively), they are well below the potential yields (3.8-5.7 t/ ha for sorghum and 3.3-4.1 t/ha for wheat), a yield gap of up to 3.51 t/ha for sorghum and 2.39 t/ha for wheat.

A report on the Gezira Scheme was prepared by the World Bank at the Government's request in 2000 to assess the main constraints on the sustainable development of the Gezira scheme and to develop short- medium- and long-term plans to address them. The report particularly showed that tenants were in financial difficulties. Most of the approximately 120 000 tenant farmers could not earn enough for their families from crops on a typical eight-ha irrigated farm. The majority of tenants did not consider higher yields and more intensive cropping systems feasible under the circumstances and preferred to rely on off-farm income. Farms had been left in the charge of relatively unmotivated hired labour; the low yields (cotton yields were about 1/3 of research yields) attest to this.

Table 14: Average Yields for Irrigated Crops, the Sudan		
Crop	Average Yield (t/ha)	Recommended (t/ha)
Millet	0.6	3.6
Sorghum	1.5	3.8 – 5.7
Wheat	1.6	3.3 – 4.1

Source: Agricultural Statistics Department, MOAF in FAO Nile Country Report: the Sudan (2008)

A recent survey of farmers highlighted 14 key problems in their livelihoods on the Gezira scheme (Table 15).

As at Gezira, the statistics for the Raha scheme (Table 16) demonstrate that there are major gaps in yields, not only between the minimum and maximum actual yields, but also between the maximum and the potential yields for the four crops. Notably,

Table 15: Farmers' Problems - Type and Frequency, Gezira, the Sudan		
Problem	No. of Farmers	%
Insufficient labour cash advance from SGB	11	20.0
Shortage/timing of irrigation water	9	16.4
Inadequate/late land preparation	9	16.4
Delayed payments for cotton crops	4	7.3
Inadequate pest control	4	7.3
Cleaning of Abu Ishreen	4	7.3
Health problems (malaria, bilharzia)	3	5.5
Water charges too high	2	3.6
Cost of spraying too high	2	3.6
Low returns	2	3.6
SGB should market production and protect prices	2	3.6
Improved varieties not available	1	1.8
Silting in canals	1	1.8
High taxes	1	1.8
Total	**55**	**100**

Source: PRA during study field visit for FAO Nile Country Report: the Sudan (2008)

Table 16: Potential and Actual Crop Yields in the Rahad Scheme, the Sudan					
Crop	Potential Yield (t/ha)	Minimum Actual Yield (t/ha)	% of Potential	Maximum Actual Yield (t/ha)	% of Potential
Groundnut	0.76	0.16	21	0.34	45
Sorghum	0.40	0.12	30	0.28	71
Wheat	0.60	0.10	17	0.38	63
	kantar/ha	**kantar/ha**		**kantar/ha**	
Cotton	3.6	1.2	32	2.9	80

Source: FAO AQUASTAT

the minimum actual wheat yield is only 17 percent of the potential and the maximum actual yield only 63 percent of the potential.

The figures in Table 16 demonstrate that there is significant potential to raise yields in existing schemes – through improved water- use efficiency and with appropriate management Raising the entire groundnut yields from 0.16 t/ha to 0.34 t/ha and/or all sorghum yields from 0.12 t/ha to 0.28 t/ ha would have a major impact on local food security and export earnings.

Some very specific crop-related issues (in addition to the issues in Table 15) have also emerged.

Cotton production is labour intensive; production requires 155-167 workdays/ha, but this is constrained by the lack of finance to hire labour. Since many farmers have very low liquidity, they are forced to minimize costs, especially on labour for crop establishment and maintenance, which is an out-of-pocket expense. This is especially damaging to yields as harvesting is the most labour-intensive phase of cotton production. In recent years, farmers report that advances paid by the scheme pay only a small portion of the labour costs for harvesting, with farmers financing the rest. As a result subsequent cotton planting is often late, which reduces yields.

Wheat was not a traditional crop in the Gezira, but the recent rapid rise in demand for wheat (stimulated to a large extent by the subsidized bread price) led to an expansion of production promoted by Government "crash programmes" in irrigation systems such as Gezira in the mid 1980s. In the early 1990s, wheat became a mandatory part of the four-crop, one fallow rotation. Wheat production in Gezira, however, has had many difficulties. Yields declined in the late 1990s because of poor land preparation and a loss of farmer confidence in being able to grow wheat profitably. Even in its best years, yields achieved were a little above half of their reasonable potential (Table 11). With liberalization of the market for all grains, imported wheat undercut domestic wheat and wheat farmers incurred losses. In crop year 1998/99 regulations changed and wheat cultivation was no longer mandatory. Farmers are now free to grow other winter crops such as sunflower and sesame, or vegetables in place of wheat.

Groundnuts, when grown in the standard rotation are seriously affected by termites. Termites develop in the sorghum stalks left from the previous year[5] and this negatively affects the groundnut crop which follows.

Sorghum has proved difficult to fit into the rotation and yields have been low (half of the potential – see Table 11), principally due to the termite problem.

The previously mentioned World Bank report on Gezira (FAO Nile Country Report: the Sudan, 2008) considered there were three main causes for the low yields of all crops:

- lack of funds for labour for crop management and harvesting;
- no formal financial credit facilities;
- shortage of irrigation water.

Following the recommendations in the World Bank report, a number of major changes have been made to the scheme and, with the 2005 Gezira Act, to the way it will operate. All the large traditional irrigation schemes in the Sudan are designed and run on the Gezira model.

Elsewhere in the Sudan and other Nile Basin countries, the main constraints limiting the development of the large-scale traditional irrigated farming system are:

- unsettled land rights (with the exception of Gezira);

[5] Sorghum stalks are left in the field longer because of their role as fodder, thus this problem remains unsolved

[6] In the fields and also in storage.

- inefficient water delivery systems;
- inadequate or mistimed use of inputs;
- inadequate water/input supplies;
- losses due to pests and diseases[6];
- limited choice of crops;
- poor maintenance of irrigation canals and control structures;
- poor water management resulting in huge water losses;
- inadequate farmer training/information services;
- inadequate financial and marketing services.

Opportunities

Across sub-Saharan Africa, public- sector irrigation schemes have generally been expensive to construct and maintain and their performance has been disappointing. Not only have predicted production increases been lower than anticipated, but systems have often been unsustainable due to low output prices and high operational and maintenance costs (e.g. the Gezira and the Awash Valley scheme in Ethiopia, (FAO and WB, 2001)).

Increasingly, economic liberalisation has led governments to attempt to restructure parastatal schemes on a commercial basis, or to hand over management to farmers in an effort to lower running and maintenance costs. This strategy has met with success only in the case of the *Office du Niger* (outside the Nile Basin, in Mali). The remaining options are to redesign systems as series of smaller, more manageable schemes, or to find private companies willing to operate them on a commercial basis.

Large-scale irrigation schemes are very important to national food security and agricultural growth in many Nile Basin countries. In view of environmental concerns it is preferable to focus on improving productivity (per ha and per m^3 of water) rather than on expansion of the area under irrigation – although many of the country reports (FAO Nile Country Reports, 2008) state that there is ample scope for such expansion in the region. The main household-level strategies to escape poverty in this system are intensifying production though more reliable water supplies and diversifying to higher-value products.

Assisting farmers to move into higher-value crops and to establish market linkages for inputs and outputs can address the low profitability of existing schemes. Improvement is also vital in product grading and packaging, in parallel with support for agro-processing of perishable products. It is also important to identify niche markets, for example organically-grown produce, as these bring higher economic returns and reduce environmental impacts.

For large, centrally-managed schemes, interventions should be supported by a clear policy for sustainable agricultural production, free of controls over production choices. Improvement measures should include: a transparent pricing system; clear management and beneficiary obligations; modernization and decentralization of agricultural support services; delegation of responsibility for managing schemes to water users' associations: and restructuring parastatal corporations along competitive commercial lines. In the short term, the priority should be to rehabilitate, re-equip and modernize irrigation and drainage systems. In the long term, if technically feasible, priority should be given to subdividing larger schemes into smaller units, to make it easier for scheme farmers to take over their management.

Productivity of the large-scale irrigation schemes in the Sudan and elsewhere in the Nile Basin, as well as the livelihoods of those who depend on it, could be substantially improved if farmers had greater responsibility in decision-making regarding land use, technology to be adopted and sourcing inputs. But they also need to have good extension services, reliable water supplies, access to new technologies[7] and marketing information.

Land tenure issues are critically important, particularly reform of the rules relating to land transfers, sales and consolidation. To improve the productivity of schemes (water use and crop yields), the question of the increasing numbers of absentee landlords must also be addressed as absentee land is reportedly farmed sub-optimally.

Scheme boards (e.g. Gezira) have been slow to examine the possibility of fundamental changes in cropping patterns, which many farmers would like to see. There is a clear distinction in farmers' minds between "tenants' crops" (legumes, vegetables, sorghum and groundnuts) which are money makers, and "government crops" (cotton and wheat), which are generally money losers.

Facilities for small-scale credit need to be developed to avoid the high interest payments required in the informal "Sheil" system. Credit facilities need to be developed so that sharecroppers and women farmers, who make up a growing proportion of farming communities, can access cheaper credit.

Asset ownership and diversification have proved beneficial for local livelihoods. Farmers and labourers who have cattle, sheep and goats are generally farming better, as they have an alternative income source as well as nutritional supplements from dairy production. Further encouragement of cattle and other livestock would greatly enhance the creation of buffers against poverty and adversity in the communities. Livestock can be fed on crop residues and by-products without additional water (see 4.3).

Development of fair and clear water pricing and management systems are critical to the success of the schemes. Currently there is no full appreciation among farmers of what a fair water price might be; however there is a view that the present system of fixed water charges is not working and is in need of reform. There is a clear need to align the price charged for water with the number of irrigations and the reliability of delivery.

Sharecroppers and others farming under many different kinds of private

[7] The range of new technologies includes hydro-flumes, land levelling and the implementation of precision farming.

arrangements need to have a say in water management and water payments so as to increase the efficiency of production at the farm level.

National-level policies have had considerable impact on this farming system. While their impact was positive in some sub-sectors (e.g. livestock), it was negative on the irrigated sub-sector. In many countries, large irrigated schemes were privatised without a transitional stage that could have paved the way for active private-sector involvement. Privatisation thus led to the degradation of irrigation infrastructure, the withdrawal of basic agricultural services, and a lack of alternative source of credit.

Irrigated (small-scale, traditional)

General Description

Traditional irrigation farmers in Egypt and the Sudan have used the waters of the Nile for centuries, taking advantage of the annual Nile flood. This continues into the 21st century and is practised in most of the basin countries. For example in Ethiopia traditional small-scale irrigation schemes have been established under self-help programs and initiatives by farmers' groups, with sizes varying from a few to 100 ha. Despite the fact that traditional small-scale systems are the most common in the basin, information on them remains sparse. Traditional irrigation is practiced in the different agro-ecological zones, making use of rivers, creeks or gully waters that can last up to three months in the dry season. These systems are less capital-intensive than large-scale ones and are managed by traditional community rules and water rights, which make them an integral part of indigenous farming systems.

Agricultural Productivity

Irrigated agriculture in the Ethiopian component of the Nile Basin is not well developed, but includes both traditional and modern small-scale systems. There is considerable variation in the types and mix of crops cultivated, cropping calendars, cropping intensities, water usage and productivity, depending on the agro-ecologies and socio-economic settings in which they operate.

The most common systems are traditional river diversions, although the number of pump irrigation systems has increased recently. The major driving forces that have led to an increase in the area of land under traditional small-scale irrigation in the basin are: growing pressure on land; inconsistency of rainfall patterns; the abolishment of collective land ownership; and production quotas.

The typical cropping pattern is:

- dry season: vegetables – principally potatoes, onions and peppers – from early September to 2nd week of April;
- wet season: all cereals – including barley, teff and rice – from early May to mid-November.

[8] onions, potatoes, peppers and tomatoes – for sale in urban areas.

Table 17: Comparison of Crop Yields and Costs under Existing and Improved Management in the Traditional Irrigated Farming Systems, Ethiopia)

Crop	Season	Yield in t/ha (under existing practices)	Cost in USD/t (under existing practices)	Yield in t/ha (under improved management)	Cost in USD/t (under improved management)
Maize	Dry	3	181.10	4	154.69
Pepper	Dry	4	301.10	6	218.31
Tomato	Dry	15	77.84	25	45.47
Potato	Dry	13	74.23	20	49.47
Rice	Wet	2	194.50	3	131.75
Teff	Wet	1.2	385.61	1.2	393.61
Oil crops	Wet	0.7	425.93	1	353.24

Source: FAO Nile Country Report: Ethiopia (2008)

In the irrigation schemes around Bahir Dar, the tendency is towards increased sugar cane as a permanent crop with vegetable production during the dry season and very limited cereals output in well- drained plots. Schemes in the Lake Tana area devote the wet season increasingly to rice production and to some other cereals while producing vegetables[8] during the dry season. Irrigated areas have developed around Addis Ababa to grow vegetables during both the wet and dry seasons to meet urban demand (with lower transport costs than Lake Tana produce).

The data in Table 17 illustrates the gap between yields currently achieved and predicted yields under improved management practices. The yields of all crops, apart from teff, have potential for increase through better water and agronomic practices. For example maize yields could be increased by 1 t/ha (33 percent), peppers by 2 t/ha (50 percent) and potatoes by seven t/ha (almost 50 percent). In all cases, apart again from for teff, improved management would significantly reduce the cost per tonne of production, with win-win benefits for farmers' incomes and local and national food security.

In Egypt, the total land area is around 1 million km^2 (100,145 million ha), and a small but growing percentage of the land is cultivated (all under irrigation). The total cultivated area was about 3.61 million ha (less than five percent) of the total area in 1996 and reached 6.22 million ha (over six percent) in 2006. Multi-cropping systems are common in all areas, with fodder and horticultural crops inter-cropped in some areas, leading to some of the most intensive crop rotations in the world[9] (see Annex 1). Average farm size is very small at less than 2.1 ha. Almost all the cultivated land use surface irrigation systems. An exception is a small area located in land newly reclaimed from the desert, where drip or sprinkler irrigation systems are practiced. Such practices benefit from accumulated

[9] More than one crop and sometimes three are planted annually on the same plot of land.

experience going back thousands of years, adapting cropping to the weather, availability of irrigation water and soil fertility.

Water is the greatest constraint on Egypt's agricultural production system, which is by far the largest user of water in the country. Agriculture depends on irrigation from the Nile, which accounts for more than 80 percent of total water resources. Rain provides a small percentage of Egypt's water, around the Nile delta.

In addition to water, the other factor directly constraining production is soil fertility. The demand for food and other agricultural commodities is increasing in Egypt due to population growth and improvements in living standards and diets. Farmers follow a number of traditional sustainable land management practices to improve crop yields and quality by restoring and maintaining soil fertility, including:

- Planting clover (berseem) as winter fodder before the cotton crop. After one or two cuts are taken it is ploughed into the ground as green manure.
- Incorporating farmyard manure into the soil during seed bed preparation. This is usually done before important cash crops such as cotton or maize are planted.
- Including a legume crop in the rotation (e.g. broad beans, clover or soybeans) which has a positive effect on soil fertility, providing nitrogen.
- Efforts are being made to increase the composting of agricultural residues in soils as organic matter improves their physical, chemical and biological properties.

Egypt is quite competitive in the production of horticulture crops and cotton and wheat. It is also moderately competitive in maize, beans, potatoes, long berseem and oilseeds. National production has increased over the past two decades, reflecting the success of various development projects which almost doubled the cropped area from 3.19 million ha in 1996 to 6.22 million ha in 2006, as well as increasing yields over the period (1993-2005). For most crops, yields are now relatively high compared with world averages and those of countries with similar agro-climatic conditions (Annex 1).

Although yields at the national level are relatively high, additional yield increases and narrowing yield gaps could be achieved through wider use of high-quality seed, greater mechanisation, strengthened extension support and better soil and water management. Performance on the new lands has been below expectations and the yield gaps are even higher there than elsewhere. Increased productivity in old and new lands could be achieved through better research and extension support along with better management as well as a proper marketing chain system.

In 2005/06, Egypt produced the world's top yields for sugar cane, rice, sesame and sorghum. It held second place for yields of groundnuts and broad beans. However, Egypt ranked only third and the fifth in lentil and wheat yields respectively, and tenth and 12th in maize and potato yields. Egypt has a relative advantage in producing cotton with high technological properties, which has allowed the country to become the world's number one producer. In recent years, the average yields of most planted crops have increased dramatically through wide implementation of recommended cultivation techniques.

The Egypt country report (2008) showed the increase in average productivity per hectare for most crops under study. The most impressive gains are reflected in average cereal yields:

- Average yield of wheat rose 24.1 percent to 6.5 t/ ha in the period 2003-2005 compared to 5.3 t/ha in 1993-1995.
- Average yield for summer rice rose 24.2 percent to9.9 t/ha in 2003-2005 from 7.9 t/ha in 1993-1995.
- Average yield for Nili rice increased 74.2 percent to 6.0 t/ ha in 2003-2005 from 3.4 t/ha in1993-1995.
- Average yield of summer maize rose 29.2 percent to 8.26 t/ha in 2003-2005 from 6.4 t/ha in 1993-1995.
- Average yield of Nili maize rose 25.6 percent to 6.0 t/ ha in 2003-2005 from 4.8 t/ha in1993-1995.

For legumes, the average yield of broad beans increased from 2.6 t/ha in (1993-1995) to 2.9 t/ha in 2003-2005, an increase of 13.7 percent. The average yields of lentil was 1.7 t/ha for the period 20032005, compared with 1.5 t/ha for the period 1993-1995, an increase of 18.08 percent.

For oil crops, the average yield of groundnuts rose from 2.7 t/ha in 1993-1995 to 3.2 t/ha in 2003 2005, an increase of 18.5 percent. Average yield of sesame increased 12.5 percent to 1.3 t/ha in 2003-2005 from 1.1 t/ha in 1993-1995.

Average cotton yield rose from 2.3 t/ha in 1993-1995 to 2.5 t/ ha in 2003-2005, an increase of 2.2 percent.

The average yield of flax climbed to 7.5 t/ha in 2003-2005 from 7.2 t/ha in1993-1995, a 4.5 percent increase.

The average yield of sugar cane increased from 108.5 t/ha for the period 1993-1995 to 119.8 t/ha for 2003-2005, an increase of 10.4 percent. For sugar beet, the average yield reached 48.7 t/ha in 2003-2005, compared with 45.7 t/ha in (1993-1995), an increase of 6.6 percent.

In Eritrea, the Nile Basin area is a major production region so the Government has given higher priority to development there than anywhere else.

- There are small irrigated areas (126 ha), mainly producing fruit and vegetables. Unlike the small-scale irrigation systems described above, water is obtained by farmers using shallow wells dug along the course of the Setit River (Table 19).
- Currently, there are two river diversions in the area, one at Anguliet and another at Deriesa (Table 19). Both diversions are designed as spate irrigation systems, each to irrigate about 3 000 ha of land. In 2007, smallholder farmers irrigated about 750 ha of cropland using the Anguliet diversion and average yields rose to about 1.5 t/ha, nearly tripple the national average of 0.53 t/ha (Annex 1). The Deriesa diversion is still under construction and is expected to be completed soon.
- The Gerest dam project, currently under construction, aims to irrigate 5 000 ha (under sprinkler) of farmland for wheat

Table 18: Cropped Areas (ha), Production (t) and Yields (t/ha) of Major Crops in Different Farming Systems (2005), Egypt

Crop	Irrigated Farming Systems			Rainfed Farming Systems			Groundwater Farming Systems		
	Cropped Area	Production	Yield	Cropped Area	Production	Yield	Cropped Area	Production	Yield
Winter Season Crops									
Wheat	12 052 000	79 680 600	6.61	272 900	635 100	2.33	213 400	1 093 900	5.13
Eg Clover	8 804 400	544 698 000	61.87	8 400	240 000	28.57	46 800	4 226 600	90.31
Barley	285 100	1 042 500	3.66	271 600	319 700	1.18	61 500	308 000	5.01
Br. Bean	880 350	2 869 600	3.26	17 900	51 400	2.87	31 100	97 300	3.13
Lentil	9 648	18 191	1.89	900	600	0.67	30	40	1.33
Fenugreek	62 410	140 530	2.25	0	0	0	500	700	1.40
Lupine	14 500	27 600	1.90	0	0	0	200	300	1.50
Chickpea	62 810	130 220	2.07	0	0	0	0	0	0
Flax	162 000	686 800	4.24	0	0	0	140	4 100	29.29
Sugar Beet	1 673 500	34 295 500	20.49	0	0	0	0	0	0
Total	**24 006 718**	-	-	**571,700**	-	-	**353,670**	-	-
Summer season Crops									
Maize	8 127 900	65 556 800	8.07	14 400	63 100	4.4	6 800	35 500	5.22
Rice	14 580 000	61 220 700	4.20	0	0	0	0	0	0
Soybean	197 500	255 000	1.29	0	0	0	3 400	3 200	0.94
Peanuts	594 800	1 922 800	3.23	500	1 800	3.60	26 300	68 800	2.62
Sesame	277 200	363 600	1.31	400	100	0.25	3 100	3 400	1.10
Sunflower	310 900	300 100	0.97	1 200	1 900	1.58	2 500	2 100	0.84
Sorghum	1 475 300	8 341 800	5.65	0	0	0	9 100	39 800	4.37
Total	**25 563 600**	-	-	**16 500**	-	-	**51 200**	-	-

(Continued)

Table 18: (Continued)

Crop	Irrigated Farming Systems			Rainfed Farming Systems			Groundwater Farming Systems		
	Cropped Area	Production	Yield	Cropped Area	Production	Yield	Cropped Area	Production	Yield
Nili season Crops									
Sesame	3 700	4 200	1.14	0	0	0	0	0	0
Sunflower	36 400	41 000	1.13	0	0	0	400	300	0.75
Peanuts	900	100	0.11	0	0	0	0	0	0
Total	**41,000**	-	-	**0**	-	-	**400**	-	-
Other Crops									
Vegetables	18 969 200	207 319 100	10.93	68 750	5 832 700	84.84	331 800	3 935 200	11.86
Orchards	11 977 700	98 784 400	8.25	145 290	3 893 200	26.80	95 000	195 700	2.06
Alfalfa	391 000	14 322 700	36.63	2 770	547 300	197.58	20 000	220 000	11.00
Cotton	2 756 500	6 433 600	2.33	0	0	0	1 100	1 800	1.64
Sugarcane	3 213 900	163 173 500	50.77	0	0	0	0	0	0
Total	**37 308 300**	-	-	**216 810**	-	-	**447 900**	-	-
Grand Total	**86 919 618**	-	-	**805 010**	-	-	**853 170**	-	-

Source: FAO Nile Country Report: Egypt (2008)

Table 19: Existing agricultural areas under irrigation or water control in the Nile Basin of Eritrea

Sub-Regional Administration (equivalent to District)	Scheme Name	Water Source	Type of Water Control	Geographical Location of the Water Control Facility (UTM-Coordinate)	Area Equipped for Irrigation (ha)	Area Actually Under Irrigation (Effectively Irrigated) (ha)	Description of Water Withdrawal and Conveyance (pumped and/or gravity)	Technology Used for Irrigation Water Application	Main Crops
Golluj	Anguliet	Surface water	Diversion	37261270 E 1632244 N	3 000	750	Gravity	Spate irrigation (supplementary)	sorghum, sesame
	Deriesa	Surface water	Diversion	37237561 E 1640290 N	3 000	Under Development	Gravity	Spate irrigation	?
	Gersset	Surface Water	Dam	37259653 E 1647809 N	5 000	Under Development	Pumped	Sprinkler	wheat and vegetables
	Small-scale horticultural	Groundwater	Shallow wells	Omhajer bank of Setit River	126	126	Pumped	Surface	vegetables and fruit

Source: NBI Eritrea Report (2008) from Eritrean Ministry of Land, Water and Environment

Table 20: Proportion of parcels under irrigation in Lake Victoria Basin, Kenya

Basin	Proportion of parcel under irrigation
Nzoia/Yala,	2%
Nyando/Sondu	0.4%
Gucha/Migori	0.8%
Northern/southern shoreline	0.7%
Basin	2.1%

production during the cold season from October to February and for vegetables during the warmer months from March to June. It is expected that the government will make infrastructure facilities available for irrigation, provide credit and supply inputs such as seeds, fertilizer, pesticides, tools and tractor services.

Studies are under way to investigate the potential to divert rivers for agricultural production in Shelalo and Adi Maekel.

Currently, only about two percent of land is irrigated in the Nile Basin area of Kenya (Table 20). Most of the existing schemes are well organised, benefiting from water users' associations, and grow lowland rice and horticultural crops. For the future, irrigation has been identified as the possible solution to the frequent food shortages facing Kenya. In its "Vision 2030" plan, the Government through the help of the stakeholders aims to bring 600 000 to 1 200 000 ha under irrigation. It is projected that with proper intervention a huge number of parcels could be brought under irrigation.

Smallholder schemes in Uganda range in area between 0.2-10 ha (small-scale) and 10-50 ha (medium. In Masaka District demonstrations of clonal coffee irrigation under motorized and pressurized systems have produced yields of 6.5t/ha, up from 2.5t/ha. Given the proximity of large-scale irrigation schemes at Doho and Kibimba, smallholders have adopted surface irrigation for lowland rice production in the eastern districts of Iganga, Bugiri, Palisa, Tororo, Buteleja and Sironko, covering an estimated total area of 78 000 ha with average paddy yields of 4t/ha).

In contrast to irrigation systems practiced in countries of the lower and mid-Nile, irrigation in hilly Rwanda is limited to reclaimed marshes and swamps which have thus ceased to exercise the valuable hydrological function of regulating downstream river flows. The total irrigated area in Rwanda is estimated to be 165 000 ha, of which 112 000 ha is on small marshes/swamps (each less than 200 ha) and 53 000 ha on large marshes/swamps (Figure 3). Within this total area, only 94 000 ha (57 percent of the total swamp area) is exploited – only eight percent of the cultivable land in the country.

Irrigated agriculture is considered highly important not only as it increases and assures crop yields, but also because it improves the quality of agricultural produce (e.g. the size and protein level of grains) and maximizes the efficacy of nitrogen fertilizer. It has been noted in Rwanda that irrigation can double or triple tomato yields.

Table 21 shows the yield gap between rainfed and irrigated production, demonstrating the enormous benefits which irrigation and correct use of inputs could bring to agriculture in Rwanda. However, it is important to appreciate the limitations in the extent of land suitable for irrigation available in Rwanda.

Water Management

Many different irrigation systems are used across the basin, from the traditional systems in the lower Nile, left over from the days when the Nile flooded annually. They include hand-operated Shaduf devices, water wheels and other ways of transferring water onto the fields along the

Table 21: Importance of Water on Crop Yields (2000-2003), Rwanda

Crop	Average Yields (kg/ha)	Average Yields with Irrigation (kg/ha)	Average Yields with Irrigation (t/ha)	Area of Crop (ha)	Rainfed Production (t)	Expected Production with Irrigation (t)	% Increase in Crop Production
Sorghum	994	2 982	3.0	141 433	140 584	421 753	200
Maize	781	2 343	2.3	30 107	23 514	70 541	200
Wheat	698	2 094	2.1	6 189	4 320	12 960	200
Rice	3 255	7 000	7.0	65 000	211 575	455 000	115
Beans	678	2 034	2.0	126 249	85 597	256 790	200
Peas	510	1 530	1.5	14 167	7 225	21 676	200
Groundnuts	613	1 839	1.8	5 219	3 199	9 598	200
Soya	532	1 596	1.6	13 821	7 353	22 058	200
Bananas	6 378	19 134	19.1	171 318	1 092 666	3 277 999	200
Potatoes	8 465	25 395	25.4	39 186	331 709	995 128	200
Sweet Potatoes	6 085	18 255	18.3	108 568	660 636	1 981 909	200
Coco-yam and yam	4 680	14 040	14.0	17 218	80 580	241 741	200
Cassava	6 900	20 700	20.7	65 573	452 454	1 357 361	200
Fruit and Vegetables	7 114	21 342	21.3	15 769	112 181	336 542	200

Source: adapted from FAO Nile Country Report: Rwanda (2008) water courses. Other small-scale systems include shallow wells dug along rivers, river diversions and spate irrigation schemes.

Being small, these systems suffer less from the major problems affecting larger ones, including distant management and farmers being reliant on organizations over which they have little control. However small size can also create different problems such as unreliable supplies which can have serious repercussions if climate or weather patterns change.

Issues

Most of the agricultural land in the hilly countries of the upper Nile, particularly in Rwanda and Burundi, is not suitable for irrigation, due to poor soils, sloping ground, elevation and distance from a dependable water supply.

Where irrigation is feasible in these and other countries, the traditional small-scale irrigation schemes are often widely scattered over remote and inaccessible areas. It makes It difficult to assure an adequate provision of supplies while also making it harder to access extension services and integrate into markets.

The delay in development of extensive areas of irrigated agriculture is attributed to:

- lack of pertinent primary economic data on crop response to irrigated agriculture, which would justify the viability of irrigation technology in the country
- limited capacity to promote and popularize the technology among smallholders

Opportunities

Development of small-scale irrigated agriculture has immense potential to contribute to agricultural growth and economic development, but this must be based on thorough analyses of the comparative advantages and sustainability of irrigated and rainfed systems determined for each location. Blanket approaches in irrigation development have many drawbacks. Ideally, irrigation projects should also be considered from the viewpoint of supplementing and supporting rainfed agriculture – notably using rainwater harvesting, and avoiding a massive extension of large-scale irrigation systems (3.1).

Looming water problems have focussed attention on water economics, crop water requirement and the efficient use of water to maximize yields in Egypt. Various other approaches could also be introduced more widely in the Nile Basin, notably re-use of treated water and use of drainage water.

Manipulation of biotechnology techniques in crop production could resolve some of the more complex problems.

With the relentless increase in population pressure, Egypt's farmers are being advised to save land and water. For sugar crops, sugar beet has been introduced as a substitute for sugar cane. This helps save land as sugar beet stays in the fields for only 6-7 months, compared to 12-18 months for sugar cane. Moreover, sugar beet requires only 8 to 9 waterings per crop, as against 30 or more for sugar cane. Sugar beet is clearly a water-saving crop.

Crops productivity could be increased in both the old and the newly-reclaimed areas through releasing improved varieties, along with their optimum cultural practices, plus high-quality seed and other inputs. In addition, with better involvement of extension, yield gaps could be narrowed or even closed. It is projected that the increases in food production required over the next two decades will be achieved through a combination of both yield increase and horizontal expansion of irrigated agriculture.

Table 22 shows the expected area, yield and production of some crops during 2007-2012 and 2012-2017. Major increases in area, yield and thus total production of the main cereal crops — wheat and maize — are expected. Sugar crops are expected to increase in yield and total production. However, due to water shortages, the area under sugar cane will remain around 121 800 ha. Other main crops including cotton, sunflower, rape, soybean and broad beans are expected to increase in area, yield and production.

Great efforts are currently being made to introduce high-yielding, early-maturing wheat varieties as well as high-yielding maize hybrids. This is likely to further shift the comparative advantage toward these crops. Also, the target of increasing productivity per unit of water and land could be accomplished by minimizing the gap between the currently grown varieties' potential yields and those achieved in practice. Developing fast-growing varieties which maintain higher-yielding

Table 22: Predicted Area (ha), yield (t) and Production (t/ha) of Selected Crops (2007-2012) and (2012-2017), Egypt

Crops	Item	(2007-2012)	(2012-2017)
Wheat	Area (ha)	1 197 001	1 470 001
	Yield (t/ha)	8.2	8.6
	Production (t)	9 815 408	12 597 909
Maize	Area (ha)	1 155 001	1 323 001
	Yield (t/ha)	9.3	10.0
	Production (t)	10 718 409	13 230 010
Rice	Area (ha)	420 000	420 000
	Yield (t/ha)	11.9	13.1
	Production (t)	5 000 000	5 500 000
Sugar cane	Area (ha)	121 800	121 800
	Yield (t/ha)	135.7	142.9
	Production (t)	16 530 000	17 400 000
Sugar beet	Area (ha)	84 000	126 000
	Yield (t/ha)	61.9	66.7
	Production (t)	5 200 000	8 400 000
Cotton	Area (ha)	420 000	441 000
	Yield (t/ha)	3.4	3.4
	Production (t)	1 417 500	1 496 250

Source: MALR, 2003. Ministry of Agriculture and Land Reclamation (MALR). The Strategy of Agricultural Development in Egypt Until the Year 2017, FAO, May 2003.

capacity would be another way of achieving the target.

Wherever irrigation is practiced, intensified production should be supported by appropriate use of yield- enhancing land management techniques, inputs and extension services.

To enhance the productivity and efficiency of water use in traditional small-scale irrigation systems, the following are critical:

- Development of appropriate designs.
- Improvement of extension services to provide access to up-to-date technical innovations.
- Support for the development of cooperatives and water users' associations.
- Selection of appropriate crops and cropping mixes.

Irrigated (commercial)

General Description

A number of large-scale irrigation schemes which are owned and operated by the private sector have been developed in recent decades.

Agricultural Productivity

In the Sudan, sugar production has grown relative to other major crops over the past few decades, more than tripling since 1980 (Figure 4). Sugar is well-suited to the Sudan because of the abundance of fertile delta lands between the Blue and White Niles and the intense sun and availability of water. This results in some of the highest sugar cane yields in the world (Figure 4). Since 1980, total production (partially due to increased area) and yields have doubled while production of irrigated sorghum has varied enormously from year to year while yields of sorghum and groundnuts have remained substantially constant (Figure 3).

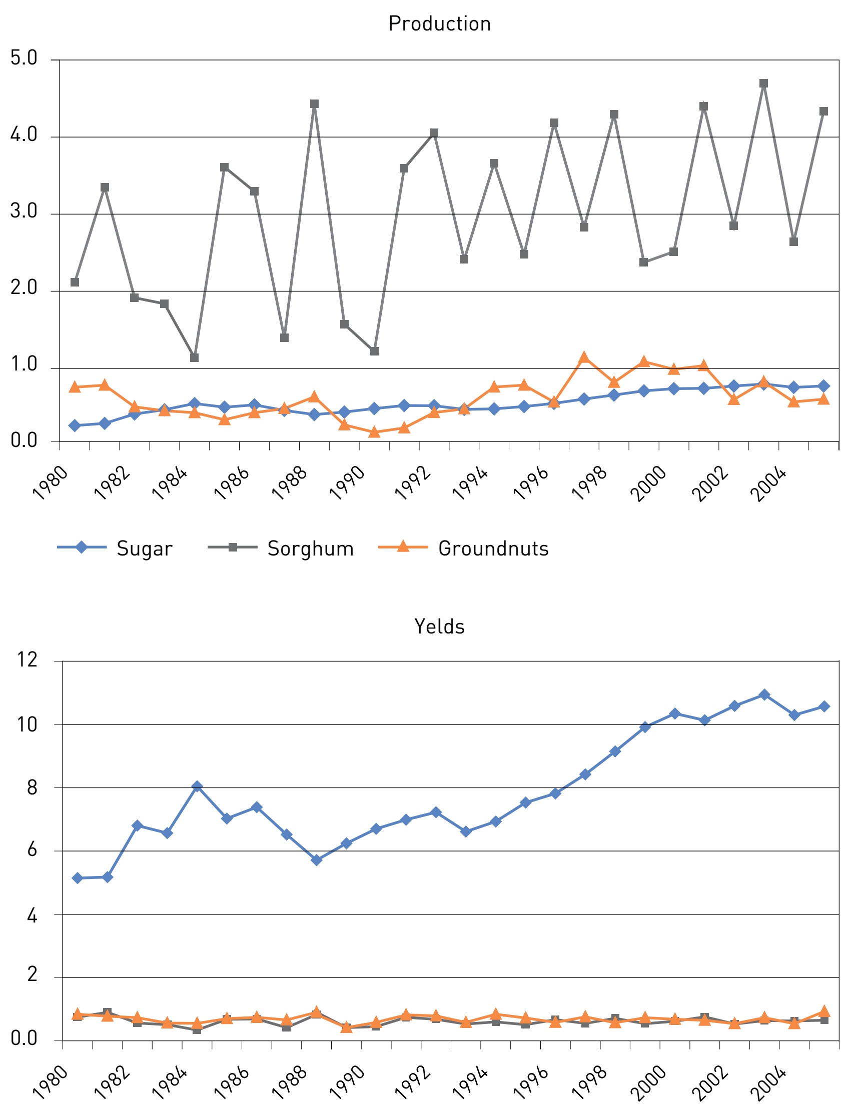
The prospects for sugar production in the Sudan are encouraging and there are plans for the expansion of areas controlled by the Kenana Sugar Co. and the Sudanese Sugar Corporation, as well as for the construction of new estates on both the Blue and White Niles. This will enable the Sudan to grow in importance as a sugar exporter and will have major benefits for populations around the sugar estates.

The five sugar companies in the Sudan Nile Basin currently employ roughly 15 000 permanent employees, 12 000 seasonal employees and 2 500 outgrower farmers. The jobs are sought-after by people living near the sugar factories and beyond because the wages paid are well above those for other local jobs – up to 3000 Sudanese dinars (15 United States dollars) a day for seasonal workers.

The sugar companies also provide services to local communities such as free schools, medical facilities, roads, and water for crops and household use. Such services are valuable and are often better than those offered by the government. This partially offsets the loss of land taken up by sugar companies and creates ties between them and communities. It also improves the living conditions of sugar company workers who often reside in nearby villages.

The Kenana sugar scheme in the Sudan is a gravity supply scheme. Owned and managed by the Kenana Sugar Company ("the world's largest integrated sugar company") it is the country's biggest producer. Once dubbed a "white elephant" by critics, the company is now 34 percent-owned by the Sudanese

Figure 3: Time Series Production and Yields of Sugar, Sorghum and Groundnuts (1980-2006), the Sudan



Source: Ministry of Agriculture and Forestry, and the Sudan Sugar Companies.

government, with the Kuwait Investment Authority holding 30 percent and the Saudi Arabian government 12 percent. This has proved vital for the stability and ultimate success of the project.

Latest information from the Kenana Sugar Co. indicates that the Sudan plans to more than triple sugar output within three years after sugar prices rose to record levels in 2009 (raw sugar rose by 98 percent in New

York and 77 percent in London) according to Bloomberg. Kenana was expected to lift its refined supply by about 40 percent to more than 600 000 tonnes in the crop year ending April 2010 and plants under construction across the country will take combined production from a current 900 000 tonnes to more than three million tonnes. With impressive potential in land, water and climate, the Sudan is recognized as having an important role to play in filling the gap between world sugar supply and demand for human consumption and bioethanol production.

In contrast to the Sudan, commercial agriculture is a relatively recent introduction in the basin in Ethiopia and its contribution to total agricultural production is therefore still small. Most of the large-scale farms are concentrated in the north-western lowlands of the basin, where agricultural machinery and fertilizers are used to grow a range of crops including flowers for export. Productivity on the farms is still low, as expertise must be built up, but prospects for increasing yields are good (FAO Nile Country Report: Ethiopia, 2008).

Egypt has begun to implement a series of giant horizontal expansion projects for commercial agriculture all over the country. The purpose of these mega projects is to increase agricultural production, improve national income distribution, generate employment in the project areas and achieve balanced development among various regions. They are the Toshka Project, the Al-Salam Canal Project, the Sharq Al-O'waynat Project and the Darb El-Arba'een Project.

In Uganda, commercial irrigation focuses on developing floriculture, using drip irrigation systems and greenhouses to grow flowers[10] all year round. The business has grown rapidly, covering a current total area of 220 ha with the potential to more than double to 550 ha within the next two years. Production of flower stems and cuttings and management of plant pots under drip irrigation is the most recent innovation, with hydroponic technology used in 70-80 percent of cases.

Flower exports earnings surged from USD27 million in 2006 to USD32 million in 2007. Production sites are centred on the Lake Victoria crescent, but in future the focus will target expansion to higher-altitude areas, where it is easier to produce larger flower buds, which are in greater demand.

In Kenya, it is estimated that over 212 616 ha of irrigable land exists in the Nile Basin, of which 37 230 ha is under irrigation and 38 882 ha is equipped with irrigation infrastructure. The numerous rivers in the basin which from time to time cause flooding and cause destruction of resources in the Nzoia/Yala and Nyando/Sondu sub-basins are viewed as indicating untapped potential for irrigation.

In terms of coverage, this is the smallest farming system in the basin. But it already plays a relevant role in local agriculture, supporting several thousand households and indirectly providing incomes for thousands of others who trade in the products which it produces. Surface irrigation (drawing on Lake Victoria waters and numerous rivers) is the most common

[10] Stems, cuttings and potted plants.

technology used to grow various types of crops including rice, horticultural crops, maize, sugar cane, beans, bananas and even cassava. The farm sizes are smaller than average (about one ha).

Rice is the major crop in this farming system and production levels vary from below 2.3 to 4.9 t/ha. Other crops include tomatoes and kales, with varying production levels as shown in Table 23. Despite the use of water for irrigation, production is not close to potential yield. This gap is attributed to current poor water management, lack of associated technological expertise and limited availability of inputs. If these issues are successfully addressed the gap would be closed.

Water Management

Whether large or small, modern commercial irrigation schemes use modern technologies to carefully control and gain maximum benefits (yields) from water.

Issues

Over-abstraction of water and reduction in water quality due to excessive use of fertilizers and pesticides are having negative impacts on land users downstream and on wider ecosystems.

Opportunities

The sequencing of these policy reforms is important because their success relies on the private sector to make necessary investments to import and export sugar. The government sugar companies will also need to increase their management staff in preparation for greater autonomy in operations. It is therefore essential that the government clearly signal its policy reform intentions and release a firm schedule for policy implementation.

Particular recommendations for the sugar cane growing system in the Sudan include:

- liberalisation of sugar imports subject only to VAT;
- elimination of excise duty on sugar to benefit consumers and industrial users of sugar;
- allowing domestic sugar prices to be determined by market forces;
- allowing sugar companies free access to export market opportunities in the EU, COMESA, and the regional market;
- reduce government involvement in the four state sugar companies by fully privatising them or allowing them greater autonomy in managing production and marketing.

Table 23: Average Current, Highest Attained and Potential Productions for Key Irrigated Crops, Kenya

Major Crops/ Enterprises in each Farming System	Average Production	Highest Attained Production in each Farming System	Potential Production in each Farming System
Rice (t/ha)	2.2	4.9	9
Tomatoes (t/ha)	14.1	23	30
Kale (t/ha)	9.6	20	30

Source: FAO Nile Country Report: Kenya (2008)

Pastoral

General Description

The environmental conditions which differentiate pastoral areas from the other rainfed farming systems of the Nile Basin include:

- altitude (below 1 500 m asl);
- average daily temperature 26 °C to 35 °C, in some areas reaching 45 °C;
- mean annual rainfall of 350 mm, with a single rainy season from July to October, although within this period rain is erratic and unevenly distributed (in time and space).

The climatic conditions lead to sparse vegetation cover (grassland, shrubs, also gum and resin trees) over often fragile soils, with a scarcity of surface water. The farming system can support only sparse human populations and is not suitable for rainfed crop production – only well adapted livestock. The system covers over 29.6 million ha (9%) of the Nile Basin inhabited by over 7 million people (4%), with a population density of 24/km^2.

The production system is governed by social and community laws concerning the management and utilization of natural resources. Deeply entrenched in the cultures and traditions of the different ethnic groups, such laws cover regulation of herd movements, utilization of water resources, conflict resolution and social justice.

Although there are profound similarities, the different ethnic groups practicing the system exhibit considerable differences in their overall enterprise patterns, seasonal movements and the other natural resource--based activities they may engage in for income. There are also wide variations in the level of integration of pastoralists into the market economy.

Typical pastoral family size is relatively large and has a high dependency ratio, mainly due to cultural factors. It is common for men to have more than one wife, which is believed to make mobility of livestock from place to place easier. Secondly, the nature of animal husbandry and the mobility of herds demand extended families in order to distribute the workload and defend economic and/or cultural/social interests. Better-off pastoral families with huge livestock resources create employment for poorer/marginalized families.

Agricultural Productivity

Livestock production in pastoral areas is dependent upon climate, vegetation and animal type. The main sources of feed in pastoral areas are grasses, shrubs and browse.

Pastoralists follow traditional management systems, which critically include the sustainable management and proper utilization of whatever forage and water is available to ensure the survival of their livestock. Customarily, pastoralists attempt wherever possible to avoid overgrazing so that pastureland has a chance to regenerate for the next season. In order to maintain their herds and the vegetation, pastoralists adopt distinctive management systems, including:

- Undertaking seasonal migrations in response to availability of grazing.
- Keeping different species of livestock, including small and large ruminants. Cattle and sheep are kept in areas with reasonably abundant water and where grazing species are predominant; goats and camels are reared in drier areas, where browse species predominate.

These strategies reduce the risk of herds succumbing to drought and lack of forage.

During the wet season there is normally ample forage and water, and pastoralists and their livestock stay In and around their permanent settlements. During the dry season, the situation is quite different. To satisfy feed and water requirements pastoralists are compelled to migrate to areas where they can be found.

Pastoralists generally do not practice any controlled livestock breeding programme. Bulls graze in the pastures with all females and consequently mating and calving can take place at any time of the year. This is also true of sheep and goats.

This farming system links up with the rest of the agricultural economy in that male cattle are sold to highland farmers for draft power. There is also linkage in the opposite direction as pastoralists import breeding bulls from the highlands to bring new blood into their herds.

Livestock provide a major portion of pastoralists' subsistence requirements (milk and meat) but also income from livestock products (meat, hides and skins) which are sold at the nearest markets and in neighbouring countries. The money serves to purchase grain and clothes and to pay for other necessities such as medical care, animal health charges, school fees and certain social commitments and taxes).

The pastoral and agropastoral production systems extend from the north-western to south-western parts of the Nile Basin. Table 24 shows the estimated livestock population in the combined pastoral and agro-pastoral systems of Ethiopia[11]. The average density of livestock in the farming system is 81.5 TLU/km^2. Livestock ownership is 5.19 TLU per person (30.01/hh). The breed of cattle kept is the indigenous "Barka" type, which is favoured for its meat and milk yield. Demand for this breed is steadily increasing in Ethiopia and other countries.

The average pastoral family generates its cash income from the sale of cattle, usually pregnant cows, to urban dwellers to provide dairy products for personal consumption and/or for dairy farms. The same goes for oxen and goats. As mentioned earlier, this has been a lucrative business in the pastoral areas of the Nile Basin since local development-oriented associations and local/regional NGOs began to promote 'Barka' cows with loans from micro-finance institutions. In addition families also collect gum and incense from the forest, and take firewood, forest honey and bales of long grasses to market. The income generated is around 25 000 Ethiopian Birrs (USD25.7) a year.

On average, each pastoral family consumes more than 3 litres of milk a day and slaughters at least 5–6 goats annually for meat.

Despite being well-endowed with resources, pastoral families lack marketing, education and health infrastructure and services. Considering the endemic nature of malaria in the area, families spend significant amounts of cash income on medical care. School enrolment of pastoralist children is

[11] One Tropical Livestock Unit (TLU) is 1.28 cattle or 8.82 sheep, 10 goats, 1.52 horses, donkeys, mules, camels (camels and donkeys are used for transporting goods and people).

Table 24: Livestock Ownership in the Pastoral/Agropastoral Systems, Ethiopia				
Type	TLU	Density TLU/km^2	Livestock Holding	
			Per Person	Per Household
Cattle	908 534	70.90	4.52	26.10
Sheep	26 321	2.05	0.13	0.76
Goats	24 460	1.91	0.12	0.70
Horses	13 507	1.05	0.07	0.39
Donkeys	67 532	5.27	0.34	1.94
Mules	3 749	0.29	0.02	0.11
Camels	398	0.03	0.002	0.01
Total	**1 044 501**	**81.51**	**5.19**	**30.01**

Source: FAO Nile Country Report: Ethiopia (2008)

Table 25: Livestock Feed Requirement in the Pastoral/Agropastoral Systems, Ethiopia		
Type	Population (TLU)	Feed Requirement ('000 t)
Cattle	908 534	2 071.46
Sheep	26 321	60.01
Goats	24 460	55.77
Horses	13 507	30.80
Donkeys	67 532	153.97
Mules	3 749	8.55
Camels	398	30.18
Total	**1 044 501**	**2 410.74**

Source: FAO Nile Country Report: Ethiopia (2008)

lowest compared with children from families practicing other farming systems, due to lack of cash for school fees and their mobile lifestyle.

Similarly, in the Sudan pastoral system herds are raised entirely on natural rangelands and are mainly semi-nomadic. Households move with their animals and have no permanent base on which to grow crops. They spend the rainy season in the northern, semi-desert zone (Makharaf) because both pasture and water are to be found there and because of unfavourable conditions (mud and biting insects) in the dry-season grazing areas. In the dry season, they move further south into the savannah (Masyaf) (Figure 4).

In the central and eastern states, migration is towards the Nile during the rainy season and back during the dry season. Movement to the north is along traditional routes (Masarat or Maraheel) from the dry season endpoint (Masyaf) to the wet-season base camp (Makharaf). As an example of a traditional route, the Hawazma tribe of southern Kordofan moves within the area between El-Obied (Makharaf) in the north to the southern reaches of the Nuba Mountains (Masyaf). The onset of early rains in May-June signals the start of northward migration lasting until the end of July or early August. Pastoralists spend two months of the wet season camping in the vicinity of El-Obied; and for the rest of the period they are either on the move or in the dry season camping site in the southern reaches of the Nuba Mountains.

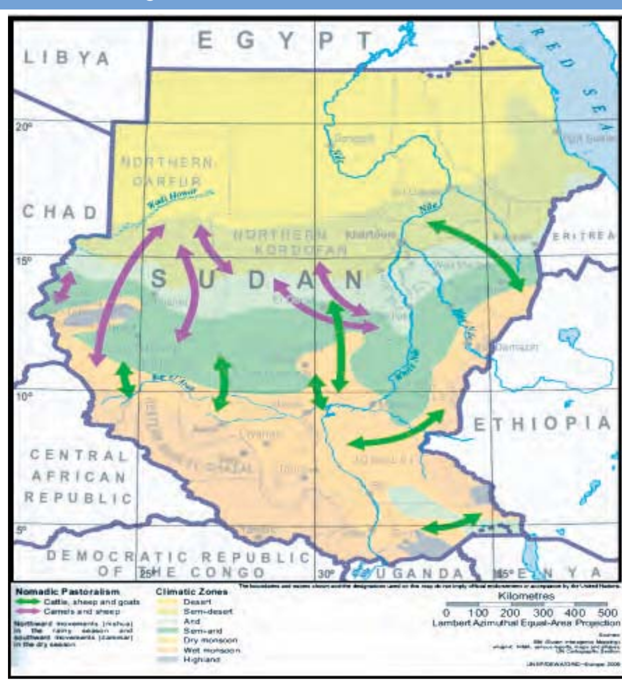
Meanwhile the Rizeigat tribe of southern Darfur (Figure 5) spend two months in the area north and east of Nyala (Makharaf or in wet-season bases around Nyala, El-Deain and Abu Matariq) for the rest of the period they are either on the move between the dry- and wet-seasons migratory ends or in the dry-season base in the Bahr El-Arab area in southern the Sudan.

At national level total livestock population is about 53.5 million AU. On this basis, demand for dry matter is 176 million tonnes and water requirements 550.5 million m^3 per year (Table 26). There is therefore a current shortage of 71.6 million tonnes (a 41 percent shortfall) of dry matter for feed (Table 26).

In common with elsewhere in the Nile Basin (and across the Sahel), pastoralists' incomes are derived from the sale of animals, meat and milk in the form of white cheese. The system is characterized by low input and low technology, but overall it supports a very large number of animals and utilizes the vast area of rangeland which extends over seven ecological zones in the Sudan alone.

As in the Sudan and Ethiopia, livestock production in the Nile Basin part of Eritrea is a traditional extensive production system, characterized by low productivity, seasonal

Figure 4: Annual Pastoral Migration Routes, the Sudan



Source: FAO Nile Country Report: the Sudan (2008)

Table 26: Feed and Drinking Water Requirements of AU of Different Livestock Species (per year), the Sudan			
Source	**AU ('000s)**	**Dry Matter (3.3 t/unit/yr) ('000s t)**	**Drinking Water (10.3 m^3/unit/yr) ('000s)**
Cattle	40 994	135 280	422 238
Sheep	5 039	16 629	51 902
Goats	4 276	14 111	44 043
Camels	3 137	10 352	32 311
Total	**53 481**	**176 372**	**550 494**

Source: FAO Nile Country Report: the Sudan (2008)

Table 27: Livestock Feed Balance	
Source	**Dry Matter (million tonnes)**
Requirement	176.4
Quantity Available	104.8
Deficient	71.6
% of Deficiency	41%
Basin	2.1%

Source: FAO Nile Country Report: the Sudan (2008)

livestock migration and use of large areas of land per animal unit – which is often concluded to be an ineffective and inefficient use of water and feed resources. Herders in the arid lowland agro-ecological zone are traditional nomadic and semi-sedentary pastoralists, with livestock representing their main livelihood. During the dry season (April-June) in Eritrea, pastoralists migrate with their livestock to the banks of the Setit River in search of water and feed, mainly going to areas such as Ayterf, Kachero, Gemel Merafae, Maeluba and Sandashna which offer good grazing.

The main livestock types are cattle, sheep and goats, with small numbers of donkeys, camels and poultry. In the Nile Basin area of the country (173 993 ha of rangeland), pastoralists and agropastoralists keep an estimated 352 104 TLU. The rangeland is characterized by relatively higher rainfall (300-700 mm) and reasonably fertile soil, which supports the growth of palatable vegetation during the rainy season (May-October). The main source of animal feed is rainfed rangeland; however a few farmers have started to use commercial products during the dry season.

According to the farmers interviewed for the FAO Nile Country Report: Eritrea (2008), over the last ten years the population of small ruminants, particularly sheep, has increased. The reasons given are that sheep are hardier, reproduce easily and achieve better market prices. Simultaneously, the cattle population has declined, which is attributed to lack of feed and water.

The major livestock products (milk, meat and eggs) are the main source of protein for local people. Interviewed farmers indicated that, on average, local cows, does and ewes produce 3.3, 0.8 and 0.8 litres of milk/ day respectively. These are very low figures, which demonstrate that there is potential to increase yields significantly both through improved husbandry and also by concentrating on keeping the Barka and Hassan land races, which have higher yield potential. Currently, any excess liquid milk is processed to butter for household consumption by the traditional churning methods.

A range of factors limit livestock production, including shortages of water and animal feed, animal diseases, fire damage to rangeland, lack of capital, and lack of milk collection and storage facilities.

Water Management

Pastoral farming systems are highly dependent on rainfall as livestock graze on rainfed rangelands. Both herders and their livestock obtain water from rivers, lake, ponds, wells and dry riverbeds (known in Ethiopia as "chirosh") along their traditional livestock migration routes. The ponds only have water for about one month at the beginning of the dry season. Dry riverbeds are used throughout the dry season, although as it advances the pastoralists travel up-stream and have to dig deeper to find water. Some water is available all year round from permanent rivers, lakes and wells.

Water requirements for livestock depend on many factors but increases particularly with dry matter intake and temperature. In the Nile Basin area of Eritrea for example, annual temperatures range from 20 to 45 °C, with an average of 25-29 °C. The water requirement per kg of dry matter consumed by one TLU of animal at between 25 and 29 °C and at over 29 °C is 4.7 and 5.5 litres respectively. From this it can be concluded that the lower and upper limit water requirement for drinking per TLU/day is 35 litres (0.035 m^3) and 55 litres (0.055 m^3) respectively. Thus the upper limit of drinking water required annually by the total livestock population in the Nile Basin of Eritrea is almost 7 million m^3.

It is important to bear in mind that drinking water is not the only limiting factor to livestock production. Water is also crucial to grow animal feed and Astatke and Peden (2005) estimated the amount of water needed annually for that purpose to be about 450 m^3/TLU, which is 1.23 m^3/TLU/day, thus approaching 153 million m^3. Table 28 gives details of annual water and feed demand for this farming system.

An assessment for Ethiopia shows that the livestock drinking water requirement in the Ethiopian area of this farming system alone is some 12.12 million m^3 per year (Table 29). Extrapolating from the figures for Eritrea the total water requirement to sustain livestock would be around 282 million m^3 per year.

Issues

The pastoral rangelands are used and managed communally. Consequently households tend to maximize their livestock holdings[12]. Growth in human populations has corresponded with a decline in the area of rangeland due to the expansion of urban areas and encroachment of both traditional and mechanized agriculture. This has resulted in concentration of livestock on ever-smaller areas of land and, in some cases, the closure of traditional livestock migration routes – leading to the overgrazing of the rangelands.

[12] Traditionally pastoralists hold their wealth in livestock. They are therefore reluctant to sell livestock and are more concerned with increasing the numbers of head than improving the quality of their herds.

Table 28: Total Tropical Livestock Unit, Water and Feed Demand by Livestock Species in the Nile Basin, Eritrea

Livestock Type	Total population	TLU	Total TLU	Daily water demand[13] (m^3)		Annual water demand (m^3)		Annual feed demand (t)
				Lower limit (1.27m^3)	Upper limit (1.29m^3)	Lower limit	Upper limit	Upper limit
Cattle	271 061	1.00	271 061	344 248	349 669	125 650 327	127 629 072	989 373
Sheep	171 892	0.10	17 189	21 830	22 174	7 968 054	8 093 535	62 741
Goats	176 752	0.10	17 675	22,448	22 801	8 193 339	8 322 368	64 514
Camel	14 101	1.40	19 741	25 072	25 466	9 151 126	9 295 238	72 056
Donkey	26 437	0.50	13 219	16 788	17 052	6 127 436	6 223 931	48 248
Poultry	65 992	0.008	528	670	681	244 708	248 562	1 927
Total	**726 235**		**339 413**	**431 055**	**437 843**	**157 334 989**	**159 812 705**	**1 238 858**

Source: FAO Nile Country Report: Eritrea (2008)

In the Sudan, as elsewhere in the basin, the per capita consumption of milk is only 50 percent of that recommended by FAO. This is largely attributed to the low productivity of the local breeds of cattle, sheep, goats and camels. At the same time rangeland in the Sudan has been subject to recurrent drought during the last three decades while the livestock population increased 30 percent from 103 million head in 1997 to 134 million in 2004.

With low rainfall over pastoral areas there is little opportunity for growing supplementary feed, and dry season shortages are a chronic problem.

Pastoral areas are highly vulnerable not only to droughts but also to floods, which are increasing in frequency and severity with climate change. Combined with growing livestock numbers, the droughts exacerbate the problems of finding enough water along migration routes, particularly during the summer months.

The rangelands are prone to fires, both natural and set by humans. Fires have some benefits, notably clearing shrubs and encouraging new herb growth. However, fires also result in capping on the soil surface, which inhibits rainfall infiltration, limiting soil moisture and vegetative growth and causing overland flow. Topsoil is removed, resulting in high silt content in water courses, with consequent flash flooding.

The combination of issues in Eritrea demonstrates the complexities of the problems facing pastoralists in the 21st century. Although animal feed availability is relatively good in the basin area compared to other parts of the country, it is not enough to feed the current high number of livestock all year round.

[13] In the case of pregnant cows the quantity of water required is multiplied by 1.5 and for lactating cows is increased by 0.87 litre per kg of milk produced.

Table 29: Livestock Drinking Water Requirement in the Pastoral/Agropastoral System, Ethiopia

Livestock Type	Rate/Yr (m^3)	Population	Water Requirement ('000 m^3)
Cattle	9.125	1 164 788	10 628.69
Sheep	1.825	263 205	480.35
Goats	1.825	244 599	446.39
Horses	4.38	20 465	89.64
Donkeys	4.38	102 321	448.17
Mules	4.38	5 681	24.88
Camels	10.95	604	6.61
Total		**1 801 663**	**12 124.73**

Source: FAO Nile Country Report: Ethiopia (2008)

This shortage is compounded by recent droughts, the over-frequent burning of grazing areas[14] and the scarcity of water points. In those areas where animal feed is abundant into the dry season, there is an acute shortage of water, triggering migration of animals to other parts of the country. As a result, rangelands with plenty of feed can remain ungrazed from year to year, which may result in other forms of degradation (invasion of shrubby vegetation and Alien Invasive Plants (AIPs).

Pastoralists depend on locally collected wood for fuel. As the numbers of pastoralists per km^2 increases, this is leading to accelerating rates of deforestation, denuding the rangelands of trees which are a vital component of the systems. They provide shade for people and livestock, cycle soil nutrients and are a habitat for important biodiversity (including functional agrobiodiversity such as bees and birds).

People and livestock are particularly vulnerable to diseases in remote pastoral areas where the infrastructure is very poor, and consequently social, medical and veterinary services are also poor. Infrastructure creates further enormous challenges for families including access, to transport and communications, education, markets and appropriate new technologies.

An important feature of this system is that when animal feed is scarce during the dry season, farmers are often forced to sell some of their animals when they are in poor condition and thus fetch low prices.

Market shocks in recent years have adversely affected pastoral livelihoods, as have the negative impacts of taxes on animal production and export in some countries.

Local conflicts for pasture and water, including both inter-clan disputes and conflicts between crop producers and livestock herders, and lack of security in border areas further impact adversely on pastoral livelihoods. Yet this system is probably the one that can best cope with the uncertainties of living in such challenging environments.

[14] According to the Ministry of Agriculture report, in 2007, nearly 30 000 ha of grazing rangelands were burned in Eritrea.

The case of the Sudan exemplifies many of the above issues; the area available for pastoralists has been subjected to considerable reduction due to horizontal expansion of mechanized, rainfed cultivation. Together with drought and the increasing numbers of livestock per km^2 it is leading to widespread land degradation exacerbated by the growing numbers of livestock.

Conflicts often occur over use of the resources, particularly as most of the rangelands are used communally, with no codified land tenure system. The SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of the traditional livestock production system in the Sudan (Table 30) indicates that it has more weaknesses and shortcomings than strengths. Although weaknesses can be improved, the cost would be very high and beyond the means of the herders. Government intervention is therefore needed. The most important threats are droughts, which are increasing in frequency due to climate change and are having even greater impact due to land degradation.

Opportunities

The local livestock and forage resources, local experience in livestock production and the traditional livestock management systems are some of the potentially valuable aspects of this farming system which should be capitalised on in pastoral area development. Such traditional knowledge should be shared, especially with neighbouring agropastoralists and dryland farmers who are experiencing increasingly erratic rainfall due to climate change.

Some of the possible interventions which would contribute to increasing the sustainability of this traditional farming system include:

- Rehabilitate and increase yields of pastures by undertaking minor Soil and Water Conservation (SWC) activities to reduce rainfall run-off and loss of topsoil; re-seed degraded areas, including using N-fixing legumes and possibly inorganic fertilizer to correct nutrient imbalances.
- development of fodder banks;
- development of reliable water supplies for livestock and people, including water-harvesting along stock routes;
- formation of marketing groups and farmer capacity building;
- establishment of abattoirs and tanneries;
- development of agro-processing (e.g. to prolong the shelf-life of produce);
- restock with small ruminants in drought-affected areas;
- weed and bush control;
- enact (if necessary) and enforce limitations on rangeland burning;
- Improve animal health services – including training "para"-vets, particularly to help control endemic diseases and advise on improving the genetic quality of stock.
- Encourage increased off-take and smaller herd sizes.
- Education and training (for children, young people and adults);
- infrastructure development including livestock markets and related facilities (e.g. shade, sanitation, cold stores);
- Promoting non–farm incomes from shrubs and livestock-based diversification (improving honey production would be one major way of improving the livelihoods of agropastoralists. Emerging livestock and game ranching, including crocodiles, ostrich, snakes and several types of birds would be another).

The rangelands of the Nile Basin in Eritrea have vast potential for animal

Table 30: SWOT Analysis for the Traditional Pastoral Farming System, the Sudan

Strengths	Weaknesses
• Uses vast areas of land, which if left un- or under-utilized would become more degraded. • A large-scale rotational grazing area which can be sustainable, is ecologically efficient and helps maintain biodiversity. • Provides "free" livestock feed.	• Seasonal water and feed shortages. • Animals always on the move, stressing animals and predisposing them to diseases. • Livestock have low genetic potential and no genetic improvement programs have been implemented. • Mud and biting flies prevent utilization of some parts of rangeland during rainy season. • High mortality rates among young stock. • Being always on the move does not permit application of strategic feeding and modern technologies to augment reproductive performance. • Animal growth is slow: consequently animals attain marketable weights and start reproduction at relatively old ages. • Marketing livestock is seasonal and takes place when animals move to their wet-season grazing grounds. • Export of livestock raised under the system is complicated by the fact that supplies are not continuous throughout the year and the quality of meat is poor. • Social constraints: large numbers of animals are kept for prestige rather than production and as a result annual off-take rate is low.
Opportunities	**Threats**
• Provide stock water by drilling wells and rainwater harvesting systems. • Conserve surplus rangeland grasses for dry-season feeding. • Introduce new pasture species and tropical legume forages to improve grazing quality and increase yield. • Apply inorganic fertilizer to improve rangelands yield and quality. • Irrigate pasture. • Select and breed from animal landraces which perform well under current rangeland conditions.	• Decreasing area of rangeland available (due to expansion of arable agriculture and urban areas). • Recurrent droughts. • Degradation of rangeland resulting from overstocking. • Degradation of rangeland resulting from frequent fires. • Large-scale commercial growing of feedstock for biofuel (e.g. jatropha) could further reduce area available for grazing.

Source: Elsamani (2008)

grazing. Livestock from different part of the country already migrate to this region during the dry season. An opportunity exists to establish an intensive grazing rangeland management system, which could increase the sustainable carrying capacity of the pastures, through improving soil fertility (e.g. introducing nitrogen-fixing legumes); seeding with more productive and palatable grasses; encouraging the practice of rotational grazing ("holistic grazing management"); control of the frequency of rangeland burning and construction of water points.

There has been a small rangeland management project in the Eritrean part of the basin since 2006, promoting semi-intensive rangeland development across an area of 2 000 ha, with the capacity to graze more than 1 000 cattle. The main activities of the project are: repairing a macro-dam, construction of new macro-dams, and sowing of new selected varieties of grasses ("Abertata", "Dgela") and trees (Ziziphus spina christi and Leuceana leucosephala). The beneficial results of this project should be scaled up.

Options also exist to promote expansion of the modern livestock sector, as intensive production for export is gaining favour in many countries. This includes rainwater harvesting to support increased pasture productivity (possibly irrigated pasture), introduction of the modern technologies in the feed industry, breeding, and expansion of the delivery of extension services (either by the public or private sector). Introducing of integrated crop-livestock production systems in areas which have potential for irrigation (e.g. Gerset dam, Kachero, Tekezu, and Biakonda through diversion from the Setit River in Eritrea) would support intensive dairy and meat production.

Nevertheless, this does not mean that all pastoralists should become settled farmers. Indeed experts in adaptation to climate change advise that the nomadic systems can best adapt to the predicted impacts in rangelands. Strengthening the attachment of the pastoralists to their land through polices that enable them to participate in planning and implementing programs related to agricultural transformation should bring beneficial results. This should include holistic grazing management – to restore a more natural pattern of grazing (intense for short periods, followed by time for recovery).

Efforts are required to encourage livestock herders to keep smaller but more profitable herds through increasing off-take, which also require improve market integration.

The development of such a farming system will raise standards of living and promote food security by supplying more meat and dairy products for the pastoralists and agropastoralists, some of the poorest people in the Nile Basin. It would also supply much-needed high-protein food to local, national and export markets.

Agropastoral

General Description

The agropastoral farming system is found under conditions fairly similar to those of the pastoral system, the key difference being the slightly greater availability of water. It is a semi-nomadic livelihood in which livestock production is dominant (see Figure 2 and Tables 5 & 6). Crops are grown, but play a less significant role than in most other farming systems as moisture stress is a critical limiting factor on crop production. As in the pastoral farming system, livestock production Is the major source of food and income (milk, meat, also hides and skins). Milk is sold at markets in nearby small towns and settlements during peak periods of production.

This farming systems covers over 18 million ha (six percent) of the basin, with over three million people (two percent thus 17/km^2, with 6.6 million ha of cropland (2.12 ha/person).

Agricultural Productivity

The average family's cultivated landholding is small, in contrast to their average grazing land. Each family usually cultivates a number of small areas at different locations along their annual migration route, often managed by members of their extended family. The main crops are sorghum and maize, the former being preferred. However, yields are low (estimated at less than 0.5 t/household/year) and of poor quality. While not marketable it does provide the families' main staple food, along with bread, milk and milk products such as yoghurt). Sesame and pulses are also grown by some agropastoralists, often as cash crops.

The rainfed crop production is based on the traditional practice of shifting cultivation, with slash-and-burn clearing used to turn rangeland into farm plots. After 2-3 years of crop production, plots are abandoned as soil fertility has been depleted and the agropastoralists move to new areas. Land preparation is carried out using oxen and/ or hand tools depending on the area. Sloping areas with light soil are usually cultivated with hand tools and usually only a single ploughing is carried out. Some farmers use branches, twigs and sticks to level their plots. Opportunistic crop production along river banks and during seasons of favourable rainfall is also practiced.

The agropastoral production system in Ethiopia extends from the north-western to south-western parts of the Nile Basin. It is practiced along riverbanks in particular and in areas neighbouring the pasture zones which receive slightly higher rainfall (FAO Nile Country Report: Ethiopia, 2008). The average family owns between 1.0–1.5 ha of cultivated land although more land is often available for exploitation if required. They also own a minimum of 6 cattle and more than 6 goats. The main reason for increasing crop production in this farming system is the ever-rising farmgate price of cash-generating crops such as sesame. Secondly, land is available for families to grow crops, mainly because of relatively stable rainfall patterns and the potential for small-scale irrigation systems, either through rainwater harvesting or diversion of streams and rivers.

Recently, due to the increased demand for live animals in the international market. households have also started to concentrate on rearing goats to increase their cash income. Incomes have effectively risen and the average number of goats kept per family is increasing significantly.

The main crops grown are sesame, cotton and sorghum. Minor crops are vegetables[15] and fruit. Production per household is 0.9 tonnes of sorghum, 0.15 tonnes of cotton and 0.45 tonnes of sesame. Milk production amounts to 24 litres/hh/day. Sorghum is the preferred staple and is grown mainly for home consumption. Sale of sesame, cotton and livestock (cattle

[15] Cabbage, pumpkin, maize, green beans, peas and yam are grown around settlements. Only local varieties are planted and no agricultural inputs are used.

and goats) are major sources of cash. Additional cash is obtained from sale of fruit and vegetables, honey, gum and incense, firewood and grasses.Household food supply is adequate due to the diversified range of income sources.

In Kenya, land ownership is mainly communal within this farming system and can exceed 1 000 ha per clan/community. Very little agricultural land has a formal title deed, making it difficult to get loans for land improvements from financial institutions. The communities in all sub-basins keep indigenous livestock; these are the principal source of livelihood. Cattle are the source of cash for all household needs (from milk, meat, hides and skins) and take priority over all other activities including crop farming. The grazing system is communal and nomadic, with high levels of conflict between farming and pastoral communities. In addition to the traditional free grazing/migratory patterns, a number of ranches have been set up in the area recently.

As in the pastoral farming system, most of the farmers view their livestock as a "moving bank" and only sell their animals when they need cash for expenses such as medical bills. In times of drought, hundreds of livestock die and agropastoralist have to restock.

Water Management

Livestock in the agropastoral farming system obtain water from rivers, lake, ponds, wells and dry riverbeds (known in Ethiopia as chirosh).

The ponds are used for a period of about one month at the beginning of the dry season.

Dry riverbeds are used during the dry season. As it advances the agropastoralists travel upstream and have to dig deeper into riverbeds to find water for their livestock.

Water from the permanent rivers, lakes and wells is available year-round in some places. Agropastoralists particularly benefit from being able to graze their animals along the perennial Nile tributaries, which helps them cope in drought periods.

Issues

The major challenges in the farming system include ecological disturbance and land degradation associated with slash-and-burn shifting cultivation, moisture stress and lack of adequate water supply, human and livestock diseases, livestock feed shortages during the dry season and poor infrastructure.

Recent increases in the numbers of livestock being kept in the system across the basin, coinciding with reduction in the areas available for grazing (due to expansion of settled agriculture) is exacerbating the impacts of recent droughts.

As in pastoral areas, the main constraints in this farming system include:

- sociologic factors: reluctance of agropastoralists to sell their livestock;
- transport and communication;
- marketing;
- livestock diseases;
- land tenure;
- inter-clan disputes;
- disputes between agropastoralists and settled farmers;
- lack of security in border areas;
- low rainfall, which limits opportunities for growing supplementary forage/ fodder.

The main source of vulnerability is drought, leading to crop failure, weak animals and the distress sale of assets.

The poor state of the infrastructure is a challenge in this farming system as farmers need inputs at the right time and also need to transport their produce to market in good condition. With poor roads, farmers depend on middlemen to buy their milk (and cereals and legume grains too), usually at a low price – often far less than the cost of production. The middlemen reap the profits, especially as during the planting season they may sell seed to the farmers at twice the price.

There is inadequate market information and almost no formal marketing system. Use of farm inputs such as fertilizer, certified seeds and pesticides is minimal except in isolated cases. Food self-sufficiency is quite low but in good years households have enough cash to buy food from selling their livestock. The small ruminants are first to be disposed of to meet immediate household needs and cows are sold later if the need persists.

A further challenge to this farming system in Kenya is the presence of large number of wildlife due to proximity to the national parks and game reserves. There is high incident of human/ livestock/wildlife conflict.

Opportunities

As with pastoral areas, the local livestock and forage resources, local experience in livestock production and the traditional management systems are some of the potentials of the farming system that should be capitalised on in development.

Some of the possible interventions to improve the situation in this farming system include:

- rehabilitate and increase yields of pastures (undertaking vegetative SLM and minor SWC activities to restore soil functioning, which will reduce rainfall run-off and loss of topsoil and also increase water storage in the topsoil;
- re-seed degraded areas, including with N-fixing legumes and possibly inorganic fertilizer to correct nutrient imbalances) (World Bank, 2009);
- develop fodder banks;
- develop reliable water supplies for livestock and people – including water harvesting along stock routes;
- formation of marketing groups and farmer capacity building;
- establishment of abattoirs and tanneries;
- development of agro-processing to prolong the shelf-life of produce;
- restock with small ruminants in drought-affected areas;
- weed and bush control;
- enact and enforce limitations on rangeland burning if necessary;
- improve human health services;
- improve animal health services – including training "para-vets", particularly to help control endemic diseases and advise on improving the genetic quality of stock;
- education and training (for children, young people and adults);
- infrastructure development;
- encouraging increased off-take and smaller herd sizes, livestock markets and related facilities (e.g. shade, sanitation, cold stores);
- promoting non–farm incomes from shrubs and from livestock-based diversification (improving honey production would be one way to improve livelihoods for agropastoralists significantly. Emerging livestock and game ranching, including crocodiles, ostrich, snakes and several types of birds, would be another.

Dryland Farming

General Description

Dryland farming is undertaken in rangelands ecosystems where there is sufficient soil moisture or groundwater to allow settled farming. The system has many similarities with the agropastoral model, the main difference being in the relative importance of the arable and livestock components. In dryland farming crops are more important. It is practiced widely across the Nile Basin (Figure 2) in a wide range of ecological zones (semi-desert to high rainfall savannah), in Eritrea, Ethiopia, the Sudan, Uganda and the United Republic of Tanzania. Soils used vary from light shallow soils in upper positions in the landscapes to dark clay soils and alluvial deposits in the flat bottomlands and valley bottoms. The farming system covers almost 65 million ha (21%) of the basin, with over nine million (six%) of the population, and average population density of 14/km^2. It covers almost eight million ha of cropland (22% of the basin's total), with 0.87 ha/person (Table 6).

Agricultural Productivity

This system is rainfed, based on mixed crops, and is practiced in altitude ranges of 500-1 500 m asl. Sorghum production, mainly for local consumption, dominates but crops such as pearl millet, finger millet, maize, cassava, groundnuts, sesame and some vegetables are grown. Drought-tolerant varieties of teff (in Ethiopia), wheat and other oil crops are grown in some areas.

Household livestock holdings tend to be large and Includee cattle, sheep, goats and donkeys. Oxen are the main draught power for cultivation, which is mainly carried out withtraditional ploughs. The livestock in the system are primarily indigenous, with some particular local distinctions. Notably, the cattle include Barka (Begait); Arado (cows can produce up to 4 litres of milk per day, with an average of one litre/day); Fogera (yielding up to 340 kg of milk per six-month lactation).

Livestock management in the farming system is traditional, but with distinct local variations[16]. Livestock are kept around residential and crop areas throughout the year. Herders take livestock out for grazing each day, returning to the homestead at sunset or later. The livestock in this farming system depend on forage from local rangelands (grasses, legumes, shrubs, bushes and trees), supplemented by some fodder (crop residues). Bees are abundant in the shrubs in this farming system and communities are also involved in beekeeping.

The areas of the dryland farming system which are known to be food self-sufficient or produce a surplus are generally those where land holdings are larger (over 0.5 ha/hh).

Subsistence food production is supplemented by cash income, significantly contributing to better livelihoods, generated from:

- cattle and small ruminants;
- fruit such as bananas, mangos, honey, spices and coffee;
- commodities like sesame, a high- value crop producing export earnings;
- off-farm activities, such as the sale of firewood.

The food-insecure areas are found where the average family has less than 0.5 ha

[16] There are numerous distinct husbandry practices with respect to herding, housing, feeding and breeding of livestock.

of land and in households which lack draught power. They produce only around 0.5 tonnes of crops annually (most of which is for home consumption). Ownership of small ruminants and poultry is the main source of cash income. Other sources of cash are wage labour (either locally or, if not available, further afield). In addition, household members engage in petty trade, such as selling firewood and may be beneficiaries of "cash for work" schemes or find employment in construction works in nearby towns.

This farming system is found extensively in the Sudan (about 8.4 million ha), in almost all parts of the country. It includes millions of small-scale subsistence farmers, who grow sorghum, pearl millet, finger millet, cassava or maize for food, and sesame, groundnut and some minor crops for cash. They usually keep some goats, but also sheep and/or cattle. They depend mostly on family labour, use locally-made hand tools in farming, grow their favoured livestock landraces and save their own seeds after harvest for the following season. Generally they use no fertilizers or pesticides. The farms, which are privately owned and operated, vary considerably in size, which is the key factor in determining whether farming households are food-secure (see earlier section). These farmers, with their varied traditions, diverse ecological zones of production and conservatism, are the great custodians of germplasm diversity.

Table 31, shows the areas harvested, production and average yields from 1999 to 20030. It demonstrates the inter-annual variation in the areas planted to, and the yields of, sorghum, which is the staple food crop. Yields range from 0.41 to 1.15 t/ha compared with a national average of 0.63 t/ha – see Annex 1. The areas harvested for the other food crops also fluctuated during the period, but with some positive trends in yields (e.g. millet from 0.20 t/ha to 0.23 t/ha as against a national average of 0.27 t/ha).

The system is exemplified by the sedentary cattle owners of Darfur and Kordofan, who also grow a range of crops. During the wet season, these dryland farmers graze their animals during the daytime on rangeland near their homesteads and then bring all their cattle back to spend the night at their base. This continues until shortly after the end of the wet season, when the harvest is brought in. For the remaining part of the year cattle are allowed to roam freely, grazing the stubble, grain stalks and weeds, clearing the ground and spreading manure. The milk produced by the cattle is a valuable source of protein for local consumption.

It is estimated that the annual production of forage in the Sudan is around 81 million tonnes and that the livestock which depend on the forage number around 48 million AU. Therefore, the available forage produced per animal unit is around 1.7 t/year compared to the 1.8–2.2 t/year required.

The basin in Eritrea has vast dry farmlands, with fertile soils and large grazing areas. It is one of the major crop and livestock producing areas of the country, often referred as the "bread basket" of Eritrea. A wide range of crops such as sorghum, pearl millet, finger millet, maize and sesame is grown. Sorghum is the major staple crop, grown by small holder farmers, private and parastatal farmers. The smallholder farmers also produce sesame for cash and for traditional sesame oil processing. Pearl millet is cultivated by the Kunama and Nara ethnic group as this crop is their staple food. Finger millet is cultivated to make a local drink and also as source of cash, as it fetches a higher price than other cereals.

Farmers rely on local crop varieties that have been used for generations. They are adapted to local conditions (climate, soil, pests and diseases) but have limited yield potential. The seeding rate used varies widely within crops and rotations are limited to sorghum, pearl millet and sesame. Legumes are not grown in the basin.

Crop yields ultimately depend on the weather during the growing season, and especially on the distribution of the rainfall. In years of good rains (>450 mm, with good distribution) sorghum can yield 1.0-2.0 t/ha. However, poor rains can bring yields down to 0.3-0.6 t/ha.

Crop plants require different quantities of water depending on the species. In the Nile Basin of Eritrea, the major crops are cereals, oil crops, vegetables and fruit (Table 32). Cereals and oil crops (sesame) are cultivated during the rainy season from June to October. Sesame and pearl millet have a growing period of 70-90 days with 80-100 days for sorghum. Vegetables need 145-180 days, including seedling raising and transplanting. Fruit are perennial crops that require water throughout the year to developt and ripen.

The water requirement for cereals and sesame ranges from 357-484 mm per growing season. The rainfall data of the basin shows that it has a high level of variability but in most years is less than 450 mm. And even when the rainfall is above average (i.e. more than 500 mm), its distribution is erratic, ranging from a low of 3-5 mm – not enough to wet the soil – to a high of 40-60 mm on the same day., In general rainfall in the basin is not enough for crop production without supplemental irrigation or use of early maturing crops/ varieties (40-60 days). Vegetable and fruit crops are currently cultivated under irrigation from wells dug along the bank of the Setit River. Production of these crops requires large amounts of water (range 733-1 913 mm), as these crops are cultivated during the dry season, when the rate of evapotranspiration is very high (Table 32).

Table 31: Performance of Major Crops in Dryland Farming System (1999-2003), the Sudan

Crop	1999-2000			2000-2001			2001-2002			2001-2002		
	Area ('000 ha)	Prod. ('000 t)	Yield (t/ha)	Area ('000 ha)	Prod. ('000 t)	Yield (t/ha)	Area ('000 ha)	Prod. ('000 t)	Yield (t/ha)	Area ('000 ha)	Prod. ('000 t)	Yield (t/ha)
Sorghum	2 111	1 013	0.48	1 704	699	0.41	2 252	2 590	1.15	1 739	956	0.55
Millet	2 310	462	0.2	2 145	450	0.21	2 805	561	0.2	2 371	545	0.23
Sesame	769	85	0.11	583	58	0.1	681	102	0.15	605	79	0.13
Groundnut	1 401	827	0.59	1 353	744	0.55	1 487	877	0.59	1 382	774	0.56

Source: FAO Nile Country Report: the Sudan (2008) from Department of Agriculture Statistics General Administration for Planning & Agricultural Economics, Ministry of Agricultural & Forestry (2004)

The yields of the crops for the area (2002-2007) show a high level of inter-annual variation (Table 33). The yields for all crops were higher in 2005-2007 and lower during the period 2002-2004 as most of the farmers were evacuated and temporarily sheltered in Adi Keshi. In 2005, 2006 and 2007 the basin had good rainfall in terms of both distribution and amount, which is reflected in the yields. Cost-benefit analysis comparing a bad year (2004, with a poor yield attributable to poor rains season) and a good year such as 2007 (with good distribution of rainfall and a higher yield) for Golluj sub zoba showed that the benefit for the good year was 52 percent or USD280.47 (4 207 Nakfa) while in bad year it was only 1.7 percent or 2.67USD (40 Nakfa) per ha (Table 33).

With good rainfall, farmers produce more grain than they consume and sale of grain covers their taxes and enables them to buy and pay for essentials. However, during a poor rainy season production is very low, not enough to cover food consumption until next season. In order to ensure food security and that enough is produced to generate an income, better use of rainwater is vital.

The MoA strategy for the Nile Basin of Eritrea is to maximize production through intensive crop management. The main strategic crops for the area for 2007-2009 are: sesame, sorghum, maize, beans and groundnuts. These crops will be produced for import substitution, to provide raw materials for industries and for export. The MoA provides periodic training to farmers on crop production and protection, supplies inputs like pesticides and offers tractor services to maximize production.

Water Management

The main sources of water for livestock are seasonal springs, ponds, hand-dug wells and boreholes as well as perennial rivers. Intermittent rivers, streams and flood water also provide water in the wet season and the early weeks of the dry season. When they dry up, water is available under dry river beds. Springs provide water mainly during the wet season, but could also extend into the dry season for a short period.

Most of the crops grown in this farming system are rainfed, although some rainwater harvesting is already undertaken. Table 34 reveals the wide range and generally low levels (compared to the national average, detailed in Annex 1) of crop yields achieved in this farming system in the Sudan. In the case of sorghum, for example, yields in North Kordofan and Darfur are only 26 percent of the national rainfed average. Yet South Kordofan and Darfur achieve yields of 76 percent of the national average. The pattern for water productivity (kg/m^3) is similar; the southern states achieve 63 percent and the northern 38 percent respectively. The variation in crop yields and water productivity are smaller in the case of groundnuts and traditional sesame. However, contrary to many expectations, mechanized sesame does not achieve yields much higher than traditional sesame per m^3 of water or per workday. Tractors are not a panacea for higher yields.

Issues

A number of constraints limit the ability of farmers in this farming system to ensure household food security or contribute to food security at the national level. These include:

- short and long-term droughts;
- low productivity due to limited adoption of modern technologies;
- use of local crop varieties and landraces
- lack of inputs;

- crop pests (including Striga) and diseases;
- insufficient fodder and forage;
- deforestation;
- animal diseases;
- lack of rural savings and credit institutions;
- marketing bottlenecks;
- inadequate research and extension services;
- inadequate physical infrastructure (roads, water supply);
- inadequate safe water resources (for humans and livestock).

Table 32: Crop Water Requirement Values of the Common Crops, Vegetables and Fruits, Eritrea

Crop	Total length of growing period	Plant date	CWR (ETo) (mm/growing season)
Sorghum	100	June/July	416
Sesame	90	June	386
Pearl millet	90	June/July	357
Finger millet	110	June	409
Maize	110	June	484
Onion	150	August	764
Pepper	145	May/June	762
Tomato	145	Dec/Jan	805
Okra	145	Dec/Jan	762
Cabbage	140	Sept	733
Lime	365	Jan	1 236
Lemon	365	Jan	1 236
Orange	365	Jan	1 236
Guava	365	Jan	1 236
Banana (1st yr)	390	Mar	1 913
Banana (2nd yr)	365	Feb	2 254

Source: FAO Nile Country Report: Eritrea (2008)

Table 33: Areas and Production of Major Crops in the Nile Basin (2001-2007), Eritrea

Year	Maize		F. Millet		P. Millet		Sorghum		Sesame	
	Area*	Prod**	Area*	Prod**	Area*	Prod**	Area*	Prod**	Area*	Prod**
2002	121	28	81	10	683	154	63 005	57 941	2 776	690
2003	-	-	-	-	1 048	314	49 181	33 895	12 256	3 857
2004	56	72	124	62	1 728	430	51 115	32 092	7 280	1 913
2005	35	21	62	28	1 551	721	55 430	59 754	19 772	8 812
2006	45	23	115	68	8 682	4 141	71 069	67 306	18 761	9 346
2007	55	30	95	57	11 733	6 120	67 527	83 001	23 861	12 192

Source: FAO Nile Country Report: Eritrea (2008)
*(*areas in ha, **production in t)*

Livestock constraints include diseases, particularly trypanosomiasis and the limitations of the traditional feeding system; overgrazing; and traditional livestock management practices (i.e. large herds of poor quality stock and low off-take rates which undermines the productivity and production of livestock.

Opportunities

The traditional dryland farming system is practiced widely across the Nile Basin, through a wide range of ecological zones (semi-desert to high-rainfall savannah). Such variety in climate means the system has great inherent potential for crop diversification across all countries. Although it benefits from vast diversified resources and considerable biodiversity, it has suffered from long-term neglect by Governments, national research institutions and development agencies. This neglect has led to the current situation of low productivity and consequently its minimal contribution to countries' agricultural GDP.

Recently, successes have been achieved in increasing yields of low-productivity crops, by the re-introduction/adoption of complementary crop rotations that critically include legumes to fix nitrogen in soils and restore fertility. This diversification in crop rotation could make it possible to better integrate livestock in the system, although this is currently limited due to shortage of water after August. Shortages of water could be overcome through the development of water harvesting/small-scale water storage systems and wells (e.g. solar powered).

The total land area given over to this farming system in the Nile Basin is huge (almost 65 million ha), extending across large areas of the Sudan, Ethiopia Eritrea, the United

Table 34: Estimates of Water and Labour Productivity for the Important Rainfed Crops (based on the average productivity of 1992-2004), the Sudan

Crops	Area	Crop yield (t/ha)	Quantity of water (m^3 /kg)	Labour (workday/ ha)	Water Productivity (kg/m^3)	Labour Productivity (kg/workday)
Sorghum	national average (rainfed)	0.49	2 100	48	0.10	10.2
	North Kord and Darfur	0.13	1 470	29	0.04	4.5
	South Kord and Darfur	0.37	2 520	29	0.06	12.83
Groundnut	North Kord and Darfur	0.46	1 470	71	0.13	6.4
	South Kord and Darfur	0.53	2 520	83	0.09	6.34
Mechanized Sesame	Gedarif	0.22	2 100	36	0.04	6.07
Traditional Sesame	South Kord./ Darfur	0.14	1 470	29	0.04	4.92
	North Kord./ Darfur	0.18	2 520	31	0.03	5.92

Source: FAO Nile Country Report: The Sudan (2008)

Republic of Tanzania and Uganda (Figure 2). Dryland farming has been identified as the expected main location for future livestock development programmes, up-scaling and adapting traditional management techniques to cope with new challenges such as growing populations, decreasing land areas and climate change. Specifically it has been found that there is a need to expand rangeland fodder production[17] and storage in order to develop, highly beneficial integrated crop-livestock systems in these traditional rainfed areas, where fodder/forage availability is a problem in the dry season.

In summary, possible interventions for livestock development include:

- control and eradication of tsetse and trypanosomiasis;
- development of water harvesting and storage systems;
- development of fodder production and storage;
- establishment of animal health services;
- strengthening of livestock extension activities (capacity building);
- establishment of markets, abattoirs, tanneries, cold stores and other processing facilities;
- establishment of outlets for livestock and livestock products;
- livestock research in the farming system.

Recent attempts have been made to explore ways of increasing the productivity of this important system.

For example FAO has implemented a pilot programme under its Special Programme for Food Security (SPFS) to increase productivity of the Gardood soils in Northern Kordofan using water harvesting techniques. The increase in yield of the new technology over the traditional was 1 455 percent for sorghum, 290 percent for sesame and 433 percent for groundnuts (FAO Nile Country Report: the Sudan, 2008).

Drylands-grown water melon, karkade (used to make a herbal tea and valuable for its vitamin C and medicinal properties) and gum arabic are considered as competitive and high-value export crops. There are also opportunities to increase the production of oil and fibre crops as raw materials for processing and local use, and also for export. This will require the intensification and increased use of surface water, which in these fragile ecosystems requires careful management and protection.

Governments can take a more proactive role in enhancing the performance of the traditional rainfed dryland farming system. This includes increased soil water conservation and improving rangeland management. Such a role might be through support programmes, including agribusiness orientation, awareness of the appropriate high-value productive enterprises, training and extension, provision of infrastructure, inputs and social services.

To ensure reliable crop production and achieve food security, available rainfall could be used more effectively through a system of rainwater harvesting or supplementary small-scale irrigation through the diversion of rivers and dams. In Eritrea, there are plans to divert the Seit River at Abala, Tekezu and Biakonda to irrigate about 240 000 ha of land. It is planned to grow some 30 000 tonnes of staple crops such as sorghum, maize, sesame and vegetables – a

[17] To maximize the efficiency of water use, this should be using crop residues, not specially grown fodder.

substantial contribution to the food security of the country. In addition the diversion boost vegetable production in the country during the dry period January to June, when it is usually very low.

Crop yields would be further improved -higher in good years and less likely to fail in bad years – through increased crop diversity, use of improved varieties, and introduction of legumes and/or green manures in rotations.

Rainfed farming in the dry and semi-arid areas of Uganda is practiced where the rural communities are largely concerned with looking after large numbers of livestock. Where adequate rainfall permits, farmers grow a range of crops and are also often involved in non-farm activities [e.g. mining, quarrying and harvesting of Mirungi (a narcotic plant)].

Cropping is carried out in areas where rainfall is more favourable and drains to valley bottoms. The annual crops grown include: cotton, upland rice, cassava, sweet potatoes, sorghum and vegetables (i.e. cabbage, eggplants, onions, tomatoes, amaranthus, greens). Citrus fruit and perennial mango fruit trees are also grown. However, there is need to raise the awareness of farmers about the benefits of adopting improved varieties. This should coincide with increased availability and accessibility of chemicals to combat pests and diseases, and of motorized pumps.

It is estimated that about 22 percent of Uganda's households are livestock keepers, of which 60 percent belong to the cattle corridor. Mixed-farming smallholders and pastoralists own about 95 percent of cattle and 100 percent of small ruminants. Large-scale commercial ranches and dairy farms make up only five percent of cattle production. The exotic and crossbred animals are confined to fenced farms or kept in small enclosure due to their susceptibility to tick-borne diseases and the adopted zero-grazing management practices.

Currently the per capita availability of livestock products is still low in Uganda (i.e. 40 litres of milk and 8.8 kg of meat per year, as compared to the 200 litres of milk and 50 kg of meat recommended by FAO and World Health Organization). The annual milk and meat consumption deficit is estimated at between 99-200 million litres and at 80 000 tonnes respectively. The demand for livestock products has risen steadily due to social and economic changes affecting the population as well as urbanization and population growth. There is therefore a need to increase productivity per head of livestock as well as per unit area of land to improve dietary standards.

In contrast, poultry is kept by virtually every household in the country. Central region districts are the largest producers of exotic birds, namely 2.3 million broiler chicken and 1.5 million layers. The number of exotic birds in other regions is 840 000, 416 000 and 49 000 for eastern, western and northern Uganda respectively.

Highland Tropical (perennial)

General Description

This farming system, found in Ethiopia, the Democratic Republic of the Congo, Kenya, Uganda, Rwanda and Burundi (Figure 2), covers over 8 million ha (three percent) of the region, in the sub-humid and humid agro-ecological zones. But it accounts for three million ha of the cropland and has a human population of over 18 million (11%) (Table 6). Land use is intense and holdings are very small (average cultivated area per household is just under one ha, but more than 50 percent of holdings are under 0.5 ha), with an average population density of 94 people/km^2 and 0.17 ha of cropland/person.

Agricultural Productivity

The system is based on perennial crops such as banana, plantain, enset and coffee, complemented by cassava, sweet potato, beans and cereals. Around 11 million cattle are kept for milk, manure, dowries, savings and social security.

In Uganda, this rainfed farming system is practiced on both gentle and steep slopes in hill areas. It is a mixed farming system, with limited numbers of livestock and crops including: Arabica coffee; bananas and beans; apples, pears, apricots, peaches and grapes; cereals (principally maize); and vegetables (carrots, cauliflower, broccoli and Irish potatoes). In some districts, sericulture and apiculture is popular.

The landforms and low temperatures limit aquaculture production. This farming system includes tea estates, particularly in the south-west and west, with a number of adjacent tea factories.

Animal husbandry complements cropping, often with semi - or zero-grazing, and banana pseudo - stems, peelings and integrated hedgerows (grasses/leguminous trees) as feed. Most of the cattle breeds kept are either exotic or crosses, chosen for their milk production levels which could, however, be still higher if better feeds were used. [Milk production ranges between 8-10 l/day.] However, the carcasses produced in zero-grazing systems are heavier (150-200 kg), as a result of restricted movement.

The districts in this farming system have some of the most organized farmer organizations/associations for apiculture, producing the best quality of honey for regional export. However, production levels remain below potential and sericulture promotion faces similar problems. Yet this system embraces some of the districts with the best conditions for sericulture promotion.

Table 36 shows that farmers do not achieve yields close to those demonstrated on research stations. While it is acknowledged that farmers cannot be expected to achieve such high yields, they should be able to obtain results much closer than at present. Widespread scaling up of supplementary irrigation using rainwater harvesting has the potential to overcome moisture deficiency

Table 35: Population Trends in Major Livestock Species, Uganda

Livestock Species	Numbers ('000)				
	1991	1997	2001	2002 (PHC)	2005 (UNHS)
Cattle	3 357	5 460	6 144	6 283	7 531
Goats	3 880	5 825	6 620	5 168	8 078
Pigs	672	1 425	1 644	773	1 708
Sheep	144	980	1 108	1 555	1 217
Chicken	11 442	22 271	29 671	12 859	23 523

Source: FAO Nile Country Report: Uganda (2008) problems which currently hamper the timely sowing/ planting and maturation of crops, particularly at late crop development stage. However, it should be noted that:

- Not all crops need supplementary irrigation becausee their requirements are based on their drought tolerance characteristics and location (climatic zone).
- The erratic nature of rainfall and the length of intervening dry periods vary greatly from one area to the other.
- If continuous or multiple cropping or the growing of high-value crops is envisaged, supplementary irrigation is not a choice but an imperative to gain full benefit from other inputs and improved seeds.

The principal agricultural activity in Rwanda is subsistence food crop production[18], which occupies 92 percent of the total cultivated area. Table 37 shows the current meagre levels of yields of the main crops.

Most families also own a small number of livestock (cattle, sheep and/or goats).

In common with farmers across the basin in this farming system, Rwandan farmers face the serious limitation of the small area of farmland and the small size of the country, which limits their opportunities. The total cultivable area is estimated at around 1 385 000 ha (only 52 percent of the country). The cultivated area is estimated to be about 852 000 ha, (only 31 percent of the country) and the average area available per family for cultivation is 0.6 ha.

A wide range of livestock species and land races are kept (Table 38) and their populations are all growing (Table 39) at rates which seem unsustainable, given the limited land area and high human population density. Cropping occupies the majority of the farmed land and livestock must forage on fallow land, roadsides and around marginal areas. National agricultural policy is that in the arable areas, livestock should be zero-grazed, requiring stabling and fodder to be cut and carried, which is labour-intensive.

The major current problems of the livestock system are that the quantity and quality of both forage and fodder is insufficient.

National policies consider it imperative to protect and develop livestock production as a complement to cropping, particularly as it provides manure to maintain soil fertility in arable areas, or for revenue.

In recent years, the whole country has been experiencing greater variability in the weather, which, particularly in the drier areas, is making people consider using irrigated agriculture.

[Further details of agricultural production in the other countries using the Highland Tropical Farming system are given in Annex 3].

Water Management

This is a rainfed farming system, which is increasingly at risk due to the effects of climate change. Some areas already benefit from rainwater harvesting systems.

Issues

Poverty is high, both in terms of severity and absolute numbers. Despite favourable natural resources and climate, there has been decline/stagnation in crop yields,

[18] Including sweet and cooking bananas (28%), haricot beans (21%), potatoes (12%), sorghum (10%) and cassava (8%).

Table 36: Comparison of Yields from on-Farm and Research Station Conditions, Uganda

Crop	Farmers' Yields (t/ha)	Research Station Yield (t/ha)	Farmers' Achievement (%)
Banana	5.9	35.5	17
Beans	1.0	3.0	33
Cassava	9.0	50.0	18
Finger Millet	1.5	5.0	32
Maize	1.8	8.0	22
Irish potatoes	7.0	35.0	20
Sweet potatoes	4.0	30.0	13
Upland rice (NERICA)	1.7	4.5	38
Lowland rice (milled)	1.5	7.0	21

Source: FAO Nile Country Report: Uganda (2008)

Table 37: Land Areas and Yields of the Principal Crops, Rwanda

Crop	% of Cultivated Area	Average Crop Yield (t/ha)
Bananas	28	6 to 7
Haricot Beans	21	0.7
Potatoes	12	8.5
Sorghum	10	1
Cassava	8	6 to 7
Coffee	6.3	-
Tea	1.6	-

Source: FAO Nile Country Report: Rwanda (2008)

while both the overall agricultural growth potential and the poverty reduction potential are considered fairly low, due to very small farm size, absent or under-utilised resources, shortage of appropriate technologies, poor infrastructure (*inter alia* roads and markets) and few opportunities for off-farm activities.

The available data for Uganda exemplifies the recent substantial decline and stagnation in crop and livestock production:

- Coffee production has declined from 4.5 million t in 1995 to 2.7 million t in 2007;
- Friesian milk production has declined from 25–30 litre/day in the 1960s to 10–15 litre/day today;
- There is increased mortality, morbidity and cost of production in the livestock sub-sector.

The people cope with diminishing farm size, declining soil fertility; increasing poverty and hunger by working the land more intensively, but returns to labour are low.

Production constraints include:

- limited knowledge on temperate crops;

- poor agronomic and animal husbandry practices;
- over grazing;
- soil erosion;
- use of rudimentary tools and technologies (i.e. hand hoe, sickles);
- incorrect fishing gear, poor feed for dairy cattle and aquaculture);
- crop diseases (tomato wilt, Irish potato virus and leafy vegetable caterpillars, black sigatoka on bananas);
- limited of availability of disease-resistant planting materials;
- limited availability of seeds of high yielding varieties;
- minimal/limited use of fertilizers on crop due to their high cost and limited availability;
- non-compliance to contour planting - to facilitate contour irrigation in case of drought and reduce erosion in heavy rains;
- rainfall variability and unpredictability (occasional late onset of rains and mid-seasonal droughts);
- high level of reliance on traditional knowledge – which ideally should be used in combination with more up-todate scientific information – to develop locally-adapted sound systems;
- lack of specialised scientists (Agronomists, Plant Pathologists,

Table 38: Principal Livestock Races, Rwanda

Type of Livestock	Races
Cattle	Ankole, Sahiwal, Friesian, Alpine Brown, Australian Zebu, Ndama
Goats	Alpine, Anglo-Nubian
Sheep	Karakul, Merinos, Dörper
Pigs	Large White, Landrace, Piétrain
Poultry	Leghorn, Rhode Island Red, Derco, Sykes, Anakole
Fish	Tilapia, Clarias
Rabbits	New Zealand, Californian, Flanders Giant, Normandy White

Source: MINAGRI (2006) in FAO Nile Country Report: Rwanda (2008)

Table 39: Growth of Livestock Populations (1999-2004), Rwanda

Type of Livestock	1998	1999	2000	2001	2002	2003	2004
Cattle	657 137	748 976	732 123	806 726	815 450	991 700	1 006 572
Goats	481 145	629 429	750 406	829 023	915 785	938 353	1 263 962
Sheep	192 344	277 991	254 441	261 905	300 640	371 766	686 837
Pigs	120 928	209 168	177 220	185 674	207 784	211 918	326 652
Poultry	-	-	1 090 458	755 254	2 432 449	2 482 124	2 841 399
Rabbits	-	-	338 616	454 937	488 629	634 411	643 927

Source: MINAGRI (2006) in FAO Nile Country Report: Rwanda (2008)

Breeders) to handle production requirements of temperate crops;

- breakdown in traditional extension services;
- current levels of knowledge of new technologies and ability to absorb extension information are low, due to cultural and educational factors;
- socio-cultural barriers which delay some farm operations only exacerbate the situation leading to frequent and warranted famine;
- need to develop farmers' organizations;
- institutional factors (physical insecurity, access to markets, lack of financial services and lack of agricultural planning);
- limiting factors both the upstream and downstream (access to inputs, lack of agricultural services, poor quality of genetic material – plant and animal, lack of market organization and agro-industries, geographical dispersal);
- poor management of ecosystems (deforestation and over grazing);
- climatic variability (inadequate rainfall for crop production);
- conflicts between farmers and stockbreeders.

The increase and the diversification of production necessarily require the elimination of these constraints and especially the improved use of available water (supplementary irrigation).

Opportunities

All highland tropical farming system areas have high levels of resource endowments, but are constrained in many cases by population pressure and difficulties in escaping the poverty trap. Various options exist to increase agricultural production – and in addition in some of the alternatives have enormous potential, including agro-silvo-pastoral production, hydroelectricity and tourism in Burundi (FAO Nile Country Report: Burundi, 2008).

Actions to combat constraints on agriculture include:

- improved control of river flows;
- dams in hilly areas to allow development of gravity irrigation systems;
- increase mirco- hydroelectiricity and other forms of renewable energy;
- raise awareness of rainwater harvesting for agriculture and domestic use;
- technology transfer to improve agricultural production, processing and storage;
- raise awareness of improved pasture management;
- up-scaling of SLM (World Bank, 2009);
- encourage improved land management, particularly affected by soil erosion;
- identify and popularise species (land races) of animals and plants which are better adapted to local conditions.

In Uganda there is widespread interest in promoting irrigated agriculture given that agricultural production is increasingly becoming constrained by unreliable rainfall, which makes it a low-intensive (low-input and low-output) system. Irrigation therefore is viewed as one of the most important areas agricultural intensification. However, it is also noted that Uganda's cultivable land area of approximately 200 million ha [mainly the highland tropical (3.7) and lowland tropical (3.10) farming systems] in some respects seems underutilised as annually only about 60 million ha are put under cultivation. Since rainfall contributes the bulk of the internally-generated water resources, water harvesting technologies could be put into practice to improve agricultural production. For example, with annual average rainfall of 1 000 mm, rainwater harvesting would contribute annually 240 million m^3 of water and the achievement of only 60 percent would result into annual water storage of 144 million m^3. Unfortunately, not even 1/100 of this volume can be accounted for and yet there were already signs of climate change commenced 35 years ago. Medium to large-scale multipurpose irrigation infrastructure (dams and valley tanks) should be given due consideration as the water held in these structures lasts longer and would benefit more smallholder households.

Highland Temperate

General Description

This farming system is found only but extensively in Ethiopia in the Nile Basin (Figure 2), in the highland complexes comprising mountain chains and plateaus at altitudes of 2 000 to 3 000 m asl. The system covers over 13 million ha (four percent), with over 12 million (eight percent) of the population, thus 94 /km^2, including 3.5 million ha of cropland (0.29 ha/person).

Most of the areas are categorized under the so-called "wet dega" agro-ecological zone, receiving annual average rainfall of over 1 400 mm. What remains of the once rich natural plant cover still features a considerable diversity of species, including among others *Juniperus*, *Hagenia*, *Podocarpus*, *Arudinaria*, *Aningeria*, *Hypericum* and *Erica*. Long years of agricultural activities combined with increasing livestock and human populations have resulted in massive destruction of diversity, of coverage of flora and fauna and in degradation of the soils. At these higher elevations, soils are now extremely shallow due to the slow rates of organic matter decomposition. Thery are exposed to high levels of erosion due to violent rains, steep slopes, intensive cultivation and overgrazing.

Agricultural Productivity (including livestock issues)

Traditional rainfed subsistence farming is practiced on the highland plateaus, with the average land-holding shrinking due to growing population. Valley bottoms, traditionally used as communal grazing areas, are increasingly cultivated due to population pressure. Teff, wheat, barley, maize, sorghum, broad beans, field peas, chickpeas, vetch and oil crops are grown. Not only is the traditional crop rotation involving legumes and cereals being altered in favour of the latter, which achieve relatively better market prices, but inferior quality cereals such as wild oats – only useful as livestock feed - are coming into the crop mix, as farmers cannot afford to buy higher-quality seed. The greater part of the Nile Basin's agricultural produce in Ethiopia, particularly cereals and pulses, is grown under this system so that it makes a significant contribution to local and national food supplies. However, the technologies deployed are traditional, making little use of yield-enhancing inputs, new approaches to cultivation and improved seeds. Yields are consequently poor (Table 40).

The most labour-intensive and time-consuming operation is ploughing in the cereal mixed farming system, requiring about 300 oxen hr/ha. This system uses the traditional plough the "Maresha" which only makes a very shallow furrow on the topsoil without turning it, thus is widely considered ineffective. There is an increasing trend for farmers, where possible, to use hired tractors as a more effective alternative, although currently demand outstrips supply. The seeds used are usually local varieties, saved from previous harvests, are broadcast then covered by passage of the "Maresha" at shallow setting.

Soil fertility has traditionally been maintained through crop rotation (cereals and pulses) and in very rare cases fallowing, with limited use of commercial fertilizers. As the practice of crop rotation[19] is declining, soils are being degraded and fertility is being diminished.

The livestock in this system include cattle, sheep, goats, horses, donkeys, mules, poultry and bees. The livestock population is estimated to be 12 862 997 TLU (Table 41).

Cattle are kept for draft power, milk, manure, meat, and hides. Similarly, small ruminants are reared mainly as a source of cash income, with meat, skin, and manure being secondary. Horses and donkeys are predominantly used for the transportation of goods and equipment to and from the farm, as well as for human transport. Poultry are kept in the backyard receiving no special attention, mainly as a source of cash to cover small household essentials. Bees are kept for the production of honey for home consumption and for sale. They also provide a valuable ecosystem service – pollination.

Livestock are mainly of indigenous types, with some improved stocks and flocks in and around major towns. Livestock productivity is low. Cows calve about every second year and cattle take four to five years to reach maturity. The cattle herds just maintain their numbers, but there is thought to be little opportunity for increased off-take. Lambing percentage is around 110 percent, but mortality is high (up to 30 percent) and weight at sale about 20-25 kg. On the higher table-lands, sheep form the majority of the small ruminant population, but on the steeper slopes and at lower altitudes goats dominate.

Table 40: Crop production: Highland Temperate Farming System, Ethiopia

Crops	Area (ha)	% Area	Production (t)	Productivity (t/ha)
Teff	868 937	30	933 095	1.07
Barley	449 450	15	477 245	1.06
Wheat	419 487	14	564 527	1.35
Maize	269 670	9	533 095	1.98
Sorghum	149 817	5	230 078	1.54
Finger millet	89 890	3	88 378	0.98
Pulses	449 450	15	419 927	0.93
Oilseeds	209 743	7	96 300	0.46
Total	**2 906 444**	**100**		

Source: adapted from FAO Nile Country Report: Ethiopia (2008)
[Total area is 13 224 484 ha (from Table 6) and cultivated area 2 906 444 ha (Table 6 3 085 776 ha)]

[19] which brings multiple benefits to soil properties and functionality.

The major sources of feed for livestock in this system are natural pastures, although fallow land, crop residues (especially during the dry season) and also industrial by-products contribute. In some areas locally-grown improved forage/fodders contribute to the feed sources of livestock. Natural pasture in the system comprises prominent grazing land, shrubs, land unsuited for cultivation such as waterlogged, flooded areas, steep slopes and roadsides particularly in the intensively cultivated areas. In addition, some forests and bush land provides some feed to the browsing animals. Growing human population, expanding cultivation and increasing cropping intensity are rapidly diminishing the areas available for grazing, leading to nutritional stress in livestock for much of the year. The most common industrial by-products used to feed livestock are wheat bran, wheat short, noog cake and meat & blood meals. In very rare cases, concentrate feed is used, where available, to selected animals (dairy cows and animals in fattening regimes). Livestock owners were badly affected by the rapid increase in feed prices in 2008.

The total feed requirement for the livestock population is 29 million tonnes per year (Table 42).

Households with limited land holdings and/or with highly degraded land are generally food insecure. In these areas, cultivated land per household is less then one ha and crop production less than 1 000 kg. Cattle ownership is less than two per family but ownership of small ruminants is higher (four to six). Sources of cash are: sales of small ruminants, wage labour and small trade, food aid and remittances from relatives abroad.

The areas which are self-sufficient in food or have a surplus are in the south-west side of the central highlands of the Nile Basin, where landholdings are generally slightly more than one hectare. Families there have additional sources of food crops such as enset (false banana) and plantations.

Table 41: Livestock Statistics for the Highland Temperate Farming System, Ethiopia

Type	TLU	Density TLU/km^2	Livestock Holding	
			Per Person	Per Household
Cattle	10 673,258	71.24	0.41	2.39
Sheep	437 197	2.92	0.02	0.1
Goats	374 310	2.5	0.01	0.08
Horses	245 967	1.64	0.01	0.06
Donkeys	901 344	6.02	0.03	0.2
Mule	67 618	0.45	0.003	0.02
Camels	25 526	0.17	0.001	0.01
Total	**12 725 220**	**84.94**	**0.48**	**2.86**

Source: adapted from FAO Nile Country Report: Ethiopia (2008)

Cattle ownership is also higher (four or more per family) and the same is true for small ruminants. Main sources of cash income in food-secure areas are enset, cattle, small ruminants, wage labour, grain and livestock commerce, honey, poultry, and small trade.

Before the depletion of the natural forest cover to the precarious current level, the sale of firewood and wood for construction, and the sale of forest products made a significant contribution to the livelihoods of farmers.

Water Management

The major sources of water for livestock in this farming system include: rivers, springs, lakes, ponds (natural and man-made) and wells (shallow and deep). The annual water requirement for the livestock in this farming system is 148 million m^3 (Table 43).

Issues

Growing pressure on land due to high rates of human and livestock population growth in the highland areas has led to severe shortage of land and deterioration of the natural resources base, the foundations of the farming system. Farmers have limited knowledge and also restricted capabilities to invest in land improvement due to fragmentation of agricultural land and declining holding sizes.

The decreases in vegetation cover, intensive cultivation of land, including extension of cultivation onto marginal areas[20], have exposed large areas to physical loss of soil and nutrient impoverishment. Soil erosion reaching 42 t/ha/yr is reported from cropped areas and up to 70 t/ha/yr from previously cropped unproductive land due to agricultural activities without proper SWC measures. Overgrazing is also leading to damage to the vegetation cover and is exacerbated by the rugged and sloping topography.

Soil nutrient levels are progressively declining, due to extractive (low or no input) production and abandonment of sustainable practices such as fallowing, organic matter application and crop rotation involving N-fixing legumes.

Commercial fertilizers used are mainly DAP and in very few cases urea, but usually these are not applied at recommended rates

Table 42: Livestock Feed Requirement in the Highland Mixed System, Ethiopia

Type	Population (TLU)	Feed Requirement ('000s t)
Cattle	10 673 258	24 335
Sheep	437 197	997
Goats	374 310	853
Horses	245 967	561
Donkeys	901 344	2 055
Mules	67 618	154
Camels	25 526	58
Total	12 725 220	29 013

Source: FAO Nile Country Report: Ethiopia (2008) [The feed rate is 2.28 t/ TLU/yr]

[20] Steep slopes and dominant black soils with poor drainage and management challenges.

due to the high costs and/or supply problems. Frequently, fertilizers reach farmers very late fields after have been sown. In the Bale cereal growing areas, where farmers are increasingly dependent on commercial fertilizers, they travel long distances to obtain them.

Crop diseases, weeds and pests further limit crop yields and are a result of the narrowing of the crop spectrum and reduced crop rotation. Weed infestation is one of the most serious crop production constraints in this system. Weeding is carried out by hand, but is usually delayed until weeds can be grasped by hand, by which time they have already caused substantial damage to crops. Weeding is further complicated due to the random distribution of crop plants in the field. The risks of mis/over-application of potentially hazardous chemicals are considerable, while improved hand-weeding implements are generally not available.

Factors which specifically limit yields and food security include:

- Weed infestation. This varies from place to place depending on soil type, climatic factors and management practices. According to research, weeds cause yield losses ranging between 10 and 40 percent on cereals in the area. Weed problems are more severe in continuous cereal monoculture highland areas. Major weed species in order of importance include: *Plantago lanceolata, Phalaries paradoxa, Guizotia scarba*, *Galinsoga parvifora*, *Cyprus blysmodis*, *Amaranthus hybridus*, *Avena fatua* and *Avena vavilovia*. Weed control by farmers is done manually as chemicals are unaffordable.
- Crop diseases. Then cause yield losses in the range of 25-35 percent. Yellow rust, stem rust, leaf rust septoria and tan spot are recorded on wheat with yellow and stem rust inflicting the most damage. Net blotch and leaf rust on barley, powdery mildew, downy mildew and Aschchyta blight on field peas, rust on lentils, chocolate spot, rust and Aschochyta blight on faba beans cause significant yield losses. Frequent breakdown of resistance to rust diseases of wheat is becoming a serious challenge to farmers and breeders in the research centres.
- Eighteen field and four-storage insect pests have been recorded on barley, wheat and Emer wheat. Leaf rust of Barley and Barley shoot fly (*Delia armabourgi Seguy*) are the most destructive on barley. Several field and storage insect pests are also recorded affecting faba beans, field peas, and lentils out of which green pea aphid (*Acrytosiphon pisum*) and African bollworm (*Hellicoverpa armigera*) are the major ones.
- Harvesting is carried out using a simple hand tool, the sickle. This very slow process causes considerable loss of grain due to shattering. At peak harvest seasons, when most of the fields mature simultaneously, the operation is constrained by lack of adequate manpower. Some combine harvester rental services have started in limited areas, usually around big farms, but their accessibility and coverage is very limited. From the point of view of SLM, they are considered inappropriate.
- Animal trampling of harvested crops and beating by sticks are the common threshing practices. The traditional forked stick is used for the removal of the straw and winnowing. The operation is associated with qualitative and

Table 43: Livestock Water Requirement in Highland Temperate Farming System, Ethiopia			
Type	Rate/Annum (m^3)	Population	Water Requirement ('000 m^3)
Cattle	9.125	13 683 664	124 863
Sheep	1.825	4 371 971	7 979
Goats	1.825	3 743 101	6 831
Horses	4.38	327 677	1 435
Donkeys	4.38	1 365 672	5 982
Mules	4.38	102 451	449
Camels	10.95	20 923	229
Total			**147 768**

Source: FAO Nile Country Report: Ethiopia (2008)

quantitative yield losses and is very time-consuming.

- Raised baskets of woven sticks usually plastered with mud, straw and animal dung and thatched roofs are the common household storage facilities. Insects, rodents and storage fungi cause considerable qualitative and quantitative yield losses. Fumigation and improved storage facilities are neither known nor accessible to the small-scale farmers.
- For financial reasons, farmers in many areas are forced to sell their produce to local traders in local markets immediately after harvest at lower prices than would be the case if they waited. Cooperatives established in some areas try to stabilize prices but lack the capital base and management skills to do so effectively. Technical problems arising from handling and storing large quantities of agricultural products are also serious constraints.
- There are great concentrations of livestock on the few remaining communal areas and consequently serious land degradation due to diminishing grazing opportunities, also poor integration of crop and livestock production.
- Livestock management lacks the intimate knowledge found among pastoralists as livestock are considered subsidiary to the main crop enterprise.
- Various types of widespread livestock diseases and general health problems are further constraints to livestock development as is the inadequacy of veterinary services. The prevalence of livestock diseases significantly limits the potential for exports and earning of foreign exchange.

Lastly, changes in distribution and volume of precipitations are significantly affecting productions in both cropping seasons.

Opportunities

A multi-faceted approach is required to reverse the extremely advanced level of degradation of land and natural resources through comprehensive participatory conservation measures, particularly:

- reduction of pressure on land by livestock and human population through livelihood diversification and promotion of urban-rural linkages;
- urgent measures to fill existing policy gaps in tenure security to enhance investment in sustainable technologies and systems.

Watershed-level development approaches will be most appropriate for interventions in this farming system as for example implementation of measures to limit degradation in mid-altitudes would be futile if upper slopes are not protected. Improvements in the availability of inputs (such as improved seeds, fertilizers for micro-dosing, pesticides). Also needed are extension services to revive traditional practices (fallowing and rotations) introduce new technologies (*inter alia* low/zero tillage, conservation agriculture), rainwater harvesting, field and farm storage, also development of farmers' Organizations (for field schools, marketing etc) could make significant contributions to enhancing productivity in this system.

There is a growing demand for livestock products among local and national populations and market proximity for livestock and products. Interest on the part of farmers to accept new innovations and availability of infrastructure are some of the positive aspects conducive to livestock development programmes in the farming system. Examples include provision of abattoirs and cold storage, also milk processing.

Improved breeds of dairy cattle, sheep and poultry would further enhance production and better provision of general animal health services would be highly beneficial.

Highland Cold (barley, sheep)

General Description

This farming system is only practiced in Ethiopia at very high (over 3 000 m asl), with a precipitation range of 686 -1 135 mm per year in the sub Afro-alpine agro-ecological zone (Figure 2). The area covered is over 3.6 million ha (one percent) with a population of almost 4.5 million (three percent) (123/km^2). Cropland amounts 1.25 million ha of cro-pland (three percent), thus 0.28 ha/person (Table 6).

The climate is cold, with frequent night frosts during the dry-seasons. The soils are thin, often water-logged when flat and are not suitable for extensive crop production. Cold temperatures at very high altitude together with humidity limit the range of crop and livestock types adapted to such harsh conditions.

Agricultural Productivity (including livestock issues)

This system features two components, barley cropping and grazing in the lower part (up to 3 300 m) and pure grazing above that altitude; most farmers use both components. One or two crops of barley are produced per year, while highland sheep and goats dominate livestock production. In the barley cropping and grazing component, the crop is usually grown during the short rainy season, as conditions during the long rains are too cool and damp in most areas to achieve reasonable yields.

Many of the features of this farming system are similar to that of the highland temperate system. However, the very high altitude and low temperatures narrow the crop and livestock spectrum, limiting crop yields. The average household cultivating 1.5 ha, consequently produces only around 900 kg of crops.

Livestock are a particularly important component of the system as the crop (barley) yields are not only low but also unreliable. Cropping based on traditional practices depends on keeping oxen for ploughing and if possible having cows for breedingand to provide milk. Table 45 shows the statistics on livestock holdings, comprising over 2 million TLU, with an average holding of 4.18 TLU/hh and density of 71 TLU/km^2.

Natural pastures and crop residues (hay and barley straw) are the major sources of livestock feed in the highland cold farming system. The sheep graze and browse woodlands, shrublands, scrub fen and other Afro-alpine steppe types. Sheep are run in flocks extending from 30 to several hundred. They are shepherded by day on permanent natural grazing and barley stubble. The harsh weather conditions, with cold temperatures and frequent rain, compel livestock to stay indoors at night. The basements of farm-houses are used for livestock while in farms without basements livestock stay in one corner of the house together with the household.

Natural pasture alone is adequate for both maintenance and production in the wet months but inadequate for the rest of the year. Barley residues are the main source of fodder. In some areas, livestock are also fed additional pulses and teff straw. Generally, the quantity is small and nutritive value is also low, resulting in poor livestock productivity. Grain rejects and local beer residues provide additional feed where available.

At the rate of 2.28 t dry matter/TLU/year, the total feed requirement is 4.59 million t/year (Table 46).

As in most of the other rainfed farming systems of the Nile Basin, household food security is dependent on the area of land and the number of livestock owned. A family, which cultivates more than one ha, owns two or more cattle and four sheep is likely to be self-sufficient. If a family can produce more than two tonnes of crops, this will meet their subsistence needs. They also depend on additional sources of income, including the sale of small ruminants, cereals, pulses and oil seeds and petty trade.

Families cultivating less than one ha, owning fewer than two cattle and producing less than one tonne of crops are likely to be food insecure. However, ownership of sizable number of small ruminants (more than four) can generate enough cash to achieve food security.

Water Management

The annual drinking water requirement for livestock in the highland cold farming system is estimated to be 23.8 million m^3 (Table 47).

Issues

The major agricultural production constraints include:

- land not inherently suited to cropping;
- little knowledge of pasture improvement;
- livestock health problems (the high rainfall and cold stresses the animals and makes them more susceptible to disease than in other farming systems);
- poor access to infrastructure;
- only local breeds of livestock kept;
- manure used for other purposes (i.e. fuel) rather than soil fertility restoration;
- human population pressure;
- shortage of draught power;
- low incomes.

Opportunities

Establishment of livestock health services, forage and fodder development and storage, also increased rainwater harvesting and storage, improved farmer knowledge, improved access to inputs, marketing and knowledge, also breed improvement programme are recognized as vitally important development programmes.

Table 44: Crop Production Statistics for the Highland Cold Farming System, Ethiopia					
Crops	Area (ha)	% Area	Production (t)	Yield (t/ha)	National Average Yield (t/ha)*
Teff	25 551	9	22 941	0.89	n/a
Barley	119 239	44	124 009	1.04	1.14
Wheat	36 907	14	42 059	1.14	1.42
Maize	8 517	3	13 153	1.54	1.83
Sorghum	28 390	10	29 531	1.04	1.32
Finger millet	2 839	1	4 105	1.45	1.02 [21]
Pulses	45 424	17	48 068	1.06	n/a
Oilseeds	5 678	2	3 157	0.56	n/a
Total	**272 545**	**100**	**287 022**		

Source: adapted from FAO Nile Country Report: Ethiopia (2008) (note, figures differ from Table 6)
[National average yields from Annex 1

Table 45: Livestock Statistics in the Highland Cold Farming System, Ethiopia				
Type	TLU	Density TLU/km^2	Livestock Holding	
			Per Person	Per Household
Cattle	1 504 291	52.99	0.54	3.13
Sheep	159 583	5.62	0.06	0.33
Goats	87 332	3.08	0.03	0.18
Horses	63 493	2.24	0.02	0.13
Donkeys	180 242	6.35	0.06	0.37
Mules	16 485	0.58	0.01	0.03
Camels	598	0.02	-	0.001
Total	**2 012 024**	**70.87**	**0.72**	**4.18**

Source: FAO Nile Country Report: Ethiopia (2008)

The increase in temperatures likely due to global warming is likely to positively benefit this farming system.

Lowland Tropical

General Description

This farming system is very important for food production, extending across plateau and highland areas at altitudes of 800 to

[21] Finger millet.

Table 46: Livestock Feed Requirement in the Highland Cold Farming System, Ethiopia

Type	Population (TLU)	Feed Requirement ('000s t)
Cattle	1 504 291.00	3 430.00
Sheep	159 583.30	363.85
Goats	87 331.95	199.12
Horses	63 492.46	144.76
Donkeys	180 241.50	410.95
Mules	16 484.96	37.59
Camels	598.04	1.36
Total	**2 012 023.00**	**4 587.63**

Source: FAO Nile Country Report: Ethiopia (2008)

1,500 m in Kenya, the Sudan, the United Republic of Tanzania and Uganda (Figure 2). The system covers an area of almost 18 million ha, which constitutes six percent of the basin (Table 6), with over 18 million people and a moderately high population density of 100/km^2. It includes almost 4.3 million ha of cropland (12 percent of the basin's cropland), thus 0.24 ha of cropland /person. Average farm sizes are rather modest - often less than 2 ha. The farming system also contains scattered irrigation schemes, but these are mostly small-scale and amount to only six percent of the irrigated area in the region. The climate varies from dry sub-humid to moist sub-humid. Where a bimodal rainfall pattern occurs farmers have two cropping seasons, but in drier areas they usually harvest only once a year from a given field.

Agricultural Productivity

Land users benefit from very high resources endowment. The system embraces production of a range of annual and perennial crops in addition to livestock rearing, apiculture, sericulture and aquaculture.

Farmers practice a diverse cropping regime, with individuals growing different portions of traditional crops and sometimes engaging in mixed cropping. Cereals in this category include: maize, sorghum and millet, pulses grown include beans while cassava and sweet potatoes are the main root crops. Cotton, bananas, coffee, pineapples and groundnuts are also grown. Other sources of income include small ruminants, petty trade and remittances. The role of trade in the sustenance of the community is even more critical in the 21st century, considering the myriad challenges facing crop production, livestock and the lake/river fishing sector.

The choice of what activity to engage often depends on humidity, rainfall, altitude and soils although local traditions and preferences also dominate decision-making. But the 2008 FAO Nile Country Report concluded that much of what local farmers were doing in their farms and fields in this farming system could not be explained by agro-ecological or biological parameters alone. Notably in the Lake Victoria zone of the United Republic of Tanzania, food preferences are closely connected with people's socio-cultural backgrounds. As a staple food, for instance, the Wahaya highly prefer banana while the Wasukuma prefer

Table 47: Drinking Water Requirement for Livestock in the Highland Cold Farming System, Ethiopia			
Type	**Rate/Year (m^3)**	**Population**	**Water ('000 m^3)**
Cattle	9.125	1 928 578	17 598.3
Sheep	1.825	1 595 833	2 912.4
Goats	1.825	873 319	1 593.8
Horses	4.38	96 201	421.4
Donkeys	4.38	273 093	1 196.1
Mules	4.38	24 977	109.4
Camels	10.95	490	5.4
Total			**23 836.8**

Source: FAO Nile Country Report: Ethiopia (2008)

maize. Thus, the Wahaya attempt to grow bananas even in relatively dry areas although other crops are better adapted.

Table 48 demonstrates the poor yields currently achieved by farmers in Uganda. This yield gap could at least in part be closed by rainwater harvesting or supplementary irrigation. Effective strategies to overcome moisture deficiency problems are therefore required. Other limiting factors include the lack of organic and inorganic fertilizers, disease control measures and weeding. It should be noted however, that:

- not all crops need supplementary irrigation water requirements depend on their drought tolerance characteristics and climatic zones
- the erratic nature of rainfall and the length of intervening dry periods vary greatly from one area to the other
- in case continuous or multiple cropping or cultivation of high-value crops is envisaged, supplementary irrigation is not a choice but an imperative.

Many Sukuma farmers in the United Republic of Tanzania prefer extensive land use systems because of their inherently high labour productivity. However, these extensive fallow systems are being put under pressure by an increase in population and gradually change into more intensive systems. In the past, the Wasukuma people migrated to new areas several times to escape an inevitable intensification of agriculture and livestock (Meertens et al., 1995). Each migration was accompanied by adaptations in agricultural methods and choices of crops, to better suit the prevailing agro-ecological conditions; as a result, farming systems have become differentiated. Recently, however, the stage has been reached were there are no more nearby areas left for Wasukuma migrations. Consequently, in some areas (e.g. around Mwanza town) the intensity of the land use system has increased to such a high level that agriculture intensification (including use of manure, fertilizer, green manure crops as ways to maintain sustainable production) has become unavoidable.

Yields of maize, lowland rice, groundnuts and beans across the system are affected by limited use of quality seed and fertilizers. Cassava production is constrained by the cassava brown streak virus while sweet potatoes production is affected by non-application of basic agronomic practices (heap size, timely weeding/loosening of heaps, and the angle of positioning the cuttings). The attacks of moles and caterpillars similarly contribute to reductions in sweet potato yields. Sunflower and sesame production, which has the potential to replace cotton, is constrained by shortage of hybrid seeds, soil fertility and limited knowledge on basic agronomic practices.

Tobacco production (flue cured) experienced a decline due to shortage in wood fuel, but since there is ready market with Zimbabwe out of production; farmers still opt to grow the crop. Sugar cane is widely grown in the farming system by both smallholders[22] and estates; once more yields mainly depend on the reliability of rainfall[23].

The main vegetables produced are: tomatoes, cabbages, onions, egg plant, okra, green and hot pepper. In some cases however, farmers grow: spinach, cucumber, spring onions, Chinese cabbage, endive, beet root etc for the urban centre markets. Amaranthus, nakati and entula are among the local vegetables with substantial command of local market. Production constraints in vegetables include: tomato wilt disease, cabbage caterpillar and limited use of fertilizers, particularly in leafy vegetables, due to high cost.

Details of livestock holdings in Uganda reflect the entire farming system. Twenty-two percent of all households in the country are livestock keepers. The most important factor that has led to limited production in livestock is dominance in the sub-sector of the indigenous breeds (95%), namely: the East African Zebu and the Ankole

Table 48: Comparison of Yields from on-Farm and Research Station Conditions, Uganda (presumed rainfed – not specified)

Crop	Farmers' Yields (t/ha)	Research Station Yields (t/ha)	Farmers' Achievement (%)
Banana	5.9	35.5	17
Beans	1.0	3.0	33
Cassava	9.0	50.0	18
Finger Millet	1.5	5.0	32
Maize	1.8	8.0	22
Irish Potatoes	7.0	35.0	20
Sweet Potatoes	4.0	30.0	13
Upland Rice (NERICA)	1.7	4.5	38
Lowland Rice (milled)	1.5	7.0	21

Source: FAO Nile Country Report: Uganda (2008)

[22] for chewing and production of jaggery and on contractual basis to feed sugar factories.

[23] irrigated crop yields increase by around 30% compared to rainfed.

Long Horn, accounting for 30 percent and 60 percent, respectively. Indigenous breeds are highly adapted to local conditions, including the climate, diseases etc, but tend to have low productivity. This is coupled with free range grazing with no pasture management programmes. Common diseases leading to immediate loss in livestock in the FS include: contagious bovine pleura pneumonia (CBPP) in cattle and contagious caprine pleura pneumonia (CCPP) in goats, trypanosomiasis (affecting 70 percent of the country's total land area), anthrax, rabies, rinder pest, black leg, African swine fever. Newcastle, Avian flu and Gumboro are rampant in poultry coupled with in-adequate and poor supply of quality feeds. Other diseases like foot and mouth disease (FMD), tuberculosis, brucellosis etc. though not fatal, equally reduce livestock productivity. However, some of these diseases like: trypanosomiasis, Avian flue, anthrax, tuberculosis, brucellosis are of zoonotic importance and hazardous to human health.

The apiculture, the system occupies about 60 percent of the country's 80 000 bee farmers with:

- the majority of them having local bee hives, which yield about 25 percent of the improved bee hives;
- lacking training in bee keeping to enhance knowledge (e.g. on when to harvest the honey);
- insufficient knowledge on scouting pest and rodents' attack on bee hives; to enhance colonization.

Other factors affecting production include: exposure to various viruses, fungal and bacterial infections carried by migrating colonies from South Africa and Europe in addition to lack of honey harvesting equipment, protective gears to facilitate monitoring of time for harvest and leaving open containers of fermented local brew (potent gin) to intoxicate and disable the bees.

Sericulture production on the other hand is affected by:

- insufficiency of material inputs, beginning with the feed (mulberry);
- preservation and treatment facilities;
- lack of working capital for interested companies in addition to affordable rural credit for sericulture farmers;
- breakdown in the extension service delivery system.

Water Management

Most of this system is purely rainfed – although some rainwater harvesting and small-scale irrigation systems have been developed recently.

Rice cultivation was originally a cash crop around Lake Victoria in the United Republic of Tanzania, but is increasingly grown as a food crop. Rainfall in itself is not sufficient to support rice production in the Lake Zone. However, due to the presence of hard pan soils ('Itogolo') on the lower slopes of certain toposequences and the occurrence of run-off water from the upper slopes, rice cultivation is possible. The run-off water is collected and diverted into bunded fields on the hard pan soils. The hard pan layer in the subsoil prevents percolation of water to deeper soil layers. These soils are not well suited for cultivation of other crops as the hard pan layer restricts the rooting of plants.

The bunded rice fields should receive enough run-off water in November-December; otherwise chances are slim that the rice crop will survive the January-February dry spells. Even in the higher rainfall zones of Sukumaland 50-80 percent of the rice fields cannot be planted in very dry years due to insufficient run-off water (FAO Nile Country Report: the United Republic of Tanzania, 2008).

There is a clear relationship between rainfall and water catchment area (providing run-off water) and the potential areas suitable for rice cultivation (receiving run-off water). Consequently, rice cultivation is mainly concentrated in the higher rainfall zones on hard-pan soils. Hard-pan soils in the drier areas (e.g. Meatu district) are either cultivated with drought-tolerant crops (cotton, sorghum), fallow and/or used as grazing areas.

The narrow valley system (where Luseni soils dominate) was the first area to be inhabited by the Sukuma in the United Republic of Tanzania. It lies in a rough circle with a radius of 30-50 km around Mwanza town, where rainfall is more favourable. Although deep, these sandy soils have limited water storage capacity. High ridges are constructed with hand hoes to prevent runoff and stabilize production. Due to the long settlement period and high population pressure, soil fertility has dropped to very low levels as traditional restorative practices have been abandoned (Budelman, 1996). Push factors for migration are strong, but there are few areas available for settlement.

In the Tanzanian component, tomatoes and cabbages have become important cash crops and are irrigated with buckets from hand-dug shallow wells during the dry season, when sufficient labour is available. The nearby market in Mwanza guarantees sufficient demand. Manure has become scarce in these areas and is even paid for in some villages. Along the shore of Lake Victoria many households are involved in fishing.

Issues

The whole system is currently in crisis as input use has fallen sharply due to shortag of seed, fertilizer and agro-chemicals. The problems are exacerbated by the high price of fertilizer relative to maize. As a result yields have fallen and soil fertility is declining. Farmers have in the past been encouraged to grow maize monocultures and they did so without restorative periods of fallow or application of manure[24] and with declining use of rotations. This is now proving unsustainable and many smallholders are reverting to extensive production practices.

There is a moderate incidence of chronic poverty, linked to small farm size and absence of draught oxen and migrant remittances. Recently, transitory poverty has sharply increased as a result of off-farm workers being laid off coupled with policy reforms affecting maize.

There has been a devastating attack on coffee by coffee wilt disease, resulting in a reduction of about 50 percent in production. Banana bacterial wilt, nematodes and weevils have caused a yield reduction of 30 percent, mainly in the variety used for brewing and dessert with minimal impact on the staple cooking type.

[24] Manure availability is limited as only 20-40% of the households possess livestock and human population pressure is too high to allow cattle to roam freely. Conflicts between livestock and non-livestock owners are common. The amount and use of oxen is low. Many households do not possess oxen and the local ridge construction method requires hand hoeing.

Cotton production on the other hand experienced multiple problems, notably:

- the introduction of organic cotton culture in an environment where the boll worm pest and diseases can only be controlled through the application of chemicals
- apparent distribution of low-quality (low percentage of germination) seed
- breakdown in extension service delivery
- climate change, with more frequent droughts and floods;
- fall in prices offered by Government and dealers.

Opportunities

In spite of the current crisis, long-term agricultural growth prospects are relatively good and the potential for reduction of poverty is high. Promotion of sustainable land management practices (e.g. rotations, green manure, organic residues, mixed cropping, low/zero tillage, conservation agriculture, agroforestry, IPPM) would increase crop yields in good years and reduce the risk of crop failures in poor ones. Judicious application (micro-dosing) of inorganic fertilizer would enable smallholders to increase yields, if combined with appropriate water management.

Since rainfall contributes the bulk of the internally-generated water resources in this system, only the application of supplementary irrigation can reduce the risk of crop failure in growing seasons where rainfall is not well distributed. But scaling even rudimentary irrigation services across wide areas of predominantly rainfed crops will always be limited by the profitability of the crops and the available storage for water resources.

Medium- to large-scale multipurpose and irrigation infrastructure (dams and valley tanks) provide better longer-term water storage systems. However, with concern increasing over the availability of water and the need to maintain water flow to the aquatic ecosystems, rainwater harvesting may be more appropriate.

Although in the 1960s cotton provided indirect food security for farmers (i.e., reliable payment and favourable prices) this function has now been taken over by rice, tomatoes and cabbages. The only way cotton may regain part of its former function is through a reliable institutional setting (e.g. competitive pricing) combined with an intensification programme to increase yields. Soil fertility issues should be among the first to be tackled.

It is noted that of Uganda's cultivable land area (of approximately 200 million ha), only about 60 million are annually put under cultivation, which reflects gross underdevelopment of resources.

Forest-based

General Description

An excellent example of this system is the "Western Forest Products System", which is important in southern Ethiopia and is distinguished in this report from the woodland farming system, which is to be found mostly in Western Sudan. Figure 2 shows that the system also occurs in small areas of the Nile Basin in Burundi, the Democratic Republic of the Congo, Kenya, Rwanda, the Sudan, the United Republic of Tanzania and Uganda – covering almost 13.4 million ha (four percent of the basin).

The system prevails in sparsely populated areas (just over 6 million people, or 47/ km^2), with dense natural forest of tropical trees and only 900.000 ha of cropland – thus 0.15 ha/ person. The population in the Ethiopian area is 95,000 people for an area of 4 306 km^2. The altitudinal range is from 800 to 1 800 m asl (covering lowlands to mid-altitude agro-ecological zones, with vegetation of forest woodlands and bamboo.

In the Ethiopian component, rain falls all year, with a short relatively dry window from December to February. Rainfall ranges from 1 500 to 2 000 mm/yr and potential evapotranspiration from 1 300 to 1 500 mm/yr. Soils under natural forest cover are inherently fertile, but this fertility declines rapidly under intensive cultivation due to poor land management.

Agricultural Productivity

Traditionally, communities depended on extraction of forest products, hunting and gathering and some pastoral livestock herding. Recently, settlers from the highlands started cereal production in this farming system, beginning by clearing the natural forest cover.

Maize, sorghum and millet are the main crops and they are grown on small plots under shifting cultivation for 2-3 years before farmers are forced to move to new sites as crop yields (Table 49) decline rapidly. In addition to grains, tuber crops such as enset and vegetables, plus fruit trees, spices and coffee trees are cultivated (wild coffee trees are found in the forest). The crop calendar for annual grain crops is complex, with maize being planted around March and harvested in October. A second maize crop is planted in August and harvested in December. Sorghum is planted in June and gathered in November while millet is planted in April and harvested in August (Table 50). Maize, sorghum, millet and enset are used for home consumption.

People's livelihoods are primarily dependent on forest products, with little livestock husbandry (mainly cattle) (Table 51). The main products are milk, meat and draft power, and livestock are also sold for cash. The environment is conducive to apiculture, thus beekeeping is common and honey is collected throughout the year.

The average family's income is neither significantly dependent on crop production nor livestock, as the average cultivated landholding is less than 0.5 ha. Households' revenues principally stem from the sale of wood for construction and fuel, as well as other forest products such as coffee, honey, spices and herbs, aromatic plants and gum arabic, supplemented to a lesser extent with sales of food crops and livestock.

The average family is relatively self-sufficient in food and has diversified sources of income from forest products. Wealthier households, which have institutionally recognized access to forest products, obtain higher incomes relative to the rest of the community. Families get additional income from handicrafts.

The main sources of feed are a combination of both natural pasture and crop residues, with a total feed requirement of 1 million tonnes of dry matter/yr (Table 52).
Table 53 shows that the annual water required for livestock is 5.13 million m^3/yr.

A variation on the above system is the "Western Perennial Forest Coffee/Spice" farming system in Ethiopia, practiced in a very fertile zone where rainfall is reliable, households are food-secure and incomes are relatively high[25]. The main spices harvested are ginger, turmeric and cardamom, most of which grow wild in the forests. Coffee and spice production is higher towards the west while food crop production increases towards the east.

The "Enset" sub-system is a zone where *Ensete ventricosum* production plays a major role as the staple or co-staple food. Animal manure is commonly used to fertilize enset fields. Cereals are also grown in this system using both the plough and the hoe. Although areas under this system make a comparatively greater contribution to the national economy through the major export product of coffee, they have not benefited as much in terms of socio-economic development.

The types of livestock kept in this farming system include cattle, sheep, goats, horses, donkeys, mules, poultry and bees.

They are typically indigenous landraces, although some improved breeds were intro duced some years ago, but with little or no success. Livestock are not reared in large

Table 49: Crop Production in Forest-Based System, Ethiopia

Crop	Area (ha)	% Area	Production (Q)	Production (t)	Yield (t/ha)	National Average Yield* (t/ha)
Teff	4 371	15	38 028	3 803	0.87	n/a
Barley	392	1	6 183	618	1.58	1.14
Wheat	482	2	7 147	715	1.48	1.42
Maize	10 460	35	255 191	25 519	2.44	1.83
Sorghum	12 781	43	126 537	12 654	0.99	1.32
Finger-millet	151	1	1 905	191	1.26	1.02
Pulses	271	1	2 370	237	0.87	n/a
Oilseeds	1 115	4	3 763	376	0.34	n/a
Total	**30 024**	**100**				

Source: FAO Nile Country Report: Ethiopia (2008)
*[Total area is 4 306 (km^2), cultivated area 30 024 (ha). * - see Annex 1]*

Table 50: Cropping Calendar in Western Forest System, Ethiopia

Crop	Land Preparation	Planting	Cons.(Green)	Harvest
Maize (Belg)	Jan-Feb	Feb-April	July-Sep	October
Maize Meher	July	August	Oct-Nov	December
Sorghum (Belg)	April	May-June		November-December
Millet	March	April		August-September
Rice	March-April	May		October
Wild food cons.			March-June	

Source: FAO Nile Country Report Ethiopia (2008)

[25] Yayu, D.Dollo, Gimbi, Godere, Sheko, Bench, Teppi woredas.

numbers, mainly due to shortage of pasture as permanent crops such as coffee dominate. Furthermore, as most of the land is occupied by perennial crops, there is little land left for grazing. Livestock generally graze along the roadside and at the borders of farmland. In many cases, animals are tethered in and around the homestead. If they are out in the field they are attended by child herders.

A limited number of sheep and cattle are reared on lands around homesteads with the help of supplementary fodder (crop residues and enset leaves). The livestock are kept mainly for milk production, manure and to some extent for draft power. As land preparation is mostly by hoe, the use of oxen is minimal. Small ruminants are mainly for meat production. In addition, around some towns and peri-urban areas dairying and fattening are practiced. Meat is frequently purchased with proceeds from coffee sales.

The abundant flowering plants, bushes and shrubs make the farming system suitable for beekeeping. Most of the beehives used by the community are traditional types although improved hives are being introduced by institutions and individuals. The annual honey yield from traditional hives is between 2.3 and 5.5 kg and farmers get a reasonable income from sales of honey.

Table 51: Livestock Statistics in the Forest System, Ethiopia

Type	TLU	Density TLU/km^2	Per Person	Per Household
Cattle	394 196	91.54	4.15	24.05
Sheep	13 484	3.13	0.14	0.82
Goats	5 346	1.24	0.06	0.38
Horses	14 956	3.47	0.16	0.91
Donkeys	5 648	1.31	0.06	0.34
Mules	5 165	1.2	0.05	0.32
Total	**438 795**	**102**	**4.62**	**26.76**

Source: FAO Nile Country Report Ethiopia (2008)

Table 52: Livestock Feed Requirement in the Forest System, Ethiopia

Type	Population (TLU)	Feed Requirement ('000s t)
Cattle	394 196	899
Sheep	13 484	31
Goats	5 346	12
Horses	14 956	34
Donkeys	5 648	13
Mules	5 165	12
Total	**438 795**	**1 001**

Source: FAO Nile Country Report: Ethiopia (2008)

Table 53: Livestock water requirement in the Forest System, Ethiopia

Type	Rate/Annum (m^3)	Livestock Number	Water Need ('000s m^3)
Cattle	9.125	505 379	4 611.58
Sheep	1.825	134 843	246.09
Goats	1.825	53 458	97.56
Horses	4.38	22 661	99.26
Donkeys	4.38	8 558	37.48
Mules	4.38	7 826	34.28
Total		**732 725**	**5 126.25**

Source: FAO Nile Country Report: Ethiopia (2008)

There are farmers' groups comprising coffee, chat and enset growers, who comparatively recently began to use the plough for land preparation.

Based on tea and coffee growing, the farming system is also practiced in Burundi, the Democratic Republic of the Congo and Rwanda. Smallholders are subsistence farmers, growing roots, tubers, cereals and bananas, and keeping small livestock such as goats, sheep, pigs and poultry. They also tend home gardens with fruit trees and vegetables.

These highland areas of the Nile Basin are characterized by a scarcity of arable land. There is competition between cropping and livestock and a general separation of crop and livestock production. Gradually, there has been a reduction in the length of fallows so that soil fertility is declining. A contributing factor is that manure is not being added to maintain enough organic matter and nutrients to sustain crop yields.

Water Management

During the rainy season, pools are used to water livestock. Throughout the rest of the year and especially in the dry season, streams and rivers are their main sources of water.

Issues

Recently in Ethiopia, settlers from the highlands have started cereal production by clearing the natural forest cover. The influx of settlers is causing accelerated change in land-use patterns, which is exerting pressure on the natural resource base on which local livelihoods depend. Indigenous populations are also increasingly adopting the settlers' way of life and their production systems. Livestock numbers remain very low due mainly to trypanosomiasis. Wild coffee in the forests has not yet been put to economic use.

The general belief that these areas have inexhaustible natural resources and agricultural potential has led to ill-conceived policy decisions and actions. It has also negatively affected people's perceptions and behaviour towards management of land and utilization of resources. The preferred settlement areas, abundantly endowed as they are with natural resources and a climate conducive for agriculture, are also extremely sensitive and fragile.They must be managed with the utmost care, as well as knowledge and understanding of their inherent characteristics and dynamics. Indigenous livelihood systems and practices are being marginalized and increasingly replaced by what seem to be more productive and efficient ones, with complete disregard for the sustainability of the new systems.

The major agricultural production, land and natural resource degradation issues and underlying causes in this farming system include:

- Destruction and over-exploitation of forests and natural vegetation due mainly to extensive land clearing for agriculture, extraction of wood for fuel and construction, and in order to prevent wildlife attacks on crops, livestock and humans.
- Replacement of indigenous sustainable livelihood and production practices by unsustainable ones due to increasing population pressure from both indigenous and immigrant groups.
- Ecological disturbances and emergence of aggressive pests and weeds (termites, striga) due to excessive nutrient mining from continuous monoculture cereal production and inappropriate grazing practices.
- Accelerated loss of soil nutrients, increasing soil acidity and accelerated erosion as a result of exposing and intensively working the light soils, plus extractive crop production without any form of fertility management.
- Degradation of grazing land and reduced carrying capacity due to permanent overstocking, high seasonal pressure on grazing areas and poor management.
- Drastic productivity decline and encroachment into intact systems due to lack of knowledge of productivity-enhancing systems, technologies and inputs.

Animal diseases, feed shortage, limited interest in livestock and poor services to the livestock sector are some of the main problems to livestock development in the farming system.

Opportunities

Widespread scaling up of sustainable land and natural resources management systems (e.g. participatory forest management) would have enormous benefits in this farming system.

Urgent policy interventions are required to improve the planning of formal and informal resettlement and to reduce the enormous pressure on land and natural resources.

Possible interventions include:

- Restore correct functioning of soils by increasing soil organic matter and fertility (e.g. planting legumes, use of organic and inorganic fertilizers); protect soils from erosion (low/zero tillage, conservation agriculture).
- Develop agro-processing, non-wood forest products (NWFPs), handicrafts, small trade and seasonal wage labour (e.g. in the Sudan for Ethiopians).
- Undertake small-scale water developments for supplementary irrigation (rainwater harvesting) and hydro-power.
- Engage in small-scale poultry production
- promote permanent crops and horticultural development as they have huge potential.
- Strengthen extension services.
- Provide adequate market information and access to improved incomes.

Although households derive only a small proportion of their income from livestock at present, there are opportunities in this farming system to feed large numbers of animals under a more intensive management system. This would be based on a zero-grazing approach using crop residues, not specifically grown fodder crops.

Woodland

General Description

Woodland has been added to distinguish the system from the "forest-based" system, which is important in southern Ethiopia (3.11), while this savannah woodland system occurs mainly in the western Sudan, but also in Eritrea and Ethiopia (Figure 2). The natural vegetation of the area comprises relatively tall trees (7-15 m), notably *Anogeisuus leiocarpus*, *Sclerocarya birrea* and the baobab. Smaller trees include mostly *Acacis spp* but also the locust bean tree (*Parkia clappertoniana*, the shea butter tree (*Butryospermum paradoxum*) the kapok tree (*Bombax costatum*) and *Hyphaene thebaica* palm in old cultivation areas. Shrubs and relatively short grasses form between the trees (Cole, 1986).

Gums and resins are the main products exploited in the "gum belt" in the Sudan, Ethiopia and Eritrea, notably gum arabic obtained from Acacia senegal and A. seyal, which is widely used in the food industry. The Sudan is the world's main producer of gum arabic (FAO, 2001a). Olibanum (*Boswellia papyrifera*), myrrh (*Commiphora myrrha*) and opopanax (*Commiphora sp.*) are other important exudates. Olibanum and myrrh are used in an unprocessed form for fragrance and as flavouring. The Sudan and Ethiopia are the main providers of olibanum to the world market (FAO, 2001a).

Acacia senegal is a multipurpose tree, not only producing gum, but also preventing desert encroachment, restoring soil fertility and providing fuel and fodder. Although it is difficult to quantify the environmental contribution Acacia senegal makes to the land-use system, a distinction can be made between benefits such as soil stabilization, water retention and nitrogen fixation, which are to some extent 'internalized' through maintaining or enhancing the yield of field crops within the system, and more 'external' benefits such as dune fixation and large-scale desertification control.

Agricultural Productivity (including livestock issues)

The woodland savannah farming system receives monsoon rainfall ranging from 3001 to 200 mm and is generally subdivided into two zones based on rainfall amounts (the low savannah receiving 300-800 mm and the high savannah benefiting from 800 mm).

The Sudan's Nile Basin forests and woodlands typically feature tall shrubs in areas of low rainfall in the north, and tropical high forest in the south. Thirty-five percent of the land in the Sudan is classified as forest and woods, of which one quarter represents timber resources and three percent are forest reserves. There are also some plantation forests and community woodlots. Food crops are intercropped with tree crops and are grown mainly for household consumption. Livestock are marginal.

There are also commercial tree crop estates (particularly for tea), providing some employment opportunities for smallholder tree crop farmers through nucleus estate and outgrower schemes. As neither tree crops nor food crop failure is common, price fluctuations for industrial crops constitute the main source of vulnerability.

In the high-rainfall savannah, forestry is an important activity producing fuelwood and wood for local industries.

The woodlands of the low rainfall savanna cover an area of 520,000 km^2 across central Sudan - one fifth of the country's total area. This "gum belt" is the source of the main NWFPs, namely exudates (gum arabic, gum karaya from *Sterculia sp.*, olibanum), but also fodder, fruit, shea butter, medicinal plants, dyes, honey and beeswax and bushmeat (FAO, 2001a).

Gum arabic is primarily produced by small-scale farmers in traditional rainfed farming areas (large gum plantations represent less than five percent of the total production). It is part of an integrated farming system, which is largely characterized by subsistence production and the use of family labour, with no modern equipment and inputs. Under this system, crop production — usually sorghum or millet — to secure the food needs of the family is *given priority*. However, small-scale farmers grow gum Arabic for extra income to meet their household needs. Cultivation of gum arabic also constitutes a crop diversification strategy, mitigating crop failure, bringing environmental benefits and representing an on-farm supply of fuelwood and fodder. Gum arabic production does, however, compete with food and cash crops for labour resources and land allocation.

The land-use system for gum production is a bush fallow system. Each plot of land is used to cultivate crops for about 4-6 successive years followed by a period of 15-20 years of fallow under regenerating Acacia senegal. In order for the tree to produce gum it has to be tapped or injured about 3-6 weeks before collection. When the production of gum Arabic declines, the trees are cut and used for fuelwood and the land is put under cultivation. During this period the trees regenerate naturally.

Gum harvest provides small farmers with an important source of revenue during the dry season when there is no income from agricultural crops. As the labour input and financial output occurs at different times compared to other crops, gum cultivation is a way to diversify livelihoods and alleviate risks. The trees have a lateral root system, which reduces soil erosion and rainfall runoff. Acacia senegal is a leguminous tree, which fixes nitrogen and thereby improves soil fertility. It has been demonstrated that nutrient (N and K) and organic matter accumulation in Acacia senegal over 15 years of fallow provides good sorghum yields for at least four cropping cycles. The environmental benefits attributable to Acacia senegal make it a preferred species in the semi-arid areas of the Sahel. It is used widely to create buffer zones against desertification and increasingly to restore degraded land.

Agricultural operations, including gum arabic harvesting, are primarily financed by village traders using the traditional 'sheil' system. Typically, traders provide cash, seeds, tools but also basic commodities like water, sugar and tea for households to get by on during the "hunger gap". Farmers pay back in kind at prices determined early in the season and usually at high interest.

The Sudan is the world's largest producer of gum arabic, widely used in the food, pharmaceutical and technical industry. In the 1996/97 season, total exports of gum arabic, mainly derived from Acacia. senegal, were 17 759 tonnes. The supplementary revenues generated by Gum arabic are crucial to the livelihoods of about six million people in the Sudan who live in traditional rainfed farming areas, where the incidence of rural poverty is in the range of 65 to 90 percent.

In Eritrea, Acacia senegal and *Boswellia papyrifera* are economically important trees which cover over 5 000 ha of land mostly on hilly slopes and in small valleys The main NWFPs from Eritrea are exudates (gum arabic, olibanum from *Boswellia papyrifera*) and leaves from the doum palm *Hyphaene thebaica*) (FAO, 2001a). Up-to-date statistics are not available, but in 1997, Eritrea exported 496 tonnes of gum arabic, 543 tonnes of olibanum and 2 064 tonnes of doum palm leaves.

The main NWFPs from the woodlands of Ethiopia are exudates (olibanum, gum arabic and myrrh from *Commiphora myrrha*), together with medicinal plants, honey and beeswax (FAO, 2001a). Ethiopia is one of the world's largest producers of olibanum with an annual output of 1 500 tonnes. Up-to-date statistics are not available, but annual production of gum arabic reached 350-400 tonnes in 1988-94 and in 1976-1983 annual honey production ranged from 19 400 to 21 000 tonnes, then representing 24 percent of total African honey production.

Water Management

Not applicable

Issues

Gum arabic is one of the Sudan's four most important agricultural export commodities[26]. Over the last 20 years, the value of gum arabic exports amounted on average to USD40 million a year. While there has been government intervention in the marketing of all agricultural exports in the past, gum arabic is now the only commodity for which government controls remain.

In the Sudan gum arabic farmers represent up to 20 percent of the population and are among the poorest. They have benefited neither from national gum arabic marketing policy nor from recent changes in the international market structure. This has led to reduced production and consequently lower exports. Those have been declining for the past 40 years at an average rate of 2.2 percent/year.

The gum arabic belt is suffering from increased deforestation due to drought and population movements. Generally, acacia trees are resistant to periods of low rainfall, however the combination of severe droughts in the mid-seventies and mid-eighties, civil conflict, internal displacements and changes in farming practices have negatively impacted on gum arabic production in North Kordofan and North Darfur. As a result, the gum arabic belt is moving south towards clay soil areas with better rainfall patterns. Production in the Blue Nile and Upper Nile regions and the southern parts of Southern Kordofan and South Darfur is increasing.

Opportunities

It is proposed that this system is developed further to encourage many more farmers to cultivate 1-2 ha plots of Acacia senegal on their land in order to diversify their sources of income.

The following recommendations were made for the Sudan, but equally apply to the other countries of the basin:

[26] Along with livestock, cotton and sesame.

- Revision of national forest policy to promote production of gums and resins
- Updating of the forest products consumption survey and national forest inventory
- Wide-scale promotion of tree planting, afforestation and reforestation, and also of sustainable forest management
- Review of, and support to, forestry education and research, particularly to promote NWFPs
- Capacity building/curriculum development[27] to instil contemporary forestry concepts such as the importance of NWFPs, sustainable forest management, criteria and indicators, legally binding and non-binding instruments, etc.

Riverside and Lakeside

General Description

A range of different farming and fishing practices are found in, and close to, the Nile Basin. Some of the people living along these water courses depend entirely on fishing. Others rely on farming (cropping and/or livestock), to various degrees.

Agricultural Productivity (including livestock issues)

In Ethiopia, livelihoods in this farming system are based on crop cultivation on floodplains supplemented by fishing and livestock rearing. The system is practiced along the major riverbanks, notably the Alwero, Baro, Akobo and Kobo, and also in the swamps around Lake Tana. The area is densely populated, particularly during the dry season as agropastoralists and pastoralists swell the numbers of resident sedentary farmers. Cultivated plot sizes are very small.

Cropping activities are carried out in bands approximately 150-200m wide along either side of rivers, in most areas twice a year. Generally seeds are directly sown using what is known as the "dibbling" system (putting 3-4 seeds per hole), usually without any form of tillage. Crops cultivated along the rivers include maize, sorghum, sesame, but also groundnuts, cowpea, rice, onions, other vegetables as well as tobacco and beans. Productivity is very low due *inter alia* to soil-borne pests and diseases since there is no soil exposure to sunlight. Only a small number of families depend solely on crop production as almost all households supplement their diets by fishing.

The livestock kept in the riverside farming system includes cattle, sheep, goats, horses, donkeys, mules and poultry (Table 54). There are no camels registered in the area (a small number appear in the tables below – owned by migrating agropastoralists and pastoralists). Wild bees are found in the forests adjacent to the farming system.

Livestock forage on the abundant natural vegetation (grasses, legumes, shrubs, bushes and tree leaves), supplemented by crop residues, although supplies of these are limited (see below re cropping), particularly as they are also used for fuel, home construction and bedding. At the rate of 2.28 tonnes of dry matter /TLU/yr, the total feed requirement for livestock in the production system is 1.48 million tonnes.

[27] This capacity building needs to encompass all stakeholders, particularly statutory authorities.

The feed supply is assessed as adequate throughout the year.

Water for livestock is available from rivers, lakes, ponds, wells and swamps, with an estimated annual water requirement of 7.79 million m^3 (Table 55). (This does not include soil moisture required for forage and fodder growth).

Milk, meat, hides and skins, and manure are the major livestock outputs. Cattle are the primary providers of milk, with sheep and goats providing small quantities.

The bees used by beekeepers are the indigenous "wild" bees *Apis mellifera*. Nine different forest types are identified, together with an indication of the size of their resident bee populations: Coniferous forest; Aningeria forest — high; Olea forest — high; Baphia – high; mixed deciduous woodland — high; Combretum and Acacia woodland — high; riparian forest — high; bamboo forest and/or woodland – medium/ high. Plantations provide excellent forage, nesting habitat and material for making hives. The bees have an important role in pollination of various locally grown crops.

The current beekeeping practices are honey hunting and traditional beekeeping, Frame hives are used to a limited extent.

Based on the data available, families can meet their food requirements from livestock, honey and the sale of forest products. Mango trees, planted along river banks, supply fruit both for household consumption and as a source of additional income.

There is little fishing in the upper catchments. In lower tributaries including the Baro, Sur, Waber, Yabi, Dibo and Uka, and also on the main River Nile, farming and hunting households supplement their diets with protein from fishing. All members of the families who live near the water are involved. The activity is highly seasonal and traditional equipment is used. The dominant species include: *Oreochromis niloticus*, *Oreochromis zilli* and *Barbus spp*, Nile perch, Nile tilapia, Catfish, Barbus, Bargus and *Labeo spp*.

Unlike other ethnic groups in the region, the Anuak tribespeople keep no livestock and depend on fishing together with dryland and floodplain cultivation and hunting. In this farming system, some fish are sold to bring in cash income.

In the Sudan, fisheries currently involve over 6 000 fishers and the resource potential is clearly considerable. The main management systems for fisheries include the following:

- sudd Swamps and related floodplains fisheries;
- reservoir fisheries in the Nile River and tributaries (Sennar Reservoir, Gebel Aulia Reservoir, Kashm El Girba Reservoir, Lake Nubia);
- aquaculture;
- freshwater fish culture.

In Egypt, the aquatic resource base is extensive, including fresh, brackish and marine waters. It can be subdivided into two main broad sectors – capture fisheries and aquaculture.

Capture fisheries exist on the River Nile, in various lakes, canals and drains and, outside of the basin, in the Red sea and the Mediterranean. The amounts of fish produced by capture represent only 39 percent of total national yield. Lakes, seas and inland waters (the Nile and its branches) respectively account for about 45 percent, 31 percent and 24 percent of the total capture catch. The aquaculture sector accounts for over 60 percent of total national production (Table 58).

In recent years there has been an expansion of fish farms in inland waters, including irrigated rice fields. However, the introduction of high-yielding – and shorter duration – rice varieties requiring shallower water and higher inputs of pesticides has led to a significant reduction in fish yields.

Semi-intensive fish farming produces some 82 percent of the aquaculture sector's output. Currently, fish farming in Egypt ranges from traditional village type ponds and the *Hosha* system (enclosed low-lying areas), to modern government and private fish farms using the latest techniques. Aquaculture is emerging as a viable source of high-protein food which has attracted investors looking for profitable opportunities.

Total production from aquaculture has shown a steady annual increase since 2000 (Table 58). The sector's fast development has been given considerable government support in the form of technical, financial and extension assistance. The most common species reared in Egypt are tilapias, mullets and carps.

Overall fish production in the Egypt's Nile Basin (excluding the seas) has increased significantly since the 1980s, with production rising over 30 percent between 2000 and 2005 alone. This increase is mainly attributable to aquaculture, which has grown steadily over that period, while the production from inland waters has seen variations both up and down.

In Kenya, fishing Is a major occupation for the communities living on the shores of Lake Victoria. The mixed farming system practiced there involves some 3.2 million people and over 600 000 households. Farm sizes range from 0.2 to 10 ha, although the average is around three ha. The area lies within the semi-humid climatic zone, where rainfall is between 700 and 1 000 mm and the system can therefore only support short-season or drought-tolerant food crops such as sorghum, millet, cowpeas, green gram and cassava, and industrial crops such as cotton and sunflower.

Livestock keeping among the communities is as important as crops due to its major role in the livelihood strategies of the communities within the basin. The role of trade is even more critical, considering the myriad challenges facing crop production, livestock and fishing.

The main source of livelihoods in this system is traditional fishing, as in Ethiopia. Fishing activities, methods and equipment have been developed to suit different water resource (lakes, ponds, river, and wetlands) and is a form of traditional knowledge passed down the generations. Some individuals and families specialize in certain types of fishing, for example river fishing, mud or wetland fishing, lakeshore fishing and fishing in the high waters of Lake Victoria. Fisheries are generally the men's preserve while women look after the drying, processing and selling.

Combining fishing and farming has been crucial to the sustainability of this system,

Table 54: Livestock Holdings in the Riverside Farming System, Ethiopia

Type	Population
Cattle	665 264
Sheep	295 861
Goats	442 027
Horses	6 486
Donkeys	11 556
Mules	64 412
Camels	37
Poultry	523 912
Bee colonies	8 331

Source: FAO Nile Country Report: Ethiopia (2008)

Table 55: Livestock Drinking Water Requirement in Riverside Farming System, Ethiopia

Type	Rate/Annum (m^3)	Population	Water ('000 m^3)
Cattle	9.125	665 265	6 071
Sheep	1.825	295 861	540
Goats	1.825	442 027	807
Horses	4.38	6 486	28
Donkeys	4.38	11 558	51
Mules	4.38	64 410	282
Camels	10.95	37	0.4
Total			**7 778.70**

Source: FAO Nile Country Report: Ethiopia (2008) which is vitally important at the national level. Although the area involved is small it accounts for 90 percent of the total fish produced in Kenya (between 105 866 and 151 804 tonnes in 1999-2003). However, the future of capture fisheries is uncertain. Despite the fact that between 2000 and 2002, the number of fishermen rose from 33 000 to 54 163 (i.e. 64%), production declined from about 200 000 tonnes to as low as 100 000 tonnes. The recent increase in the number of fishermen, boats and un-standardized fishing gear are factors blamed for the decline in annual catches.

It is very likely that fish farming will grow further in future as fish yields from Lake Victoria continue to drop. The districts fringing Lake Victoria (Suba, Bondo, Busia, Kisumu, Rachuonyo, Migori, Homa Bay and Nyando) are important areas for aquaculture production, with the highest potential for expansion. In 2006, there were 6 183 fish ponds of various sizes and 3 898 farmers.

Other key components of this farming system include exploitation of water resources such as papyrus, reeds and sand harvesting along the streams leading to the lake. Cottage industries such as weaving mats and baskets are part of the farming system.

Also in the upper Nile, fishing is practiced in the lakes and rivers of Rwanda, where only traditional techniques and equipment are used. Aquaculture is generally practiced in low-lying areas as a complementary source of revenue for families during the dry season.

Table 56: Fisheries Resources of the Reservoirs of the Sudan

	Area (km^2)	Fishery potential (t/yr)	Fish landings (t/yr)	No. of fish Species	No Fishermen	No. of boats
Sennar	140-160	1 100	1 000	22	800	450
Jebel Aulia	600-1 500	15 000	13 000	56	3 500	2 000
Khashm el Girba	125	800	500	15	350	140
Roseiris	290	1 700	1 500	22	1 200	550
Lake Nubia	830-1 000	5 100	1 000	43	150	60
Sudd swamps	16 500	75 000	30 000	-	-	-

Source: FAO, sudanimal.com and Local Department Reports

Table 57: Total Fish Production, the Sudan

Location	Amount (t)
Total fish landing from main landing places	52 000
Fish landing from other sites on River Nile	4 000
Fish production through aquaculture	1 000
Grand Total	**57 000**

Source: FAO Nile Country Report: the Sudan (2008)

Uganda is an example of a country where government intervention aims to improve fisheries' sustainability and thus benefit the communities dependent principally on artisanal capture fishing and processing, and on fish trading. The Government recently (in 2005) created structures known as Beach Management Units (BMUs) around the country's major lakes. The BMUs were designed to empower the fisheries communities to manage their resources sustainably.

Lakes Victoria, Kyoga, Edward, George, Albert and Wamala are the most important sources of fish in the country, with over 160 minor lakes and the aquaculture sector contributing additional produce. But Ugandan lakes are facing a depletion of fish stocks, with recent reductions in fishers' revenues. These have dropped from USD145.8 million in 2006 to about USD100 million In July 2007 and they were expected to drop further to USD60 million in 2008.

The overall daily catch has sunk to less than one tonne from six tonnes in nearly all BMUs in the country. A survey conducted in 2007 on Lake Victoria, showed that the average daily catch rates of Nile perch had dropped from 83.7 kg to 22.8 kg. Similar reductions have been observed in the catches of Tilapia. However, quantities of Silver fish (Mukene) and Haplochromines (Nkejje) are increasing and now contribute more than 1.5 million tonnes – 75 percent of the estimated fish stocks in the lake.

Water Management

See above and following sections

Issues

Fisheries depend on an assured continuous, plentiful supply of high-quality water, whether in rivers, lakes, irrigation channels, rice fields or aquaculture ponds. There is a range of factors contributing to making this a challenge. They include:

- unsustainable management of croplands and rangelands, leading to soil erosion and high river and lake sediment loads;
- overuse or misuse of fertilizers and pesticides – with excess runoff into drainage ditches, streams and eventually the Nile;
- over abstraction of water up-stream;
- Legal issues – for example, the future of aquaculture is rather uncertain in Egypt as fish farms are currently only allowed to use drainage water, which is risky because of pollution.

In addition, over-fishing by capture fisheries is a problem across the basin. The FAO Nile Country Report for Uganda noted a number of factors contributing to the depletion of fish in the country's lakes, including:

- use of illegal fishing gear;
- increased pollution of fishing grounds;
- use of the wrong type of fishing boats;
- receding shorelines (over 100 m in some cases), reducing the breeding grounds of a number of fish species.

The FAO Nile Country Report on Kenya noted that wider popularisation and expansion of aquaculture had been hindered by:

- lack of access to credit to fund pond construction;
- limited sources of quality fry;
- limited knowledge of pond fertilization to grow fish to table size within a given time;
- poor availability of quality feed for pond fertilization;

Table 58: Development of Fish Production from Different Resources (2000-2005), Egypt (0'000s t)						
Items	2000	2001	2002	2003	2004	2005
Capture Fisheries (Natural Resources)						
Northern Lakes						
Manzala	74 132	68 400	58 400	65 015	63 772	39 857
Boroullos	51 768	59 200	59 785	55 500	55 000	53 909
Edco	8 922	10 910	10 336	10 230	9 056	9 619
Maryout	6 378	6 200	5 303	4 861	5 024	5 292
Inland Lakes						
Qaroun	1 819	1 396	1 925	2 452	2 682	3 037
Rayian	1 876	861	1 231	1 313	1 271	1 992
Nasser/ High Dam	16 812	28 153	23 371	41 315	24 998	30 571
Almorra and Timsah	5 786	5 444	5 669	5 879	5 307	6 289
Toshkai	2 200	1 519	2 500	5 078	7 562	4 045
New valley	15	200	230	314	****	****
Total of Lakes	169 708	182 283	168 750	191 957	174 672	154 611
Inland Waters						
Nile River and branches	80 321	109 887	120 852	118 300	105 000	83 803
Total of Inland waters	250 029	292 170	289 602	310 257	279 672	238 414
Aquaculture (Fish Culture)						
Fish farming	307 664	300 778	330 551	394 772	401 849	499 834
Intensive Culture	--------	-------	1 015	1,030	2 080	2 472
Fish culture in cages	16 069	23 716	28 166	32 059	50 403	19 838
Fish culture in Rice field	16 360	18 371	16 334	17 006	17 203	17 603
Total of Aquaculture	**340 093**	**342 865**	**376 066**	**444 867**	**471 535**	**539 747**
Grand Total	**590 122**	**771 515**	**771 515**	**771 515**	**771 515**	**771 515**

Source: adapted from FAO Nile Country Report: Egypt (2008) [Original source - Ministry of Agriculture and Land Reclamation, Central Department of Agrarian Economics & Stats., Records of Statistics (excludes sea fisheries)

- breakdown in the extension service delivery system.

The sustainability of this farming system is under threat due to huge ecological damage. Most of the fishing communities are unwilling to plant trees, yet enormous amounts of wood are needed daily to dry fish[28]. There is great competition between demand for fuelwood for domestic use and from the fishing subsector. This means that growing trees for firewood could be a major income-generating activity for non-fishing households and communities. But so far it has not been pursued.

The livelihoods of the communities relying on this system across the Nile Basin remain at subsistence level. There is a need to transform the system and make it more commercially-oriented, most likely through capacity building with farmers and farmers' organizations.

Opportunities

For livelihood improvement and as a pro-poor strategy, the integration of aquaculture into farming systems is very important. Rice-fish culture, cage culture and development of capture fisheries in small water bodies and reservoirs used to store water for irrigation are among the most promising. Hence, water productivity can be increased by integrating fish and other living aquatic resources into water-use systems.

There are great opportunities to expand fisheries, including capture and aquaculture, in the basin although in all cases care must be taken in planning and management to ensure it is done in an environmentally sustainable manner. The sector has the potential to provide a much-needed source of protein and to generate employment.

Particular areas for future development noted in the FAO Nile Country Reports included:

For Kenya:

- There are still large areas of uncultivated arable land that has been degraded due to overgrazing and deforestation.
- This "idle land" could beneficially be planted with trees to provide firewood for drying fish and possibly also other NWFPs.
- The huge volume of water causing floods each year (e.g.in the Nyando basin) could be harvested and put to more productive use.
- There is vast fisheries and irrigation potential in districts with major rivers and in areas sharing Lake Victoria waters, while more rainwater should be harvested for crop production.
- More opportunities should be developed through regional integration, especially in the areas of marketing and value addition.

For Egypt

- The production of fish in irrigated rice fields could easily be restored and increased with adequate stocking and management combined with appropriate selection of rice pesticides.

For Uganda

- The country has failed to meet its annual export quota requirement of 600 000 tonnes of fish and fish products to the

[28] Firewood is required to cure the fish to increase shelf life in the absence of refrigeration facilities.

EU. Consequently, there is need to develop aquaculture as an alternative source of fish to sustain export markets and local consumption.

Market-Oriented Agriculture (including urban, peri-urban and commercial)

General Description

This farming system encompasses a wide range of specialized forms of agriculture which have developed over recent years to cater for the urban and export sectors. These aim to make best use of inputs to maximize production – often concentrating activities in restricted areas of land.

Agricultural Productivity (including livestock issues)

Commercial agriculture is a system of farming which has been introduced relatively recently into the basin area, for example in Ethiopia. On a large scale, it is geographically limited in occurrence and makes only a limited contribution to overall national agricultural production.

Most of the large-scale production farms are concentrated in the western lowlands and the north Gondar and west Gojam areas. Most farming operations are carried out with machinery and make wide use of fertilizers and other yield-enhancing inputs.

Most of the state-owned farms under the former Gojjam Gondar Agricultural Development Enterprise were abandoned (mainly due to changes in the political situation and to infestation by striga), but some private enterprises are now emerging.

Urban centres across the basin offer opportunities for rural people as markets for farm products and labour. Agriculture areas around and within cities characteristically focus on horticulture and livestock production. This farming system is very heterogeneous, ranging from small-scale, capital-intensive, market-oriented vegetable-growing, dairy farming and livestock fattening, to part-time farming by the urban poor to cover part of their subsistence requirements. The level of crop–livestock integration is often low and there are typically environmental and food quality concerns associated with peri-urban farming. Agricultural growth is likely to take place spontaneously in these areas, in response to urban market demand.

(See Annex 4 for further examples).

Water Management

Availability of good quality water is often a serious issue in the urban and peri-urban environment, where there are multiple sources of pollution and limited supplies for crop and livestock systems.

In livestock systems outside the urban/peri-urban areas, availability of sufficient safe water for livestock is also a particular concern.

Keeping livestock in irrigation systems is clearly beneficial, as they can feed on crop residues and by-products, thus not requiring extra water, and they provide a supply of manure. However, the poor quality of the water in the irrigation canals used as the main source of drinking water for animals, and also its restricted availability, affects the health, welfare and production of these animals. The shores of the canals are the greenest parts of the pastures, which naturally attract livestock for grazing. Where cattle graze, they also defecate with consequent pollution problems.

Livestock kept indoors (zero-grazed) must have adequate water at all times. In studies, fewer than half of the farmers in this system considered the quality of their water to be poor or a potential cause of disease. However it must be said that they do not have much choice regarding their source of water.

Issues

The performance and efficiency of commercial farms is generally limited, due, among other things, to poor management, scarce utilization of inputs, poor rural infrastructure, pests and diseases, inadequate marketing services, lack of technical support and shortage of labour.

For example, rainfed, semi-mechanized farming in the Sudan (Annex 5) needs to be transformed into a system ensuring the stability of production through the integration of crops and livestock (also forests). The main shortcomings are:

- low yields due to the use of traditional varieties and cultural practices;
- high cost of production;
- shortage of formal credit;
- poor infrastructure including feeder roads and water points;
- absence of machinery services for small farmers;
- Poor access to marketing services;
- Horizontal expansion and deforestation resulting in land degradation;
- Uncertain land tenure.

The top-down approach of many projects intended to develop this system often include little if any participation of target communities. Such projects also often lack clear objectives and strategies to manage and develop natural resources – leading to the collapse of initiatives.

Opportunities

The increase of productivity in semi-mechanized agriculture is considered crucial for sustainable development in the Sudan. The Arab Authority for Agricultural Investment and Development (AAAID) has carried out a pilot project to increase the productivity of crops in the rainfed farming system using zero-tillage as an alternative to traditional cultivation systems. The results showed that sorghum yields could be increased nearly five times as compared with traditional practices. (FAO Nile Country Report: the Sudan, 2008).

Organic farming has great potential in the basin in view of rising global demand for organic products and for the higher economic returns which they bring. However, pest and disease issues can severely limit production and should be addressed with alternatives to chemical pesticides. Organic fertilizers and SLM techniques to maintain soil health and fertility are also vital (World Bank, 2009).

The development of large-scale commercial farms should be seen in the context of overall private-sector development and participation in the wider economy. Provision of basic infrastructure and market access along with development in production technologies and systems should be priority considerations.

4. Principal Constraints to Agricultural Productivity Enhancement

Land Tenure

There are two major issues regarding land tenure. First, fragmentation of land holdings to sizes too small for household subsistence in rainfed cropping farming systems; second, the communal ownership of rangelands.

The fundamental importance of land tenure cannot be stressed enough, but the removal of this constraint is highly political and conditioned by national policies in relation to land and related water access (FAO, 2004).

Other particular issues noted in the country reports were:

- Declining areas of rangelands due to increasing areas being used for settled farming. This often results in the closure of traditional livestock migration routes and leads to overgrazing of rangelands.
- Unsettled land rights on large-scale irrigation schemes in the Sudan (with the exception of Gezira). Land tenure issues are critically important, particularly as regards the reform of the rules relating to land transfer, sale and consolidation. To improve schemes' productivity (water use and crop yields) the question of the increasing numbers of absentee landlords must also be addressed as their land could be much more productive.

Insecurity and Social Rigidity

Disputes between pastoralists, agropastoralists and settled farmers, inter-clan disputes and lack of security in border areas are overarching issues in the Nile Basin. Parts of several basin countries have clear scope for increased agricultural productivity, but this is limited due to current insecurity. They include:

- the western Sudan
- northern and western Uganda
- western Rwanda
- the Democratic Republic of the Congo

Outside these zones of conflict, social rigidity can have a determining effect on the choice and transition of farming systems. The pastoral system of production is governed by social and community laws concerning the management and utilization of natural resources, which are deeply entrenched in the cultures and traditions of the different ethnic groups. These include regulation of herd movements, utilization of water resources conflict resolution and social justice. Although there are profound similarities, the different ethnic groups practicing the system exhibit considerable differences in their overall enterprise patterns, seasonal movements and in the other activities in which they are involved. There are also wide variations in the level of integration of pastoralists into the market economy.

An additional constraint to livestock production and water-use efficiency across almost all farming systems of the basin is that by tradition large numbers of animals are kept for prestige rather than production. With declining areas of land available for grazing and the frequent closure of migration routes, the result is virtually continuous overgrazing with consequent land degradation. Livestock productivity and annual livestock off-take rates are low – but could be increased and the resilience of livestock keepers' livelihoods to droughts improved, thus protecting herds against being decimated and avoiding herders becoming reliant on emergency aid in times of drought.

Extension and Veterinary Services

There have been major changes In the way traditional extension services operate in most the countries of the Nile Basin due to Government restructuring and decentralisation of services – with many now privatised. This has resulted in a widespread breakdown in traditional extension services, coinciding with times of great environmental, economic, demographic and climatic pressure on the farming systems. Farmers thus have to rely on traditional knowledge and are unable to benefit from developments which could help them cope better with rapid change.

The optimum is for extension providers to help farmers adapt their traditional systems by integrating new approaches and up-to-date scientific information to develop sustainable, locally viable systems.

The following constraints were highlighted in the county reports:

- Current levels of knowledge of new technologies and ability to absorb extension information are low, due to cultural and educational factors.
- Socio- cultural barriers delay some farm operation, exacerbate the situation and frequently lead to famine.
- Not enough farmers' organizations exist.
- Lack of specialized scientists (agronomists, plant pathologists, breeders).

Specifically, extension services should be raising awareness of:

- rainwater harvesting for crop, livestock and domestic use;
- approaches to pasture improvement;
- conservation agriculture and low- tillage systems;
- restoration of rotations and the benefits of fallowing;
- restoration of diversified cropping systems;
- organic agriculture;
- correct use of inputs;
- technology transfer on improved agricultural processing and storage.

With regard to veterinary services, the livestock keepers of the Nile Basin have very limited or no services, depending instead on traditional approaches and not benefiting from modern medicines and vaccines to protect and improve the productivity of the animals on which their livelihoods depend. This issue is particularly important as:

- Pastoralists keep large numbers of stock, often compromised by poor forage and water.
- Specialist farmers are keeping livestock in zero-grazing, high-intensity units, where the risks of disease spreading are higher.

Land Degradation

Land degradation refers to the reduction or loss of the biological or economic productivity and complexity of land. It results from land uses or from a process or combination of processes, including those arising from human activities and practices. It causes long-term loss of natural vegetation; soil erosion caused by wind and/ or water; and deterioration of the physical, and chemical and biological or economic properties of soil (FAO, 2009c).

Chapter 3 details how land degradation is a major cause of damage to the natural resource base of the Nile Basin. Degradation is occurring at rates greater than soil formation, for example, and is being exacerbated by increasing climate variability. The productive capacities of cropland, rangeland and woodland are being reduced just when demand for food, fibre, fuel, freshwater, fodder, household energy and income is rising.

The problems stem from:

- ploughing, reduction in fallowing and depletion of soil organic matter leading to damage to its physical, chemical and biological properties;
- loss of top and sub-soil;
- loss of natural tree cover in woodlands and forests due to clearance or selective over-harvesting;
- reduction in the protective cover of vegetation on grass and rangelands due to overgrazing and/or excessive burning.

Particular examples from this review include:

In the **irrigated farming systems**, high levels of chemical inputs are often applied, but their full benefits are too often limited due to soil salinization, waterlogging, over-use of fertilizer, the depletion of soil organic matter and the use of tractors. Further particular issues affect the small-scale systems of the upper Nile (in Rwanda and Burundi), leading to changes in the hydrology of rivers. These irrigated areas were formerly swamps and marshes, which previously acted as sponges, absorbing heavy rainfall and gradually releasing it into out-flowing streams. Once drained, they no longer perform this role, thus downstream river levels show much greater extremes.

In the **pastoral, agro-pastoral and dryland farming systems**, which include large areas of grass and rangelands, continuous grazing, overgrazing and burning are reducing the cover of living plants on the soil surfaces. This loss is leading to erosion and in some cases the formation of a surface cap leading to the reduction of rainwater infiltration and the destruction of soil structures. Land users could rehabilitate and increase yields of pastures by undertaking vegetative SLM and minor SWC activities to restore soil functioning. That would reduce rainfall runoff and loss of topsoil while also increasing the topsoil's organic content and water storage capacity. Farmers should further re-seed degraded areas, including with N-fixing legumes – but options are limited due to issues of land tenure, the vast areas involved and lack of knowledge.

In all the arable farming areas of the Nile Basin, soil nutrient levels are progressively declining due to frequent ploughing (mainly by hand), extractive (low or no-input) production and the abandonment of sustainable practices such as fallowing, organic matter application and crop rotation including N-fixing legumes.

The main issues for farmers in the **highland tropical farming system** are both overgrazing of grasslands and degradation of soils on arable areas, exacerbated by declining farm sizes. For example in Rwanda where rural population densities are the highest in Africa and farmlands are predominantly undulating, there is widespread non-compliance with the recommended contour planting, which would facilitate contour irrigation in times of drought and would reduce erosion in the frequent heavy rains. The terrain also exacerbates soil erosion in Ethiopia, Kenya, the United Republic of Tanzania and Uganda – although in these countries the pressures are less, due to lower, although still challenging, rural population densities and more alternative livelihood opportunities.

In the **highland temperate farming system** in Ethiopia, high levels of soil erosion have occurred leaving very shallow soils as the often steeply sloping land has been inappropriately ploughed and overgrazed. Natural forest cover has been lost as cultivation has extended onto marginal land.

The **highland cold farming system** of Ethiopia is becoming degraded due to growing human and livestock populations living on often steeply sloping, thin-soiled, fragile lands. The soils of the cropped areas are being degraded due to the progressive decline in soil organic matter. Meagre crop residues are used for livestock feed and livestock manure is not returned to the soil but instead used, with straw, as fuel – or as a construction material. There is little local knowledge of approaches to pasture improvement.

In the **lowland tropical farming system** of the basin, farmers in Kenya, Uganda, the United Republic of Tanzania and the Sudan have in the past been encouraged to modernise their production system by ploughing and growing maize monocultures – without restorative periods of fallow or application of manure. and with declining use of mixed cropping and/or rotations (notably including legumes to restore soils nitrogen). This is proving unsustainable, as soils are open to accelerated rates of degradation due to rain, wind and sun following ploughing, and few nutrients are restored. In some areas, smallholders are reverting to more extensive production practices as the economics cannot sustain, for example, hiring a plough to prepare their small fields. Approaches such as conservation agriculture, low tillage and also restoration of rotations and crop diversification, which reduces the risk of crop failure, could help restore soils and increase crop yields relatively quickly if scaled up.

In the **forests farming system** in Ethiopia, a pervasive belief that these areas have inexhaustible natural resource bases and agricultural potential has cotributed to degradation. It has also negatively affected people's perceptions and behaviour towards management of land and utilization of resources. The preferred settlement areas, abundantly endowed as they are with natural resources and a climate conducive to agriculture, are also extremely sensitive and fragile – requiring utmost care, knowledge and understanding of their inherent characteristics and dynamics. Settlers who recently arrived from the highlands have started cereal production by clearing the natural forest cover. This is causing accelerated change in land-use patterns, which is exerting pressure on the natural resource base, upon which the local livelihoods depend. The indigenous livelihood systems and practices are being marginalized and increasingly replaced by what seem to be more productive and efficient ones, with disregard for the sustainability of the new system. Indigenous populations are increasingly adopting the settlers' way of life and production system.

In the **woodland farming system** in the Sudan, Ethiopia and Eritrea, Acacia senegal, the leguminous tree know to be very valuable not only for gum production but also as a buffer against desertification and increasingly for restoration of degraded land, is being degraded not only by droughts but also by pressure of growing human populations, changes in farming due to civil conflicts and changes in international market structures.

Limitations in Availability of Inputs

Organic Matter

Soil is a living medium which houses a rich and vital micro/meso fauna and flora. It is the land user's most vital asset, but it is also a finite and often fragile resource, which not only provides plants with nutrients and water, but also has a critical role in filtering and buffering action to protect water supplies and the food chain from potential pollutants. Soil organic matter (SOC) is the soil's life support system, enhancing fertility (nutrient retention), increasing rainfall infiltration rates, increasing water holding capacity, creating improved conditions for soil fauna and related macro-pores (earthworms, termites and root channels) to serve as drainage conduits for excess water - stabilizing a much improved soil structure, thus increasing "the resilience of the land".

The amount of SOC stored in soils is not static but hangs in dynamic equilibrium, a balance between the input of plant material (from photosynthesis) and losses (due to decomposition/respiration and mineralization processes). Repetitive tillage, particularly with tractors but also with hand tools, is particularly harmful to SOC in tropical, hot and dry climates, as it exposes the organic matter to the atmosphere, where it rapidly decomposes[29]. Where fields are cropped one or more times per year and particularly in warm and hot environments such as in many parts of the Nile Basin, the SOC levels rapidly decline and need to be replenished to maintain a productive soil.

Unfortunately, in most of the farming systems of the Nile, there is a shortage of organic matter for return to the soil. This arises for a variety of reasons, including:

- small numbers of livestock, for example in the woodland and forest systems;
- livestock ranging freely, therefore manure widely dispersed across pasture and rangeland;
- livestock feed on cereal stalks (in most mixed systems);
- organic matter used for thatching etc. (in all farming systems);
- manure used as fuel (in highland temperate and cold farming systems);
- burning of crop residues (in lowland tropical, highland tropical and dryland

[29] Conversion of natural systems to cultivated agriculture results in losses of between 20 and 50 percent of pre-cultivation soil organic carbon stocks.

farming systems);

- shortage of labour to distribute compost at appropriate times of year (in all farming systems).

Also

- Lack of awareness of the importance of SOC.

Increased awareness is required of the multiple benefits of SOC for soil structure and functioning which gives land users increased ability to adapt to and mitigate climate change.

Farmyard Manure

The farmyard has long been treated as a valuable source of organic matter to enhance soil fertility as manure promotes the formation and stabilization of soil macro-aggregates and particulate organic matter in integrated crop-livestock systems. Manure is particularly valuable as it is more resistant to microbial decomposition than plant residues. Addition of animal manure to soils improves their structure, functioning[30] and fertility – and hence crop yields, without the need for synthetic fertilizers.

Manure is a valuable but often neglected commodity in livestock and mixed farming systems in the Nile Basin. Across the basin, there are particular limitations on the availability of manure in many farming systems. In irrigated systems and woodlands, where there are few livestock, it is sometimes used with straw as fuel and/or as a construction material (e.g. in the highland temperate and cold systems of Ethiopia). It is labour-intensive to collect in free-grazing systems (agropastoral and drylands), while in all the farming systems it is labour-intensive to transport and distribute across arable fields. In complete contrast, commercial livestock units have the problem of disposing of large volumes of manure – which, if correctly handled, could be "exported" to farming systems lacking organic fertilizers.

In some areas, the benefits of integrating livestock into cropping systems have recently been recognized, but without fully planning their introduction. One example is the Gezira irrigation system, where the desired integration has not been achieved as the plan simply introduced fodder into the crop rotation without consideration of other production and marketing requirements for livestock.

Fertilizers

Small-scale farmers in the Nile Basin have removed large quantities of plant nutrients from their soils through harvesting without adding sufficient amounts of organic (manure and/or compost – see above) or inorganic fertilizer to replenish fertility. One important reason is that mineral fertilizers cost between double and six times as much in Africa as elsewhere. Also, they are not always available at the right time due to problems in supply chains and transportation, among others.

Indiscriminate use of fertilizers is not the solution; indeed it is costly and harmful to the environment. The widespread overuse of synthetic, nitrogen-based fertilizers is a major direct source of nitrous oxide, a potent greenhouse gas. Action is required to avoid the problem through raising awareness of the

[30] Aeration, ability to absorb and store rainwater, also restoring the soil's micro and meso flora and fauna.

risks, as current efforts to increase fertilizer availability and commercial pressures may encourage farmers who do not know the harm it can cause to use large quantities of synthetic fertilizer.

However, judicious application of fertilizer (including nitrogen, phosphorus, and potassium) increases the efficiency of all the nutrients and boosts yields. Thus farmers in rainfed and irrigated areas in the Nile Basin would benefit from focusing on nutrient use efficiency, including:

- adjusting application rates based on assessments of actual crop needs (possibly including split application);
- using controlled-release forms of fertilizer;
- applying N just prior to plant uptake, when it is least susceptible to loss;
- placing the N and other plant nutrients more precisely into the soil, to make them more accessible to crops' roots, (micro-dosing).

Judicious, correctly timed applications of fertilizers are particularly beneficial when applied to improved varieties of crops, which have a strong response to fertilizer. Traditional crop varieties generally have a poor response. Where farmers cannot afford to purchase fertilizers or wish to remain organic and obtain a price premium for their crops, leguminous crops and trees which biologically fix nitrogen should be introduced or better integrated into cropping systems[31].

The challenge to applying balanced nutrients is not only the high price of fertilizers, but also lack of knowledge of the potential benefits among farmers and the low priority that the issue is given by existing extension service providers. Ideally, extension services should include soil testing as an important step in planning sustainable land management, as it helps to determine the type of nutrients required to supplement natural soil fertility.

Improved Seed

Since the 1960s, rising cereal yields worldwide have been driven by widespread use of irrigation, improved crop varieties and fertilizers. Although crop improvements have extended well beyond irrigated areas to embrace huge areas of rainfed agriculture, sub-Saharan Africa has not participated in this agricultural success (World Bank 2007). The World Development Report 2008 (ibid.) further notes that by 2000 modern crop varieties of cereal "were sown on about 80 percent of the cereal area in South and East Asia, up from less than 10 percent in 1970 Sub-Saharan Africa is also expanding the use" – but only to 22 percent, of which most will be in commercial systems (e.g. in the large-scale irrigated systems of the Nile Basin and the semi-mechanized areas of the Sudan).

Improved seed varieties offer:

- higher germination rates;
- strains which increase the size of cereal grains;
- strains more resistant to pests and diseases and thus not only contribute to reducing losses but also to the reliability of yields from one year to the next;

[31] "Fertilizer tree systems", are reported to provide between 50 and 200 kg N/ha to the associated cereal crops and are reported to result in yield increases of two to three times those obtained under farmers' previous practices.

- strains less susceptible to lodging;
- strains with shorter or longer growing periods;
- drought-resistant strains.

In the farming systems of the Nile Basin – particularly where synthetic fertilizers and irrigation are being used[32], the benefits of improved seed strains outweigh their disadvantages. As in the case of fertilizers, availability and cost will control the speed and extent to which improved seeds help close the yield gaps identified in Chapter 3. That is especially the case in the many Nile Basin subsistence farming systems where farmers traditionally save seed from one harvest to the next. Widespread adoption of improved seed varieties does risk losing agrobiodiversity, however. This should be mitigated by specific programmes to collect and save the vital genetic resources represented by locally adapted strains of crops, which have developed over millennia through farmers selecting and saving their own seed.

Mechanization

Farm power is a vitally important component of small farm assets. A shortage of farm power seriously constrains agricultural productivity, with stagnation in household income and the danger of a further slide towards poverty and hunger.

Several recent studies of the power situation of households in small-scale agriculture in SSA reconfirm that the farm power situation is deficient almost everywhere and that urgent measures are needed to correct it if the widely promoted goals of raising the productivity of the sector, reducing poverty, and achieving food security are to be achieved.

The term "mechanization" is used to describe tools, implements and machinery applied to improving the productivity of farm labour and of land. It may use either human, animal or motorized power, or a combination of these. In practice, therefore, it involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to draught animal power and to mechanical power technologies.

Mechanization is a key input in any farming system. It aims to achieve the following:

- increased productivity per unit area due to improved timeliness of farm operations;
- an expansion of the area under cultivation where land is available;
- accomplishment of tasks that are difficult to perform without mechanical aids;
- improvement of the quality of work and products;
- a reduction of drudgery in farming activities, thereby making farm work more attractive.

The principal labour demand peaks in the farming cycle are for land preparation and subsequent weeding. The constraints to increased farm production which mechanizations can contribute to relieving are due, to a large extent, to three factors:

- an excessive reliance on human power;
- the low productivity of human labour;
- a decrease in the labour available.

Human muscles still contribute about 65 percent of the power for land preparation in SSA, which covers much of the Nile Basin. A typical farm family reliant solely on human power can only cultivate some 1.5 ha per year. This rises to four ha if draft animal power

[32] Generally, local varieties of crops do not respond as well as improved strains to additions of fertilizers or under irrigated conditions.

is available, and to over eight ha if tractor power can be used. It is quite common to combine available power sources in order to increase the area farmed or to reduce the burden on humans. Tractors or draught animals can be hired for primary tillage and subsequent planting; weeding can also be done with a combination of power sources and technologies.

Application of these alternative power sources can relieve pressure on human labour at critical times. Making more efficient use of human power, together with the efficient application of draught animal power, provides the best immediate strategy for reducing farm power shortages in the Nile Basin, thereby increasing agricultural productivity and improving the livelihoods of millions of families in the shortest time.

This review demonstrated that in some farming systems planners particularly wish to increase the use of tractors to boost production. However, in numerous cases the country reports (FAO Nile Country Reports, 2008) note that tractors are not a panacea for higher yields, for example:

- In the commercial agricultural areas of Ethiopia most of the large-scale farms, which are concentrated in the northwestern lowlands of the basin, use agricultural machinery and fertilizers to grow a range of crops including flowers for export. Productivity on the farms is still low however, as expertise must be built-up, but prospects to increase yields are good (FAO Nile Country Report: Ethiopia, 2008).
- Most of the crops grown in the semi-mechanized farming system in the Sudan are rainfed, although already some rainwater harvesting is undertaken. Table 34 revealed the wide range and generally low levels (compared to the national average, detailed in Annex 1) of crop yields achieved in this farming system in the Sudan. For example in the case of sorghum, yields in North Kordofan and northern Darfur are only 26 percent of the national average (for drylands). Yet South Kordofan and southern Darfur achieve yields of 76 percent of the national average. The pattern for water productivity (kg/m^3) is similar: respectively the southern states achieve 63 percent and the northern 38 percent. The variation in crop yields and water productivity are smaller in the case of groundnuts and traditional sesame. However, contrary to many expectations, mechanized sesame does not achieve much higher yields than traditional sesame per m^3 of water or per workday.

In contrast, it is reported that most commercial farming operations in some urban and peri-urban settings in the Nile Basin are carried out by machinery (Chapter 3), with widespread use of fertilizers and other yield-enhancing inputs.

High crop yields can also be obtained without tractors, which cause major damage to fragile soils - with the use of specially designed tools, in conservation agriculture systems – and there is a recognized need to develop local manufacturing capabilities for such tools across all smallholder farming systems of the basin.

Pest and Disease Control

Loss of crops due to field and storage pests has a major impact on crop yields, thus food security in the Nile Basin, particularly the subsistence-level systems, where farmers have limited access to agrochemicals or other means to avoid such losses.

The range of pests and diseases specifically mentioned (although many others are present) in the FAO Nile Country Reports included:

Livestock Diseases:
tsetse; trypanosomiasis; contagious bovine pleura pneumonia (CBPP) in cattle; contagious caprine pleura pneumonia (CCPP) in goats; anthrax; rabies; rinderpest; black leg: African swine fever; Newcastle, avian flu and Gumboro; foot-and-mouth disease; tuberculosis; brucellosis.

Livestock Pests:
biting flies, which prevent utilization of some parts of rangeland during rainy season.

Crop Diseases:
tomato wilt; Irish potato virus; black sigatoka on bananas; cassava brown streak virus; yellow rust, stem rust, leaf rust septoria and tan spot on wheat; net blotch and leaf rust on barley; powdery mildew, downy mildew and *Aschchyta* blight on field peas; rust on lentils; chocolate spot, rust and *Aschochyta* blight on broad beans.

Crop Pests:
locusts; army worm; leafy vegetable caterpillars; *Striga asiatica*; *Striga gesnerioides*; *Striga hermonthica*; *Plantago lanceolata*; *Phalaries paradoxa*; *Guizotia scarba*; *Galinsoga parvifora*; *Cyprus blysmodis*; *Amaranthus hybridus*; *Avena fatua*; *Avena vavilovia*; elephants; eighteen field and four storage insect pests have been recorded on barley and wheat.

Several field and storage insect pests are also recorded as affecting broad beans, field peas, and lentils with green pea aphid (*Acrytosiphon pisum*) and African bollworm (*Hellicoverpa armigera*) representing the biggest threat.

Attacks by moles and caterpillars contribute to reductions in sweet potato yields.

Crop diseases, weeds and pests limit crop yields and are exacerbated by the recent narrowing of the range of crops grown and by reduced crop rotation. Weed infestation is one of the most serious crop production constraints in this system. Weeding is carried out by hand, but is usually delayed until weed plants attain certain heights, by which time they have already caused substantial damage. Weeding is further complicated due to the random distribution of crop plants in the field. The risks of mis/over-application of potentially hazardous chemicals are considerable, while improved hand weeding implements are generally not available.

Combating pests and diseases is a necessity for farmers and as a rule decisions regarding control are made by the individual farmer. However, the presence of a pest or disease on one farm poses a threat to adjacent farms and sometimes even to distant localities. Infrastructure and services to prevent and combat pests and diseases are a public good that can be provided more efficiently by governments than by individual farmers. Yet the most effective form of government intervention depends on the pest or disease in question. Experience has often shown that government provision of pest and disease control services can create a dependency among farmers and discourage their adoption of integrated pest management approaches that enable them to address the problems themselves. In such circumstances, government provision of knowledge, science and information may be the best and most sustainable way of serving the farming community in the long term.

Livestock disease spread is exacerbated by the poor general health of many animals due to periodic droughts, shortages of forage and water, high densities of livestock at watering points and poor veterinary services.

The spread of emergent diseases and invasive species has increased dramatically in recent years. At the same time, numerous developments – such as the rapidly increasing transboundary movements of goods and people, trade liberalization and increasing concerns about food safety and the environment – have heightened the need for international cooperation in controlling and managing transboundary pests and diseases.

Rangeland Burning

Rangelands and woodlands are prone to fires, both natural and set by humans.

Fire is a widespread rangeland management practice, used for vegetation clearance, growth stimulation and pest control. Indeed the annual burning of tropical grasslands plays a significant role in the global carbon cycle (Steinfeld et al, 2006).

Savannah burning is not considered as resulting in net CO_2 emissions, as the CO_2 released in burning is subsequently recaptured through photosynthesis (vegetation re-growth). Even in savannah systems that contain woody species, it has been shown that C lost through combustion can be replaced during the following growing season. In practice, however, grasslands which are burned too often may not recover, resulting in permanent loss of protective vegetation cover (Neely and Bunning, 2008).

The damaging impact of fire arises not from the loss of C from vegetation. What rangeland burning does is to significantly reduce SOC and nutrient levels in the upper few centimetres of soil. This loss of SOC has other negative effects on ecosystem function – thus productivity and also resilience, for example to droughts. It reduces soil water retention capacity, kills micro-organisms in the surface soil and reduces their food substrate, also exposing the soil to erosion. In some soils, burning causes capped soil surfaces to form, which further increase the damage, inhibiting rainwater infiltration, reducing soil moisture availability, soil biological activity and consequently plant growth.

The review quoted above notes that fire plays an important role in limiting livestock production in the pastoral, agropastoral and dryland farming systems, along with shortages of water and animal feed and other constraints.

Many county reports, including the 2008 FAO Nile Country Reports, noted that policy makers should where necessary put in place mechanisms to enforce limitations on rangeland burning.

Anticipated Impacts of Increased Variability and Climate Change

Africa is uniquely vulnerable to climate change because it already suffers from high temperatures, less predictable precipitation and substantially greater environmental stresses than other continents (IPCC, 2001 and 2007). African countries also share with other developing countries the fact of being "especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate -sensitive sectors such as agriculture" (Stern, 2007).

Over the 21st century, the warming trend and changes in precipitation patterns observed over the last few decades are expected to continue, to increase in rapidity and to be accompanied by a rise in sea level and an increase in the frequency of extreme weather events – droughts, floods and storms (Desanker, 2002).

Predictions of the magnitude of changes in temperature and precipitation are subject to considerable uncertainties, but scenarios for Africa indicate future warming across the continent ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario) (Hulme et al., 2001; Desanker and Magadza, 2001).

The existing precipitation gradient from the tropics to the subtropics will increase in the 21st century. Predictions indicate that precipitation in humid ecosystems, already substantial, will be higher and more intense in the future, while arid, dry sub-humid and sub-humid ecosystems which receive only sparse precipitation today are likely to experience even less rain over time.

It is vital that caution is taken in considering the impacts of increased precipitation in some parts of Africa, as this does not necessarily mean that more water will be available for agriculture and wider ecosystem functioning.

For enhanced evaporation rates due to increases in temperature are likely to offset precipitation gains. It is also important to consider that in some farming systems of the Nile Basin, climatic parameters will improve – most notably in the cold high-altitude systems of Ethiopia, where crops and livestock production are constrained by the low temperatures. These could, for example, provide sources of fodder for export to the farming systems of the basin which are highly livestock-dependent[33] and where shortages of fodder are a major impediment to agricultural and wider rural development.

A study on the specific impacts of climate change on agriculture in developing countries showed that in aggregate – and without appropriate adaptation measures – African countries will be left worse-off. Indeed areas that are currently marginal could find themselves unsuitable for agriculture in the future (FAO, 2007). However, appropriate adoption of SWC and SLM practices can make major contributions to both adaptation and mitigation.

A very recent FAO publication (FAO, 2009d) notes that "Climate models are currently not sufficiently well developed for Africa to predict what will happen region by region with sufficient detail to engage in detailed planning". Instead FAO urges that climate change must be mainstreamed into general agriculture – which is vital for land users in the Nile Basin, where the impacts of increased weather variability and climate change are already being felt (see box).

[33] pastoral, agropastoral and dryland systems

Box 1: Impacts of Climate Change in the Nile Basin

Eritrea

Impact of climate and environmental changes

"There is an indication of climate change in the basin. According to the interviewed farmers the temperature of the area has increased in the last 5-10 years. Usually the temperature of the area used to reach as high as 37-40 °C, however, this has increased to 40-45 °C during the dry months of April to June.

The climate change causes erratic rainfall with late start of the rain and early stop in late August or early September. This pattern of rainfall affects crop production and some of the late or long maturing sorghum and maize varieties have already disappeared. Yet farmers prefer to plant those varieties for high yield, bigger seed size, high market demand and good quality of bread (injura local bread).

"In addition and according to local farmers, some of the grass species in the rangeland or grazing area have started to disappear. This could be due to drought or overgrazing as more animals migrate each year to the area. Many of the hills and mountains that were once covered by vegetation are barren and rocky today. This could be due to drought, deforestation for timber and firewood and overgrazing by animals."

Water points for animals have decreased or dried up and most of the animals are forced to migrate to Setit for water during the dry season. In future the sustainability of animal production in the basin will depend on construction of ponds and dug wells at strategic points.

"According to farmers and Ministry of Health officials in Tesseney and Golluj, the incidence of malaria has increased in the basin. This could be due to climate change or to the Gerset dam, which may serve as breeding area for mosquitos."

Uganda

"There is need for creation of environmental awareness and consciousness on conservation while tackling rural development. As climate change bites, there are challenges in terms of increased water stress (i.e. drying up of rivers, streams and springs and recession in lake water levels). Frequent droughts and floods being experienced in most parts of the country leading to severe food shortages watelogging, hunger/famine and acute shortage of hydropower signify the vulnerability of the country to impacts of climate change.

"The cyclic nature and unpredictable occurrence of the dry periods limit the number of crops grown under rainfed conditions. Consequently, the climatic anomaly dissuades the

(Continued)

Box 1: (Continued)

farmers from investing in inputs and adopting improved technologies. In most instances, such rainfall patterns result in postponement of sowing/planting dates till the time when farmers feel that the rainy season is definitely on, hence non-adherence to the cropping calendar. Yet studies have revealed that delaying sowing/planting time for a period of 1- 4 weeks may result in yield reduction of 20–50 percent under normal rainfall patterns. With the occurrence of mid- seasonal droughts, yield reduction could even be more severe."

Kenya

"In Nzoia basin and to some extent Gucha/Migori, both with mixed industrial crops/livestock and cereal & dairy farming, the upper altitudinal limits have risen some 90 m due to global warming. This may often affect the quality of some crops like coffee or wheat due to increased managerial challenges. The temperature there has risen 0.5 °C during 20 years and the warming process is still continuing. Considering an average temperature gradient of 0.65 °C per 100 m as typical for Nzoia basin, the corresponding altitude difference of 0.5 °C is about 75 m, and adding the temperature increase of the last years we have more than 90 metres uplift of thermal crop limits since 1981."

Source: FAO Nile Country Reports (2008)

5. The Water Constraint: Linkage between Water Productivity and Agricultural Productivity

The degree to which the availability of water determines the respective agricultural productivity of the various Nile Basin farming systems is not a straightforward calculation. For irrigated systems it is clearly a lead input around which other production factors can concentrate in space and time. Equally, for rainfed systems the nature of rainfall events and the soil moisture regime determine the seasonal outcome of crops and forage production. But if farming systems reveal anything it is that each input is but one variable in a chain of social, cultural and farming practices. Hence the relative significance of the hydrological cycle and agricultural water management are assessed here. This chapter summarises the contrasts within the basin, highlighting the variability of crop yields and the potential for yield gap closure in both irrigated and rainfed farming systems.

Irrigated Agriculture

Irrigated (large-scale, traditional)

This farming system is complex. Large-scale irrigation systems are centrally managed and generally mechanized, planned to use high levels of agrochemicals to maximize production, with full or partial water control.

Problems in water management are often blamed for the widespread underperformance of many schemes across the basin. For example:

- In the Sudan in 2000, the total area equipped for irrigation was 1 863 000 ha (Table 7). However only about 801 000 ha (43 percent) of that were actually irrigated owing to deterioration of the irrigation and drainage infrastructures.
- In the Gezira Scheme alone, about 126 000 ha were taken out of production owing to siltation and reduced water service availability.
- Due to poor water management, water supply at Gezira was reported to be about 12 percent below crop water requirements at crucial stages in the growth cycle, while at the same time, as much as 30 percent of the water delivered was not used by crops.

Theoretically, crop yields within an irrigation system should be much higher than in rainfed systems, as water availability should be dependable, water stress should be avoided and growth maximized through higher usage of other inputs. However, Table 13 demonstrated there remains a high level of inter-annual variation in crop yields on the Gezira scheme, attributable to:

- water shortages due to poor maintenance;
- inadequate and late application of fertilizers and pesticides;
- lack of information and technical

guidance for farmers;

- declining efficiency of farm machinery services;
- insufficient financial resources and low farmgate prices.

Comparison between the yields in Gezira in Tables 13 and 14 showed that although the yields for both sorghum and wheat were slightly above the national average yields for irrigated crops (2.19 and 1.71 t/ha respectively), they were well below the potential yields (3.8-5.7 t/ha for sorghum and 3.3-4.1 t/ha for wheat), a yield gap of up to 3.51 t/ha for sorghum and 2.39 t/ha for wheat.

The statistics for the Raha scheme (Table 16) further demonstrated that there are major gaps in yields, not only between the minimum and maximum actual yields, but also between the maximum actual and the potential yields for the four main crops. Notably, the minimum actual wheat yield is only 17 percent and the maximum actual yield is only 63 percent of the potential. There is significant room to raise yields in existing schemes – through improved water-use efficiency and better management. Raising the entire groundnut yields from 0.16 t/ha to 0.34 t/ha and all sorghum yields from 0.12 t/ha to 0.28 t/ha would have a major impact on local and national food security as well as on export earnings.

The productivity of the large-scale irrigation schemes in the Sudan and elsewhere in the Nile Basin, and consequently the livelihoods of those who depend on them, could be substantially improved if farmers had greater responsibility in decision-making regarding land use, the technology which they adopt and sourcing inputs. But they also need reliable water supplies, access to good extension services and access to new technologies[34] and marketing information.

Large-scale irrigation schemes are very important to national food security and agricultural growth in many Nile Basin countries. In view of concern with wider allocation and environmental issues, schemes are likely to focus on improving productivity (per ha and per m^3 of water) rather than on expansion of the area under irrigation, The 2008 FAO Nile Country Reports repeatedly state, however, that there is ample scope for expansion in the region.

Irrigated (small scale, traditional)

Using the information from Ethiopia (FAO Nile Country Report: Ethiopia, 2008) Table 17 illustrated the gap between the yields that are currently achieved and the predicted yields under improved management practices. The yields of all crops, apart from teff, can be increased through better water and agronomic practices: for example maize yields could be increased by 1 t/ha (33%), peppers by 2 t/ha (50%) and potatoes by 7 t/ha (almost 50%). In all cases, apart again from teff, improved management would significantly reduce the cost per tonne of production, with win-win benefits for farmers' incomes, local food security and national food production.

Multi-cropping systems are common in small-scale, traditional irrigated farming in

[34] The range of new technologies includes *inter alia* hydro-flumes, land levelling and the implementation of precision farming.

Egypt, with fodder and horticultural crops often inter-cropped, leading to some of the most intensive crop rotations in the world[35] (see Annex 1). Almost all the cultivated land uses surface irrigation. An exception is a small area located in the newly-reclaimed lands (desert), where drip or sprinkler irrigation systems are used. The high yields achieved there are the product of practices which benefit from experience accumulated over thousands years, adapting cropping to the weather, to the availability of irrigation water and to soil fertility. Consequently Egypt is quite competitive in the production of horticulture crops (fruit and vegetables), cotton and wheat, and is also moderately competitive in maize, beans, potatoes, long berseem and oil seeds.

National production has increased over the past two decades, reflecting the success of various development projects which have seen the cropped area almost double from 3.19 million ha in 1996 to 6.22 million ha in 2006, as well as increasing yields over the period (1993-2005). For most crops, yields are now relatively high compared not only with world averages but with those of other countries with similar agro-climatic conditions (Annex 1). Despite the relatively high yields at national level additional yield increases are achievable through wider use of high-quality seed, greater mechanization, strengthened extension support and better soil and water management.

With the relentless increase in population pressure, Egypt farmers are being advised to practice land and water saving in agriculture. For example, sugar beet has been introduced as a substitute to sugar cane. This helps to save land as sugar beets stay in the ground for only 6-7 months, compared to 12-18 months for sugar cane. Additionally, sugar beet requires only 8 to 9 irrigations per crop, compared to 30 or more for sugar cane. It is thus a water-saving crop which could be grown elsewhere in the basin to reduce water abstraction.

Currently, in the Kenyan area of the Nile Basin only about two percent of land is irrigated. Yields are nonetheless moderately high, attributable to the well-organized schemes benefiting from water users' associations growing lowland rice and horticultural crops. This approach to organization could be scaled up to neighbouring countries.

Smallholder schemes in Uganda range in area between 0.2-10 ha and 10-50 ha and benefit from the use of modern technologies. For example in Masaka District demonstrations on clonal coffee under motorized and pressurized irrigation systems have resulted in yield increases from 2.5 t/ha to 6.5 t/ha.

Table 21 showed the yield gap between rainfed and irrigated production, demonstrating the enormous benefits which irrigation and correct use of inputs can bring to smallholder agriculture in Rwanda (compared to the current, dominantly rainfed system with minimal use of inputs). The yields of all the main crops[36] could be increased by 200 percent. It is important to appreciate that little land In Rwanda is suitable for Irrigation given the hilly nature

[35] More than one crop and sometimes three are planted annually on the same piece of land.

[36] Sorhum, maize, wheat, beans, groundnuts, soya, bananas, potatoes, sweet potatoes, yams, cassava, fruits and vegetables.

of the terrain. The total irrigable area in Rwanda is estimated to be 165 000 ha of which 112 000 ha is on small marshes/ swamps (each less than 200 ha) and 53 000 ha on large marshes/swamps (Figure 3). Within this total area, only 94 000 ha (57 percent of the total swamp area) is currently exploited – only eight percent of the cultivable land in the country.

Irrigated (commercial)

A number of large-scale irrigation schemes owned and operated by the private sector have been developed in the basin over the past few decades.

Parts of the Sudan are well-suited to growing sugar cane because of the abundance of fertile delta lands located between the Blue and White Niles, the intense sun, and the availability of water from the Niles. This has resulted in some of the highest sugar cane yields in the world (see Figure 4). Since 1980, total production of sugar cane (partially due to increased area) and yields have doubled to almost 11 t/ha. On the other hand production of irrigated sorghum varies enormously from year to year and yields of sorghum and groundnuts have remained about constant.

Latest information from the Kenana Sugar Co. indicates that the Sudan plans to more than triple sugar output within three years. In future, the Sudan has the potential to play an important role in filling the world gap in sugar production for human consumption and also for bioethanol production, thanks to the abundance of the right kind of land, water and the suitable climate.

Countries of the upper Nile, notably Kenya and Uganda, also have climates suitable for sugar cane growing, notably in the lowland tropical farming system – but achieve much lower yields. Knowledge sharing could enable these nations to benefit from Sudanese expertise, maximizing water-use efficiency.

Egypt has begun to implement a series of giant horizontal expansion projects for commercial agriculture all over the country. The purpose of these mega projects is to increase agricultural production, improve national income distribution, generate employment opportunities and achieve balanced development among various regions of Egypt.

In Uganda, commercial irrigation focuses on developing floriculture using drip irrigation systems and greenhouses[37] in the Lake Victoria area. The business is flourishing and in the future it is planned to expand to higher-altitude areas, where it is easier to produce larger flower buds, which are in greater demand.

Commercial agriculture is a relatively recent introduction in the basin in Ethiopia, so that its real coverage and contribution to total agricultural production is still small. Most of the large-scale farms are concentrated in the northwestern lowlands of the basin, where agricultural machinery and fertilizers are used to grow a range of crops including flowers for export. Productivity on the farms is still low, as expertise must be built up, learning from Kenya and Uganda, but prospects to increase yields are good (FAO Nile Country Report: Ethiopia, 2008).

[37] Stems, cuttings and potted plants.

Over-abstraction of water and reduction in water quality due to overuse of fertilizers and pesticides are having deleterious impacts on land users and wider ecosystems downstream of commercial irrigation areas. These need to be minimized if scaling up is to be acceptable.

Rainfed Agriculture

Pastoral

The system of production is governed by social and community laws concerning the management and utilization of natural resources, which are deeply entrenched in the cultures and traditions of the different ethnic groups. These include regulation of herd movements, utilization of water resources, conflict resolution and social justice. Pastoralists follow traditional management systems, which critically includes the sustainable management and proper utilization of whatever forage and water is available to ensure the survival of their livestock. These strategies reduce the risk of pastoralists' herds succumbing to drought and shortages of forage.

Livestock rearing in this farming system is a traditional extensive production system, characterized by low productivity, seasonal livestock migration and use of large areas of land per animal unit – which is often concluded to be an ineffective and inefficient use of water and feed resources.

The pastoral farming system is highly dependent on rainfall as livestock graze on rainfed rangelands, while both people and their animals obtain water from rivers, lakes, ponds, wells and dry river beds along their traditional livestock migration routes.

The pastoral rangelands are used and managed communally; consequently there is always the tendency for households to maximize their livestock holdings[38]. There has been simultaneous growth in human populations and a decline in the area of rangeland due to the expansion of urban areas and encroachment of both traditional and mechanized agriculture. This has resulted in concentration of livestock on ever-smaller areas of land and, in some cases, the closure of traditional livestock migration routes – leading to the overgrazing of the rangelands.

Pastoral areas are highly vulnerable to both droughts and flooding, which are increasing in frequency and severity due to the impacts of climate change. Droughts, combined with increasing livestock numbers, are exacerbating the difficulties of obtaining adequate water supplies along migration routes, particularly during the summer months.

Local conflicts for pasture and water, including both inter-clan disputes and conflicts between crop producers and livestock herders, and lack of security in border areas further negatively affect pastoral livelihoods – yet this is the system which can probably best cope with the uncertainties of living in these challenging environments.

Possible interventions to help increase the sustainability of this traditional farming system include:

[38] Traditionally among pastoralists livestock are the form of holding wealth; therefore pastoralists are reluctant to sell their livestock and are more concerned to increase numbers of head than improve the quality of their herds.

- rehabilitating pastures to increase their yields (undertaking minor SWC and SLM activities to reduce rainfall runoff and loss of topsoil; increasing rainfall infiltration, SOC and soil water-holding capacity; re-seeding of degraded areas, including with Nitrogen-fixing legumes; possibly apply ms inorganic fertilizer to correct nutrient imbalances), (World Bank, 2009);
- developing reliable water supplies for livestock and people – including rainwater harvesting along stock routes;
- encouraging increased off-take and smaller herd sizes to raise livestock water productivity, which also requires better market integration;

The opportunity exists to establish intensive grazing rangeland management systems, which could increase the sustainable carrying capacity of the rangelands through improved soil fertility. Further measures should include encouraging the practice of rotational grazing ("holistic grazing management") and controlling the frequency of rangeland burning.

A small rangeland management project has worked in the Eritrean part of the basin since 2006, promoting semi-intensive rangeland development across an area of 2 000 ha, with a capacity to graze more than 1 000 cattle. Main activities are: repairing a macro-dam, construction of new macro-dams and sowing of selected new varieties of grasses (Abertata, Dgela) and trees (*Ziziphus spina christi* and *Leuceana leucosephala*). The beneficial results of this project should be scaled up.

Options also exist to promote expansion of the modern sector as intensive production for export is gaining favour in many countries. This includes rainwater harvesting to support increased pasture productivity (possibly irrigated pasture) and introduction of modern technologies in the feed industry.

Agropastoral (dry and hot (millet))

The agropastoral farming system is found under conditions fairly similar to those of the pastoral system, the key difference being the slightly greater availability of water from rainfall. It is a semi-nomadic livelihood in which livestock production is dominant. Crops are grown, but play a less significant role than in most other farming systems as moisture stress is a critical limiting factor on crop production.

Livestock in the agropastoral farming system obtain water from rivers, lake, ponds, wells and dry river beds. The ponds are used for a period of about one month at the beginning of the dry season. Water is available from beneath the dry river beds but as the dry season advances agropastoralists, who travel upstream, must dig deeper to get at it for their livestock. Water from the permanent rivers, lakes and wells is also available in some places. Agropastoralists particularly benefit from being able to graze their animals along the perennial riversides of major Nile River tributaries which provide water even in times of drought.

Drought is the main source of vulnerability leading to crop failure, weak animals and the distress sale of assets.

Possible interventions to improve the situation in this farming system include:

- rehabilitation to increase pasture yields with minor SWC and SLM activities to reduce rainfall runoff and loss of

topsoil; increasing rainfall infiltration, SOC and soil water-holding capacity; re-seeding degraded area, including with N-fixing legumes; possibly applying inorganic fertilizer to correct nutrient imbalances) (World Bank, 2009);
- development of reliable water supplies for livestock and people – including rainwater harvesting along stock routes;
- Encouraging increased off-take and smaller herd sizes to raise livestock water productivity, which also requires better market integration.

Dryland Farming

This system is a rainfed, mixed cropping system. Sorghum, grown mainly for local consumption, dominates but crops such as pearl millet, finger millet, maize, cassava, groundnuts, sesame and some vegetables are grown. Drought-tolerant varieties of teff (in Ethiopia), wheat and other oil crops are grown in some areas.

Table 31 showed the areas harvested as well as production and average yields in this farming system from 1999 to 2003. It particularly demonstrated the high levels of inter-annual variation in the areas and yields for sorghum, which is the staple food crop, with yields ranging from 0.41 to 1.15 t/ha as compared with a national average of 0.63 t/ha (see Annex 1). The areas harvested for the other food crops also fluctuated during the period, but with some positive trends in yields (e.g. millet from 0.20 t/ha to 0.23 t/ha – the national average is 0.27 t/ha).

Farmers in this system generally use local crop varieties which have been grown for generations, are adapted to local conditions (climate, soil, pests and diseases) but have limited yield potential. The seeding rate used varies widely within crops and rotations are limited to sorghum, pearl millet and sesame. N-fixing legumes are not often grown.

Crop yields ultimately depend on the weather during the growing season, and especially on the distribution of the rainfall. In years of good rainfall (> 450 mm, with good distribution) sorghum can yield 1.0-2.0 t/ha. However, with low rainfall and/or poor distribution sorghum will yield only 0.3-0.6 t/ha.

Table 33 showed that the yields of the crops for the area (2002 to 2007) exhibit a high level of inter-annual variation. The yields for all crops were higher in 2005-2007 and lower during the period from 2002 to 2004. The yield for 2002 and 2003 was anomalously low, as most of the farmers were evacuated and were living in temporary shelters in Adi Keshi. In 2005, 2006 and 2007 the basin had good rainfall in terms of both distribution and amount, which is reflected in the yields.

With good rainfall, farmers produce more grain than they need for their own consumption and sale of the surplus covers their taxes and enables them to buy and pay for essentials. However, during a poor rainy season production may be too low to cover food demand until the next harvest. In order to ensure food security and ensure sufficient production to generate an income, better use of rainwater is vital.

Most of the crops grown in this farming system are rainfed, although reportedly some rainwater harvesting is undertaken. Table 34 revealed the wide range and generally low levels (compared to the national average, detailed in Annex 1) of crop yields achieved in this farming system in the Sudan. For example in the case of sorghum, yields in North Kordofan and North Darfur are only 26 percent of the national average (for drylands), yet South Kordofan and South Darfur achieve yields of 76 percent of the national average. The pattern for water productivity (kg/m^3) is similar with the southern states achieveing 63 percent and the northern 38 percent. The variation in crop yields and water productivity are smaller in the case of groundnuts and traditional sesame.

The livestock in this farming system depend on forage from local rangelands (grasses, legumes, shrubs, bushes and trees), supplemented by some fodder (crop residues). It is estimated that the annual production of forage in the Sudan is around 81 million tonnes and that the livestock which depend on the forage is around 48 million AU. Available forage produced per animal units is therefore around 1.7 t/year compared to the 1.8–2.2 t/year which is needed.

Although this farming system is enriched with vast diversified resources and considerable biodiversity, it has suffered from long-term neglect by Governments, national research institutions and development agencies. This neglect has led to the current situation of low productivity and consequently its minimal contribution to countries' agricultural GDP.

Recently, successes have been achieved in increasing yields of low productivity crops by re-introduction/adoption of complementary crop rotations, critically including legumes. This diversification in crop rotation helps to better integrate livestock in the system, although this is currently limited due to shortage of water after August. Water shortages could be overcome through the development of rainwater harvesting/small-scale water storage systems and wells (e.g., solar powered).

The total land area of this farming system in the Nile Basin is vast (almost 65 million ha), extending across large areas of the Sudan, Ethiopia and also Eritrea, the United Republic of Tanzania and Uganda (Figure 2). It has been identified as the expected main area for future livestock development programmes, scaling up adaptations to traditional management techniques to cope with new challenges (including growing populations, decreasing agricultural land areas and climate change). Notably, it has been found that there is potential for expansion of rangeland fodder production and storage, to catalyse development of highly beneficial integrated crop-livestock systems in these traditional rainfed areas, where fodder/forage availability is limited in the dry season.

FAO has implemented a pilot programme, under its Special Programme for Food Security (SPFS), to increase productivity of the Gardood soils in Northern Kordofan using water harvesting techniques. The percentage increase in yield of the new technology over the traditional was 1 455 percent for sorghum, 290 percent for sesame 433 percent for groundnuts (FAO Nile Country Report: the Sudan, 2008).

Highland (tropical)

The highland tropical farming system is based on perennial crops such as banana, plantain, enset and coffee, complemented by cassava, sweet potato, beans and cereals, with cattle kept for milk, manure, bride wealth, savings and social security.

Table 36 showed that farmers do not achieve yields close to those demonstrated on research stations. While it is acknowledged that farmers cannot be expected to watch such yields, they should be able to obtain results much closer than they do at present. Widespread scaling-up of supplementary irrigation using water collected by rainwater harvesting has the potential to overcome moisture deficiency problems which currently hamper the timely sowing/planting and maturation of crop, particularly at late crop development stage. However, it should be noted that:

- Not all crops need supplementary irrigation, their requirements are based on their drought-tolerance characteristics and location (climatic zone).
- The erratic nature of rainfall and the length of intervening dry periods vary greatly from one area to the other.
- If continuous or multiple cropping or the growing of high value crops is envisaged, supplementary irrigation is not a choice but an **imperative** to gain full benefit from other inputs and improved seeds.

Table 37 similarly showed the current meagre levels of farmers' yields of the main crops in Rwanda.

Despite favourable natural resources and climate in this farming system across the basin, there has beena a decline/stagnation in crop yields, while both the overall agricultural growth potential and the poverty reduction potential are considered fairly low, due to very small farm size, absent or underutilised resources, shortage of appropriate technologies, poor infrastructure (*inter alia* roads and markets) and few opportunities for off-farm activities.

Some consultants have identified strategies to improve livelihoods in the system, The Burundi report (FAO Nile Country Report: Burundi, 2008) for example proposed agro-silvo-pastoral production, hydroelectricity and tourism. Such opportunities make better use of limited resources.

Since rainfall contributes the bulk of the internally-generated water resources in the lands where this system is practiced, rainwater harvesting technologies could be put into practice to improve agricultural production as the opportunities for irrigation are very limited, for topographic and other reasons.

Highland (temperate (wheat))

This farming system is found only in Ethiopia. In this system, long years of agricultural activities combined with increasing livestock and human populations have resulted in massive destruction of the diversity and coverage of flora and fauna, and degradation of the soils. At high elevations, soils are now extremely shallow due to the combined effects of slow rates of organic matter decomposition, and soil formation. They experience high levels of erosion, due to intensive rains, steep slopes the damage compounded by cultivation and over grazing.

Not only is the traditional crop rotation involving legumes and cereals being altered in favour of monocultures of the latter, which achieve relatively better market prices. Inferior quality cereals such as wild oats (Sinar – livestock feed) are also coming into the crop mix, as farmers cannot afford to buy higher quality seed. The greater part of the Nile Basin's agricultural produce in Ethiopia, particularly cereals and pulses, is produced under this system so that it makes a significant contribution to local and national food supplies. However, the technologies deployed are traditional: use of yield-enhancing inputs, new approaches to cultivation (low/zero tillage or conservation agriculture) and improved seeds is extremely low, resulting in poor yields (Table 40).

There is an increasing trend for farmers, where possible, to use hired tractors which are perceived to be modern and more effective in land preparation. They are costly, however, and damaging to fragile soil but nonetheless current demand outstrips supply.

Natural pasture in the system comprises grazing land, shrubs and land unsuited for cultivation such as waterlogged and flooded areas, steep slopes and road-sides, particularly in the intensively cultivated areas. There are great concentrations of livestock on the few remaining communal areas and consequently serious land degradation due to overgrazing. Thus livestock productivity is low and there is also poor integration of crop and livestock production (see 5.2).

Decrease in vegetation cover, intensive cultivation of land, including extension of cultivation onto marginal areas[39], have exposed large areas to physical loss of soil and nutrient impoverishment. Soil erosion of up to 42 t/ha/yr is reported from cropped areas and up to 70 t/ha/yr from previously cropped unproductive land.

Watershed-level development approaches are the most appropriate for interventions in this farming system. For example implementation of measures to limit degradation at mid-altitudes would be futile unless upper slopes are protected. This should encompass SLM and SWC, including rainwater harvesting.

Highland (cold (barley, sheep))

The soils are thin, often waterlogged when flat and are not suitable for extensive crop production in this Ethiopian farming system. Cold temperatures at very high altitudes and humidity limit the range of crop and livestock types adapted to these harsh conditions.

Livestock are a particularly important component of the system as crop (barley) yields are not only low but also unreliable, with crop failure not uncommon.

Natural pasture alone is adequate for both maintenance and production in the wet months but inadequate for the rest of the year. Barley residues are the main source of fodder. In some areas, livestock are also fed additional pulses and teff straw. Generally, the quantity is small and nutritional value is also low, resulting in poor livestock productivity. Grain residues and local beer by products (atela) provide additional feed where available.

Lowlands (tropical)

Average farm sizes are rather modest - often less than 2ha. However, land users benefit from very high resources endowment. The system embraces production of a range of annual and perennial crops in addition to livestock, apiculture, sericulture and aquaculture.

The choices of enterprise in some cases depends on humidity, rainfall, altitude and soils although local traditions and preferences also dominate decision-

[39] Steep slopes and dominant black soils with poor drainage and management challenges.

making. The FAO Nile Country Report on Tanzania concluded that much of what local farmers are doing in their farms and fields in this farming system cannot be explained by agro-ecological or biological parameters alone. Notably in the Lake Victoria zone of Tanzania food preferences are closely linked to people's socio-cultural backgrounds. As a staple food, for instance, the Wahaya much prefer bananas whereas the Wasukuma like maize. Thus the Wahaya attempt to grow bananas even in relatively dry areas although from a production point of view other crops would be better adapted.

Table 48 demonstrated the poor yields currently achieved by farmers in the Uganda component. The yield gaps could at least in part be closed by rainwater harvesting or supplementary irrigation. Effective strategies to overcome moisture deficiency problems, which hamper timely sowing/ planting and crop maturity, particularly at late crop development stage, are vital. Other limiting factors include of the lack of organic and inorganic fertilizers.

Sugar cane is widely grown in the farming system by both smallholders[40] and estates, although once again yields mainly depend on the reliability of rainfall[41] - thus variability could be reduced by use of rainwater harvesting combined with storage.

Rice was originally a cash crop around Lake Victoria in Tanzania, but is increasingly grown as a food crop. Rainfall in itself is not sufficient to support rice production in the Lake Zone. However, due to the fortuitous presence of hardpan soils ('Itogolo') on the lower slopes of certain hills and the occurrence of runoff water from the upper slopes, rice cultivation is possible.

Much of the system is currently in crisis as input use has fallen sharply due to shortages of seed, fertilizer and agrochemicals, problems exacerbated by the high price of fertilizer relative to maize. Yields have fallen as a result and soil fertility is declining. In the past farmers were encouraged to grow maize mono-cultures – without restorative periods of fallow or application of manure[42] and with declining use of rotations (notably including legumes to restore soils nitrogen). The system is now proving unsustainable and many smallholders are reverting to low-yielding production practices, a vicious circle which does nothing to help meet rising food demand.

Promotion of sustainable land management practices (including rotation, green manure, organic residues, mixed cropping, low/ zero tillage, conservation agriculture, agroforestry, IPPM) would increase crop yields in good years and reduce the risk of crop failures in poor years as a result of improved soil structure and functioning.

The farming system also contains scattered irrigation schemes, but these are mostly small-scale and amount to only six percent of the irrigated area in the region.

[40] For chewing and production of jaggery and on contractual basis to feed sugar factories.

[41] Irrigated crop yields increase by around 30% compared to rainfed.

[42] Manure availability is limited as only 20-40% of households possess livestock and human population pressure is too high to allow cattle to roam freely. Conflicts between livestock and non-livestock owners are common. Oxen are few and little-used. Many households do not possess oxen and the local ridge construction method requires hand hoeing.

Rainwater harvesting systems are recommended to provide supplementary irrigation, improve crop yields and in particular to reduce the risk of crop failure. Medium to large-scale multipurpose irrigation infrastructure (dams and valley tanks) provide better longer-term water storage. But with increasing concern regarding limited water availability and the need to maintain water flows for aquatic ecosystems, small-scale rainwater harvesting by smallholders may be more appropriate.

Forest-based

People's livelihoods are primarily dependent on forest products with minimal livestock husbandry. The main products are milk, meat and draft power while livestock are also sold for cash. The environment is conducive to apiculture, thus beekeeping is common and honey is collected throughout the year.

In the highland areas of the Nile Basin where this farming system is practised there is a scarcity of arable lands, competitionwith livestock and a general dissociation between crop and livestock production.

A variation on the system is the "Western Perennial Forest Coffee/Spice" farming system in Ethiopia, practised in the very fertile zone where rainfall is reliable, households are food-secure and income levels are relatively high, demonstrating that improvements are possible.

Widespread scaling up of sustainable land and natural resources management systems (e.g. participatory forest management) which concurrently protect and develop sustainable traditional livelihood practices, would have enormous benefits in this forest system.

Some of possible interventions include:

- Restoration of soils, through increasing soil organic matter and fertility (e.g. planting legumes, use of organic and inorganic fertilizers), protecting soils from erosion (low/zero tillage conservation agriculture)
- Small-scale water developments for supplementary irrigation (rainwater harvesting) and hydro-power
- Promotion of permanent crops and horticultural development. They have huge potential
- Importantly, there are farmers' groups comprising coffee, chat and enset growers who would benefit from sharing knowledge and expertise in larger groups.

Although deriving only a small proportion of their income from livestock at present, there are opportunities in this farming system to feed large numbers of livestock under a more intensive management system - zero grazing with cut- and-carry. From a livestock water productivity point of view the fodder should preferably be crop residues, not specifically grown fodder crops.

Woodland

Acacia senegal is a multipurpose tree, not only producing gum, but preventing desert encroachment, restoring soil fertility and providing fuel and fodder. Although it is difficult to quantify the environmental benefits of *Acacia senegal* to the land-use system, a distinction can be made between "internal" benefits such as soil stabilization, water retention and N-fixation and more 'external' ones such as dune-fixation and large-scale desertification control.

Cultivation of gum Arabic, largely by subsistence producers using a bush fallow system, constitutes a crop diversification strategy that mitigates crop failure in drought years, brings environmental benefits and provides an on-farm supply of fuelwood and fodder. Gum Arabic production does compete with food and cash crops for labour resources and land allocation, but it provides small farmers with an important source of income during the dry season.

The gum Arabic belt is suffering from increased deforestation due to drought and population movements. Generally acacia trees are resistant to periods of low rainfall, but the combination of severe droughts in the mid-seventies and mid-eighties, civil conflict and changes in farming practices have negatively impacted on gum production, notably in North Kordofan and North Darfur. As a result, the gum Arabic belt is moving south, towards clay soil areas with better rainfall patterns. Production in the Blue Nile and Upper Nile regions and the southern parts of Southern Kordofan and South Darfur is increasing.

Riverside

Based on available data, families can meet their food requirements from fisheries, livestock, honey and sale of forest products. Recent years have witnessed an expansion of fish farms in inland waters, including irrigated rice fields. Indeed, aquaculture has become a major contributor to fish supply in Egypt (Table 58), although the introduction of high-yielding (and shorter duration) rice varieties requiring shallower water depths and higher inputs of pesticides, has led to a significant reduction in the fish yields.

The pattern of reliance on fisheries is different in the Upper Nile, for example in Kenya, where fishing has been a major occupation for the communities living along Lake Victoria.

The main source of livelihood for the households in this system is fishing, for example in Ethiopia where traditional equipment is still used. Fishing activities, methods and equipment have been developed to suit different water resources (lake, ponds, rivers, and wetlands) and are a form of traditional knowledge. Even within these communities, some individuals and families specialize in certain aspects of this industry, for example river fishing, lakeshore fishing and fishing in the high waters of Lake Victoria.

There is a strong likelihood that fish farming will develop further in future, as fish yields from Lake Victoria continue to decline.

Uganda is an example of a country in which government intervention aims to improve the sustainability of fisheries and thus benefit the communities whose livelihoods depend principally on artisanal capture fishing, processing and fish trading. The Government recently (2005) created Organizations known as Beach Management Units (BMUs) around the country's major lakes. The BMUs have been designed to empower the fisheries communities to manage the fisheries resources sustainably and could beneficially be replicated in other Nile countries.

Fisheries depend on the assured continuous, plentiful supply of high-quality water, whether in rivers, lakes, irrigation channels, rice fields or aquaculture ponds. There are a number of factors which contribute to making this a challenge. They include:

- Unsustainable management of crop and rangelands, leading to soil erosion, thus high river and lake sediment loads;

- Over-use or mis-use of fertilizers and pesticides – leading excess run-off into drainage ditches, stream and eventually the River Nile;
- Over abstraction of water up-stream;
- Legal issues – for example, the future of aquaculture is rather uncertain in Egypt, as fish farms are currently only allowed to use drainage water, which is a risky source because of pollution.

Additionally, over-fishing of capture fisheries is a problem across the basin. The FAO Nile Country Report on Uganda noted a number of factors contributing to the depletion of fish in the country's lakes, in particular:

- Use of illegal fishing gear;
- Increased pollution of fishing grounds;
- Use of the wrong type of fishing boats;
- Receding shorelines (over 100m in some cases), reducing breeding grounds for a number of fish species.

The FAO Nile Country Report for Kenya noted that wider popularization and expansion of aquaculture has been hindered by:

- lack of access to credit to fund pond construction;
- limited sources of quality fry;
- limited knowledge of how to facilitate fish growth to table size within a given time;
- poor availability of quality feed for pond fertilization as required by the aquaculture guidelines;
- breakdown in the extension service delivery system.

There are great opportunities to expand fisheries, including capture and aquaculture in the basin. But in all cases care must be taken in planning and management to ensure it is done in an environmentally sustainable manner. For example, rice/fish culture, cage culture and development of capture fisheries in small water bodies and reservoirs used to store water for irrigation are among the most promising new approaches.

Market-oriented agriculture (urban, peri-urban and commercial)

Availability of good quality water is often a major constraint in urban and peri-urban environments, where there are multiple sources of pollution and limited supplies for crop and livestock systems.

In livestock systems outside the urban/peri-urban areas, the major issue is also the availability of sufficient safe water as high numbers/densities of livestock increase the risk of disease transmission.

Keeping livestock in irrigation systems is clearly beneficial, as they can feed on crop residues and by-products, thus not requiring extra water while they provide a supply of manure. However, concentration of livestock around canals heightens disease risk and degrades both the land and water.

The performance and efficiency of commercial farms is generally poor due to inadequate farm management, limited utilization of productive inputs, poor rural infrastructurel development, pests and diseases, poor marketing services, lack of technical support and shortages of labour.

Organic farming of crops has great potential in the basin in view of the rising global demand for this type of production and the higher economic returns which it brings. However, pest and disease issues can severely limit production and should be addressed by alternatives to chemical pesticides. Organic fertilizers and SLM techniques to maintain soil health and fertility are also vital (World Bank, 2009).

The development of large-scale commercial farms should be seen from the context of overall private sector development and participation in the wider economy.

Livestock Systems

Livestock are of great importance in all the farming systems in the Nile Basin but they consume vast amounts of water, either directly through drinking or indirectly as forage and fodder. It is therefore vital to consider livestock-water interactions to help improve water productivity for food production. Water used to increase livestock production needs to be balanced with water demands for other agricultural activities – and also for ecosystem services.

It is clear that improvements can be made to livestock-water use to increase efficiency, enabling the countries of the Nile to expand animal-based food production, notably meat and milk while limiting the amounts of water required. Using the livestock-water productivity (LWP) approach, the sources of water available for agriculture include rain, surface inflow and groundwater, while the pathways of water loss or depletion are transpiration, evaporation and discharge or outflow.

Various technical, policy and behavioural intervention strategies can improve LWP, notably:

- feed sourcing,
- enhancing animal production, and
- conserving water.

Most obviously, livestock require water for drinking – with estimates of 20 to 50 l/ TLU/day. However, 50 to 100 times this is needed to sustain production of feed and the generally accepted figure is 450m^3/TLU/ yr. Production of maintenance feed for the Nile's populations of cattle, sheep, goats and camels is about 26 km^3/yr of water. Additional water is required in processing meat and animal products – also for hygiene in dairy cattle.

Livestock contribute substantially to farmers' livelihoods, to a healthy environment, to asset savings and vitally provide calories, protein and other nutrients which contribute to human health. Livestock particularly provide manure, a which maintains soil fertility in well-integrated crop-livestock systems. But livestock can also contribute to degradation of land and water resources if not properly managed.

Given the limitations in the availability of water in the Nile Basin, it is important that efforts are made at all levels to manage animals to maximize their value while ensuring that adequate water remains available for other human needs and ecosystem services. Three main livestock management strategies can increase LWP.

Feed Sourcing.

Certain livestock keepers have choices about the types of feed animals will consume. These choices include pasture, tree fodder, specifically-grown forage crops, crop by-products and residues and food crops also intended for human consumption. Choices made can have great impact on the amount of water depleted for animal production. For each of these choices, opportunities may exist for breeding and selection of forage crops and feedstuffs to improve feed quality and quantity. All plant production requires water that is depleted through transpiration. The advantage of crop residues and by-products is that their production does not require any additional water. The advantage of some pasture crops and tree fodder is that water used in their production may not be readily used for crop production or meeting other human needs. The disadvantage of growing fodder crops is that in many cases, the water used to produce them could have been used for other purposes such as growing food for people. Judicious selection of feed sources has the potential to reduce the amount of valuable water depleted for animal production.

Feed sourcing may include the option of importing animal feeds. Imported feed does not require water for production within the agricultural system where animals are raised. Thus, maintaining animal production in places where there is insufficient water for feed production becomes possible and highly water-efficient. Importing feed enables producers to take advantage of lower-priced water for feed production in places distant from where the animals are being raised.

Enhancing Animal Production

Beneficial outputs from livestock production are diverse, but all depend on ingestion of feed that in turn depends on transpired water. The many options for improving animal production include improving the nutritional quality of available feed; selection of improved breeds and species of livestock that are more productive or better-adapted to agro-environmental conditions; improved animal health that enables higher production and the meeting of food safety and health standards governing trade in animals and animal products; and value- added production that enables farmers to get higher prices for animal products in the marketplace. This strategy has been well researched but rarely related to its potential role in enhancing water productivity.

A strategy particularly relevant for Nile Basin herders is to increase off-take, which could increase productivity but requires a major change in dominant attitudes – together with better integration to markets.

Conserving Water Resources

Apart from direct use of water for feed production, inappropriate grazing and watering practices can lead to excessive depletion of water through contamination, runoff and enhanced discharge and evaporation. Improving grazing and watering practices can have a significant impact on improving water productivity in agricultural systems. Using drinking troughs separated from wells, ponds, dams, and domestic water supplies when watering animals can greatly reduce contamination and transmission of water-borne animal and zoonotic diseases, sedimentation, and destruction of riparian vegetation. Limiting grazing pressure to levels that maintain a near-solid cover of vegetation and organic matter on soil surfaces can reduce soil loss, runoff and discharge while increasing herd productivity. By replacing bare soil with vegetation such as grass cover, water lost through evaporation can be diverted into the productive pathways of transpiration or infiltration that lead to soil and groundwater recharge. Zero-grazing and provision of trough-supplied drinking water can have the combined impacts of preventing contamination and sedimentation, facilitating shifts to more water-productive feeds and freeing up labour costs associated with driving animals to and from pasture and watering points.

All three strategies can contribute to increasing LWP in the countries of the Nile Basin, for example through:

- The use of crop residues as feed for enhancing animal productivity; it costs no additional water since the cost of water has already been included in grain production;
- improved grazing management (including holistic grazing management (Neely and Bunning, 2008); bush clearance, supplementary feeding);
- improved quality and quantity of drinking water – to reduce illnesses and disease transmission;
- attention to animal management, particularly around wells, dams;
- provision of well-dispersed watering points;
- improved livestock housing;
- improved provision of veterinary services to enhance animal production;
- increased livestock off-take;
- development of livestock processing and market infrastructure (abattoirs, tanneries, cold stores etc.).

6. Discussion

"Agriculture is the dominant activity and main means of livelihood in most of the Nile Basin countries. However, efficient water use for agricultural production remains a major challenge in most of the Nile Basin countries." (NBI, 2007)

Crop yields in all the rainfed subsistence cropping systems which predominate in the farming systems of the Nile Basin (Table 59) are extremely low (see Annex1). They are limited by insufficient water, land degradation and also lack of fertilizers, improved seeds and pest management. Food production is too low to meet current food requirements and sustain income levels for millions of food producers, and commercial import bills are rising. (FAO, 2006).

On the basis of the national reports, the farming systems in many of the countries are in an impasse where poor farmers cannot afford to purchase the inputs they need to increase yields – and are not aware of the relatively low-cost land management and soil conservation approaches which could help them increase yields and improve their livelihoods. One key factor in this situation is water management as fertilizers and other inputs deliver little benefit without sufficient water.

This conclusion should not be taken to advocate wide-scale increase in investment in equipment for large-scale irrigation. In many cases the remoteness of markets and related infrastructure in the Nile Basin make viability questionable while, arguably, the best sites with low marginal costs have already been exploited Late 20th century experience has shown that many large-scale irrigation schemes have performed poorly and opposition has grown to the resulting environmental degradation and social disruption. "Investments in water for agriculture have made a positive contribution to rural livelihoods, food security and poverty reduction" (CA, 2007), including employment gains, affordable food prices and more stable outputs. However, "poorly conceived and implemented water management interventions have incurred high social and environmental costs" (ibid.). These social and environmental costs include inequality in the sharing of these benefits, loss of livelihoods particularly through appropriation of common property resources - entire communities have been displaced by large schemes. The negative environmental effects have particularly followed the diversion of water away from natural aquatic ecosystems (rivers, lakes, oases, groundwater-dependent wetlands), leading to salinization, channel

Table 59: Proportions of Land, Population and Cropland in Irrigated and Rainfed Agriculture, Nile Basin

Type of Agriculture	% of Land	% of Population	% of Cropland
Irrigated	2	34	12
Rainfed	60	52	83

Source: derived from Table 6

erosion, declines in biodiversity, introduction of invasive alien species, reduction of water quality, genetic isolation through habitat fragmentation and reduced productivity of floodplain, and inland and coastal fisheries.

Opportunities/Scope for Improvement in Agricultural Productivity through Water Management

Increased Irrigation Efficiency

The statistics on crop yields presented earlier, particularly those relating to gaps in yields between actual yields and potential yields (Tables 16, 17, 21 and 22), clearly demonstrate that there are opportunities for increasing performance across existing systems. The key opportunities are:

- Improving the efficiency of the water delivery system to limit the number of "breakdowns" and other interruptions to supply, which often prevent farmers from receiving the recommended number of irrigations. This should also address the problems which arise due to distance from the water source (Table 12).
- Ensure fertilizers, pesticides and other inputs are available when required.
- Provide farmers with better information, via extension services, regarding agronomic, SLM and SWC practices.
- Better integrate livestock into large-scale systems, including use of manure to improve soils in irrigated fields; provision of safe livestock watering points, feeding crop residues and by-products to livestock, rather than irrigated fodder crops.
- Improve market linkages for farmers' crops and livestock products.
- Encourage development of water users' associations.

Prospects for taking irrigation to scale

Although some countries of the basin withdraw very large amounts of water for agriculture (as a proportion of renewable water resources), notably Egypt (92%) and the Sudan (56%), the other countries of the Nile Basin make negligible use of this valuable resource, notably Uganda and the Democratic Republic of the Congo (0%) and Rwanda (1%) but none over 5% (Table 60).

Major expansion of large-scale irrigated agriculture is no longer viewed as a panacea to ensure future food security. Account must be taken of the relative contribution from stabilised or improved rainfed production and the implications of price impacts on rainfed producers. However, in certain specific situations, where lack of water is a constraint to production but suitable land and water for irrigation is available, the potential contribution to the basin's food security should not be underestimated (FAO, 2006c) where;

- The structure of the irrigated sub-sector to the structure of demand can be matched.
- The value of the existing asset base can be realized and the supply chains, storage and processing can be concentrated to address specific, well-identified markets.

Opportunities exist to use the limited areas of flat land in the countries of the upper Nile (the Democratic Republic of the Congo, Rwanda and Burundi), where irrigation would be on a much smaller-scale than the major existing schemes in the lower Nile, to potentially bring three-fold increases in yields of sorghum, maize, wheat, beans, peas, groundnuts, soya, bananas, potatoes, sweet potatoes, yams, cassava and also fruit

Table 60: Irrigation Water Use by Country in 2000					
Country	Total Renewable Water Resources (km^3)	Irrigation Water Requirements (km^3)	Water Requirement (ratio in %)	Water Withdrawal for Agriculture (km^3)	Water Withdrawal (as a % of Renewable Water Resources)
Burundi	3.6	0.06	30%	0.19	5%
Democratic Republic of the Congo	1 283	0.03	30%	0.11	0%
Egypt	58.3	28.43	53%	53.85	92%
Eritrea	6.3	0.09	32%	0.29	5%
Ethiopia	110	0.56	22%	2.47	2%
Kenya	30.2	0.3	30%	1.01	3%
Rwanda	5.2	0.01	30%	0.03	1%
Sudan	64.5	14.43	40%	36.07	56%
United Republic of Tanzania	91	0.56	30%	1.85	2%
Uganda	66	0.03	30%	0.12	0%

Source: AQUASTAT

and vegetables (Table 21). However, care is required in planning such schemes, as in most cases the only flat lands are marshes and swamps, which currently play a vital role in regulating hydrological regimes. Conversion of a swamp to irrigated agriculture results in alternating unacceptably low flows and floods downstream.

Upscaling irrigated agriculture in the Highland Tropical and possibly Lowland Tropical farming systems would ensure production and be particularly beneficial when combined with increased use of improved seeds and fertilizers by farmers.

Rainwater Harvesting

Rainwater harvesting is a method of inducing, collecting, storing and conserving local surface runoff for agricultural production[46].

Various forms of rainwater harvesting have been used traditionally throughout the centuries. The importance of traditional, small-scale systems of rainwater harvesting in sub-Saharan Africa has recently been recognized, ranging from simple stone lines in Burkina Faso and Mali, earth bunding systems in eastern the Sudan, Kenya and the central rangelands of Somalia. The potential of water harvesting for improved crop production received great attention in the 1970s and 1980s following the widespread

[46] *Inter alia* contour ploughing, planting pits, uncultivated strips, contour bunds, floodwater harvesting in stream beds, ephemeral stream diversion, rooftop collection from homes and public buildings.

droughts in Africa which left a trail of crop failures and posed a serious threat to human and livestock life.

Individually-based rainwater harvesting systems have been more successful than collective systems as the latter tend to suffer from lack of care and maintenance. The potential for increasing cash income from improved crop yields can be a determining factor affecting the adoption of rainwater harvesting – if markets for the crops in question are present.

Conservation Agriculture

Conservation agriculture and other SLM practices[43] offer opportunities to improve crop productivity as they increase the infiltration and storage of rainwater in the plant rooting zone.

Conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and in quantities that do not interfere with, or disrupt, the biological processes. CA is based on three interlinked principles, namely:

1. Continuous minimum mechanical soil disturbance;
2. Permanent organic soil cover;
3. Diversified crop rotations in the case of annual crops, or plant associations in the case of perennial crops.

Experience has shown that these techniques, much more than merely reducing mechanical tillage. In a soil that is not tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch. This layer not only protects the soil from the physical impact of rain and wind but it also stabilizes the soil moisture and temperature in the surface layers.

Conservation agriculture is not a low-output form of agriculture. It produces yields comparable with modern intensive agriculture but in a sustainable way. Yields tend to increase over the years, with a highly beneficial decrease in yield variations.

Hydrological Consequences of Improved Agricultural Productivity for the Water Balance of Nile Basin

Clearly, intensifying rainfed agriculture throughout the farming systems of the upper Nile basin, above the Sudd, will have some impact on surface water and groundwater balances but this will be much less than if irrigated agriculture dominated in the lowland and highland tropical farming systems. Any potential negative impacts on downstream water availability should be offset by improvements in water productivity in downstream irrigated farming systems.

[43] *Inter alia* low/zero tillage, green manure, use of farmyard manure and compost, agroforestry, planting pits, reseeding rangeland.

Already the countries of the basin are cooperating to optimize water use. In future, such cooperation should encompass much greater trade in food and fibre. Regional cooperation would enable each country/ farming system to focus on the agricultural production best adapted to its agro-ecological conditions. Cooperation should promote exportation and importation of foods and fodder between the ten countries (and beyond) to ensure water use is optimized, maximizing water productivity in the irrigated, rainfed and livestock sectors to ensure food security for all the people of the basin, while also ensuring that sufficient water remains to maintain the Nile's hydrological and ecosystem functions.

This scenario should also include sharing of knowledge between agricultural experts in the basin countries – including the much-needed expansion of research and extension services required in most of the countries to help land users adopt practices which will ensure food security in the face of climate change.

7. Key Findings

Currently, yields of the main crops in most of the rainfed and traditional irrigated farming systems of the Nile Basin are very low – well below the potential yields (see Annexes 1 and 6). Clearly individual farmers, particularly those working at the subsistence level are unlikely to achieve the yields obtainable under optimal field conditions (Type II yield gaps). However, this review of the fourteen major farming systems of the basin has uncovered a range of common issues in each system, which currently limit productivity – most of

Table 61: Water - The Key to Closing Yield Gaps

Farming System	Key Requirement relating to Water
Large-Scale Public Irrigation schemes	Reliability of supply
Small-Scale Irrigation	Reliability of supply
Commercial Irrigated	Stability of water-use rights and crop water productivity
Pastoral	Access to water for livestock drinking and forage/fodder in dry seasons and droughts
Agropastoral	Access to water for livestock drinking and forage/fodder in dry seasons and droughts
	also
	Rainwater harvesting to increase crop yields, yield reliability and fodder production
Drylands	Access to water for livestock drinking and forage/fodder in dry season and droughts
	also
	Rainwater harvesting to increase crop yields, yield reliability and fodder production
Highland Tropical	Irrigation and/or rainwater harvesting to cope with periodic droughts
Highland Temperate	Irrigation and/or rainwater harvesting to cope with periodic droughts
Highland Cold	Livestock feed supplies
Lowland Tropical	Rainwater harvesting to increase crop yields, yield reliability and fodder production
Forest	Conservation to continue role as runoff regulator
Woodland under some form of management	Afforestation to reduce land degradation
River and Lake-side	Improvements in water quality in rivers, lakes and for aquaculture ponds
Market-Oriented	Availability of sufficient high-quality water for crops and livestock

Source: compiled from information in FAO Nile Country Reports (2008) which fundamentally relate to water and its availability. These issues can be addressed using currently available technologies and approaches to help close the large Type II yield gaps, thereby increasing food security at local, national and basin levels and contributing to wider rural development, including Millennium Development Goal 1 (eradication of extreme poverty and hunger). The technologies and approaches will also help land users to adapt to the predicted impacts of climate change.

The enhanced availability and use of water, including soil water conservation and rainwater harvesting methods, is not the only requirement to close Type II yield gaps (see details in Chapters 3 and 5). However, it is a necessary prerequisite to maximize the benefits of other inputs, including improved seeds, fertilizers, improved tools and infrastructure. Even with equatorial horticulture and plantation crops, additional water can still be a lead input.

Certain areas of some farming systems in the basin show promise, as they achieve reasonable and consistent crop yields. These can act as models to help guide improvements in the poorly-performing systems. Elsewhere yields are not only low but also show high levels of inter-annual variation and cannot be relied upon to provide for even subsistence – hence the periodic need for emergency food aid. Investment to help land users achieve a level of stability across all farming systems would obviate the need for expensive and disruptive food aid.

Notably, in Egypt and in some schemes in the Sudan the commercial irrigated sector is generally achieving high yields for food crops – which can guide improvements in the much less productive traditional large-scale schemes. Similarly, principles which guide the management of small-scale traditional irrigation systems could be extended to help in the scaling up of soil water conservation in agropastoral, dryland, highland tropical and temperate and lowland tropical systems. Likewise, the skills which the pastoralists have in caring for their livestock in the challenging conditions in which they live could help agro-pastoralists and dryland farmers improve their livestock husbandry, particularly to cope with the challenges of climate change. Pastoral expertise could also inform the commercial livestock sector.

The national studies used to compile this report (FAO Nile Country Reports, 2008) emphasize the need to extend irrigation to meet current and future demand for food and fibre. However, since the total rainfall over the course of a season in rainfed systems is frequently sufficient, the high risk of water deficits in rainfed agriculture usually refers to quite short, albeit critical, periods. But to ensure short-term dry periods do not reduce crop yields requires widespread scaling up of soil moisture conservation and rainwater harvesting methods which can be both small-scale and low-cost – or the adoption of supplementary irrigation which is not low-cost and would only be applied to high-margin crops, not necessarily food staples.

Affordable small-scale technologies and approaches for farmers hold tremendous promise for improving rural livelihoods. Small-scale rainwater harvesting structures and water storage mechanisms, pumps to tap into groundwaters (including manually operated treadle pumps, or pumps that run on solar energy or biodiesel), drip irrigation, alternation of wet and dry irrigation in rice intensification to reduce the amount of water required are all examples of low-cost technologies which could make major contribution to improvements in crop yields.

Rural communities in the Nile basin have the proven capacity to assimilate these technologies. The added benefits of scaling up would be that the technologies do not need large sources of water and that the payoff can be rapid. Experience has shown that small-plot irrigation technology can motivate farmers to move to diversified, higher-value marketable crops, thereby adding significantly to annual incomes.

Land users need to be made aware of the potential benefits of modern and traditional practices – and assisted in undertaking construction work (e.g. with the provision of materials). A major impediment to such scaling up is dissemination of information. It is important that all potential channels are used to help communicate with difficult-to-reach farmers and livestock keepers, including formal education, adult education, extension services, farmer field schools, posters, rural radio and newspapers. Supporting innovations in these areas is likely to be well worth the investment.

Undeniably, irrigation remains very important for overall food production and is the primary form of crop intensification in the basin. Irrigation already contributes to local and national food security for the countries of the lower basin. In addition, irrigation reduces poverty through higher yields and incomes for farmers and it is also crucial for society in general through increased direct and indirect employment and through its impact in lowering food prices. Arguably, by creating higher crop production levels, irrigation development has also saved millions of hectares of forest land from conversion to agriculture. Irrigated agriculture also plays a significant macroeconomic role in many countries since it generates significant foreign exchange, among other things.

It is imperative that water productivity is increased in irrigation systems through:

- Agronomic and on-farm water management practices to increase water productivity;
- Irrigation management measures to improve water productivity;
- Innovative water pricing systems and incentives to improve water productivity;
- Non-water factors which influence water productivity.

A major factor limiting the food security of households in the dryland, agropastoral, highland temperate and highland cold farming systems is shortage of land for cultivation – households have plots which are simply too small to support families with current production practices. When land users successfully close the yield gap, there will be increased food production and security. Further, with higher yields, formerly subsistence farming families should be able to benefit, from opportunities to participate in small-scale trade, agro-processing and agribusinesses. That is the experience with farming systems which have already reached that stage – notably the lowland tropical system in Kenya, Uganda and the United Republic of Tanzania.

Investment costs (per ha) to upgrade rainfed areas tend to be relatively low in the Nile basin, where most rural people live in rainfed areas. An optimistic outlook on yield growth shows that rainfed agriculture could meet food demand in 2050. The potential is particularly high in currently very low-yielding farming systems (Annex 1), which tend to be where poor people live. Realising the yield-growth potential of existing rainfed areas will not only avoid the need for emergency food aid, but also reduce the need for new large-scale irrigation developments, for which the most economic sites have already been developed. However, improving rainfed production through standard intensification and soil moisture conservation techniques still requires large volumes of investment, albeit at much more distributed and lower intensity.

Appropriate measures to close Type II yield gaps include:

Farming practice

- Promotion of household-level rainwater harvesting and low-cost irrigation systems;
- Wide-scale adoption of low/zero tillage and conservation agriculture in the rainfed areas to increase crop yields, reduce inter-annual variations in yields and reduce labour;
- Promotion of crop diversification, restoration of rotations, green manure and fallows;
- Expanding agricultural mechanisation for all agricultural operations – particularly hand- and animal-powered tools;
- Rehabilitation of natural pastures and rangelands through collection and reseeding with desired species which are fast disappearing, and also opening fire lines.

Extension

- Reviving extension services to the rainfed and small-scale irrigated sectors to bring new agricultural knowledge/ technologies for local adaptation with traditional practices (e.g., raising the awareness of the importance of SOC, the potential of using inorganic fertilizers and improved seeds);
- Provision of extension services to pastoralists to raise awareness of the importance of controlling grazing/ holistic rangeland management, maintaining ground cover and the multiple benefits of increasing livestock off-take;
- Introduction of modern practices in livestock production, particularly in the irrigated sector, including good crop-livestock integration, aquaculture and improved poultry production;
- Development of more farmers' and water users' organizations;
- Development of farmer field schools, demonstration sites and farmer exchange visit schemes;
- Projects to encourage the local manufacture of agricultural inputs to reduce their cost to farmers;
- Increasing information and training for subsistence farmers and pastoralists notably on the anticipated patterns of future climate change;
- Education and training for all rural people in crop/livestock/rangeland husbandry.

Inputs and Marketing

- Better provision of fertilizers, pesticides, market information and transport of produce to market;
- Increased provision of facilities for livestock – safe perennial water supplies, veterinary services, markets, abattoirs milk processing;
- Improving storage facilities for food and fodder in rural areas.

In common with the recent FAO and WB report on prospects for commercial agriculture in Africa (FAO and WB, 2009), the conclusion of this synthesis is optimistic about prospects for agriculture in the Nile basin. This is in part due to the much higher profile which international, continental and national organizations are placing on agriculture as the key engine for development.

The potential exists to increase both crop and livestock production within all the farming systems of the Nile basin, at lower cost, with more rapid returns and much lower environmental impact than expansion of large-scale irrigation systems.

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Annex 1

Maize

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	115.000	115.000	112.000	115.000	116.000	113.000	114.000	116.000	115.000	115.000	114.600
DRC	1.460.960	1.500.626	1.481.852	1.463.314	1.482.118	1.482.413	1.482.709	1.483.004	1.483.299	1.483.594	1.480.389
Egypt	876.987	817.224	843.029	873.035	828.132	834.103	788.520	948.000	761.220	775.600	834.585
Eritrea	38.486	20.075	20.321	11.529	14.491	13.362	10.309	16.618	21.000	17.000	18.319
Ethiopia	1.449.300	1.651.350	1.655.750	1.892.690	1.506.759	1.791.115	1.801.566	1.950.115	1.526.125	1.694.522	1.691.929
Kenya	1.475.740	1.567.240	1.500.000	1.640.000	1.592.315	1.670.914	1.351.327	1.771.123	1.888.185	1.615.304	1.607.215
Rwanda	71.212	72.673	89.053	105.560	104.628	102.820	115.000	109.400	114.836	110.000	99.518
Sudan	63.840	63.420	71.820	71.820	63.420	71.820	58.380	75.000	104.167	93.000	73.669
Tanzania	2.088.000	957.550	1.017.600	845.950	1.718.200	3.462.540	3.173.070	3.109.590	3.000.000	3.000.000	2.237.250
Uganda	616.000	608.000	629.000	652.000	676.000	710.000	750.000	780.000	819.000	844.000	708.400

Yield (tonnes/ha)														
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	% of highest basin yield (excluding Egypt)	1998-2007 average area harvested (ha)
Burundi	1,15	1,12	1,05	1,08	1,09	1,12	1,08	1,16	1,02	1,00	1,09	14	59	114.600
DRC	0,83	0,80	0,80	0,80	0,78	0,78	0,78	0,78	0,78	0,78	0,79	10	43	1.480.389
Egypt	7,23	7,52	7,68	6,98	7,77	7,83	7,91	8,12	8,37	8,05	7,74	100		834.585
Eritrea	0,75	0,79	0,20	0,79	0,21	0,33	0,31	0,15	0,17	0,16	0,39	5	21	18.319
Ethiopia	1,62	1,72	1,62	1,74	1,88	1,53	1,61	2,01	2,64	1,97	1,83	24	100	1.691.929
Kenya	1,67	1,48	1,44	1,70	1,51	1,62	1,93	1,64	1,72	1,81	1,65	21	90	1.607.215
Rwanda	0,82	0,76	0,70	0,77	0,88	0,77	0,77	0,89	0,80	0,82	0,80	10	43	99.518
Sudan	0,66	0,58	0,74	0,74	0,84	0,74	1,03	1,07	1,05	0,75	0,82	11	45	73.669
Tanzania	1,29	2,53	1,93	3,14	2,57	0,75	1,47	1,01	1,14	1,22	1,70	22	93	2.237.250
Uganda	1,50	1,73	1,74	1,80	1,80	1,83	1,44	1,50	1,54	1,50	1,64	21	89	708.400
World Mean 2005/2007 (Bruinsma, 2009)											4,73			

Sorghum											
Area harvested (ha)											
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	54.000	50.000	50.000	55.000	57.000	57.000	55.000	55.000	65.000	66.000	56.400
DRC	7.391	7.584	9.153	9.406	9.552	9.607	9.561	9.516	9.470	9.425	9.067
Egypt	158.232	165.403	162.597	148.764	156.217	167.232	152.402	152.000	156.000	148.660	156.751
Eritrea	236.231	236.372	146.389	165.821	182.058	200.933	208.806	223.163	262.000	227.000	208.877
Ethiopia	981.710	1.069.400	1.011.150	1.359.190	1.132.540	1.335.834	1.311.460	1.512.184	1.468.070	1.464.318	1.264.586
Kenya	118.824	141.370	122.493	136.078	144.294	148.985	123.155	122.368	163.865	155.550	137.698
Rwanda	114.639	129.261	174.195	185.444	171.808	179.791	179.307	196.732	170.298	180.000	168.148
Sudan	6.314.000	4.529.600	4.195.000	5.742.240	5.003.000	7.081.000	3.819.000	9.864.960	9.899.400	8.950.000	6.539.820
Tanzania	596.200	659.868	736.200	691.690	655.380	449.590	697.220	737.080	890.000	900.000	701.323
Uganda	280.000	275.000	280.000	282.000	285.000	290.000	285.000	294.000	308.000	314.000	289.300

Yield (tonnes/ha)														
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	% of highest basin yield (excluding Egypt)	1998-2007 average area harvested (ha)
Burundi	1,25	1,20	1,22	1,26	1,29	1,25	1,35	1,24	1,27	1,30	1,26	22	87	56.400
DRC	0,66	0,66	0,66	0,66	0,67	0,66	0,66	0,66	0,66	0,66	0,66	12	45	9.067
Egypt	5,61	5,77	5,79	5,80	5,78	5,74	5,67	5,61	5,69	5,68	5,71	100		156.751
Eritrea	1,14	0,88	0,42	0,47	0,16	0,32	0,21	0,51	0,57	0,57	0,53	9	36	208.877
Ethiopia	1,10	1,25	1,17	1,14	1,37	1,34	1,31	1,46	1,58	1,48	1,32	23	91	1.264.586
Kenya	0,75	0,78	0,67	0,86	0,80	0,85	0,56	1,22	0,80	0,95	0,82	14	57	137.698
Rwanda	1,05	0,83	0,89	0,95	1,07	0,95	0,91	1,16	1,10	1,04	1,00	17	68	168.148
Sudan	0,68	0,52	0,59	0,77	0,56	0,73	0,71	0,51	0,59	0,65	0,63	11	43	6.539.820
Tanzania	0,94	0,85	0,81	1,00	0,97	0,44	0,93	0,99	0,80	1,00	0,87	15	60	701.323
Uganda	1,50	1,50	1,29	1,50	1,50	1,45	1,40	1,53	1,43	1,45	1,45	25	100	289.300
World Mean 2005/2007 (Bruinsma, 2009)											1,39			

Millet

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	9.500	9.000	8.300	10.000	9.200	9.200	9.200	7.500	10.000	10.500	9.240
DRC	41.815	42.950	51.906	53.300	54.090	55.098	55.507	55.930	56.354	56.778	52.373
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Eritrea	83.002	50.000	40.733	40.420	31.814	64.481	39.000	39.000	71.000	50.000	50.945
Ethiopia	290.580	447.560	361.000	346.780	281.458	304.758	314.251	334.992	390.977	374.072	344.643
Kenya	78.988	90.082	93.150	104.292	118.570	108.258	113.223	92.430	137.711	127.114	106.382
Rwanda	4.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	4.900
Sudan	2.762.000	2.393.580	2.087.000	2.586.000	2.437.000	2.570.000	1.285.000	2.243.000	2.233.333	2.322.500	2.291.941
Tanzania	268.100	195.805	251.900	201.100	358.830	201.850	347.910	283.180	265.000	265.000	263.868
Uganda	401.000	376.000	384.000	389.000	396.000	400.000	412.000	420.000	429.000	437.000	404.400

Yield (tonnes/ha)													
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	1998-2007 average area harvested (ha)
Burundi	1,11	1,12	1,05	1,00	1,16	1,15	1,15	1,03	1,08	1,10	1,09	70	9.240
DRC	0,66	0,66	0,66	0,66	0,67	0,66	0,66	0,66	0,66	0,66	0,66	42	52.373
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Eritrea	0,62	0,46	0,11	0,12	0,15	0,18	0,21	0,45	0,39	0,40	0,31	20	50.945
Ethiopia	0,89	0,85	0,89	0,91	1,09	1,00	1,06	1,19	1,28	1,06	1,02	65	344.643
Kenya	0,43	0,66	0,48	0,43	0,61	0,59	0,45	0,57	0,58	0,94	0,57	37	106.382
Rwanda	0,75	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	51	4.900
Sudan	0,24	0,21	0,24	0,22	0,24	0,31	0,22	0,33	0,30	0,34	0,27	17	2.291.941
Tanzania	0,88	0,99	0,87	1,03	0,65	0,45	0,71	0,77	0,86	0,83	0,80	51	263.868
Uganda	1,60	1,61	1,39	1,50	1,49	1,60	1,60	1,60	1,60	1,68	1,57	100	404.400
World Mean 2005/2007 (Bruinsma, 2009)											0,86		

Wheat											
Area harvested (ha)											
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	12.000	10.000	9.000	10.000	10.000	10.000	9.000	10.500	10.000	10.000	10.050
DRC	8.093	7.704	7.304	6.924	6.557	7.000	6.650	6.685	6.724	6.763	7.040
Egypt	1.017.282	999.998	1.034.985	983.741	1.029.592	1.053.016	1.094.741	1.253.820	1.287.000	1.139.000	1.089.318
Eritrea	33.434	35.739	23.182	22.458	16.648	19.156	23.811	15.125	15.500	16.000	22.105
Ethiopia	831.770	1.031.140	1.062.010	1.203.720	1.006.271	1.166.237	1.457.495	1.570.190	1.459.540	1.473.917	1.226.229
Kenya	142.902	128.092	131.834	129.209	144.794	151.135	152.826	159.477	150.488	104.176	139.493
Rwanda	5.700	5.172	10.043	10.748	12.046	20.000	21.000	24.157	22.972	23.000	15.484
Sudan	255.000	142.000	91.980	120.120	115.500	169.000	180.000	169.000	174.583	284.167	170.135
Tanzania	99.400	57.370	71.700	52.120	30.670	26.890	34.380	35.370	40.000	92.000	53.990
Uganda	5.000	6.000	7.000	8.000	8.000	9.000	9.000	9.000	10.000	11.000	8.200

Yield (tonnes/ha)														
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	% of highest basin yield (excluding Egypt)	1998-2007 average area harvested (ha)
Burundi	0,81	0,71	0,68	0,87	0,87	0,87	0,83	0,86	0,80	0,80	0,81	13	34	10.050
DRC	1,29	1,29	1,28	1,28	1,29	1,21	1,28	1,28	1,28	1,28	1,28	20	53	7.040
Egypt	5,99	6,35	6,34	6,36	6,43	6,50	6,56	6,49	6,43	6,48	6,39	100		1.089.318
Eritrea	0,96	0,77	0,59	1,13	0,16	0,18	0,21	0,04	0,05	0,05	0,41	6	17	22.105
Ethiopia	1,37	1,11	1,16	1,33	1,44	1,39	1,49	1,47	1,90	1,51	1,42	22	59	1.226.229
Kenya	1,90	1,65	1,55	1,99	2,12	2,51	2,48	2,31	2,38	3,40	2,23	35	93	139.493
Rwanda	0,73	0,70	0,64	0,77	0,62	0,77	0,80	0,91	0,85	0,87	0,76	12	32	15.484
Sudan	2,29	1,21	2,33	2,52	2,14	1,96	2,42	2,46	3,83	2,83	2,40	38	100	170.135
Tanzania	1,12	1,44	0,46	1,38	1,56	0,80	0,82	2,66	2,75	0,90	1,39	22	58	53.990
Uganda	1,80	1,83	1,71	1,75	1,75	1,67	1,67	1,67	1,80	1,73	1,74	27	72	8.200
World Mean 2005/2007 (Bruinsma, 2009)											2,72			

Barley											
Area harvested (ha)											
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
DRC	650	700	780	780	780	780	780	780	780	780	759
Egypt	60.000	56.764	48.896	30.899	33.007	49.009	59.454	56.000	90.080	102.940	58.705
Eritrea	45.546	43.377	46.350	48.381	40.437	43.965	51.926	49.918	45.000	49.000	46.390
Ethiopia	897.200	1.045.380	880.360	938.010	821.383	1.075.437	1.254.786	1.208.631	997.868	1.019.314	1.013.837
Kenya	12.504	19.300	20.310	28.999	29.702	8.930	14.344	12.784	24.000	15.000	18.587
Rwanda	0	0	0	0	0	0	0	0	0	0	0
Sudan	0	0	0	0	0	0	0	0	0	0	0
Tanzania	2.700	2.350	2.400	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.145
Uganda	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Yield (tonnes/ha)													
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	1998-2007 average area harvested (ha)
Burundi	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
DRC	0,62	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	0,64	23	759
Egypt	2,47	2,01	2,03	3,04	3,05	2,89	2,74	2,66	1,70	1,73	2,43	86	58.705
Eritrea	1,24	0,73	0,56	0,93	0,24	0,20	0,21	0,19	0,21	0,31	0,48	17	46.390
Ethiopia	1,10	0,92	0,91	1,08	1,44	1,01	1,10	1,16	1,41	1,25	1,14	40	1.013.837
Kenya	1,85	2,22	2,22	3,89	3,13	2,98	2,73	3,22	3,38	2,67	2,83	100	18.587
Rwanda	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0	0
Sudan	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0	0
Tanzania	2,22	2,34	2,29	1,75	2,25	2,25	2,25	2,25	2,15	2,25	2,20	78	2.145
Uganda													
World Mean 2005/2007 (Bruinsma, 2009)											2,43		

Potatoes

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	9.000	10.000	10.000	10.000	10.000	10.000	10.000	11.500	10.000	10.000	10.050
DRC	19.000	19.220	19.393	19.567	19.724	19.834	19.922	20.104	20.104	20.194	19.706
Egypt	88.849	77.663	75.018	79.716	82.590	82.850	104.180	126.280	92.480	107.950	91.758
Eritrea	5.400	5.000	5.000	3.000	2.500	2.500	2.500	2.205	2.400	2.500	3.301
Ethiopia	48.000	50.950	50.000	45.000	36.736	54.603	51.698	61.812	61.812	73.095	53.371
Kenya	90.418	114.602	108.516	121.496	111.728	126.490	128.484	120.842	116.348	120.000	115.892
Rwanda	28.264	29.770	108.983	117.403	124.972	133.954	133.418	135.622	139.750	133.000	108.514
Sudan	6.650	14.800	16.092	17.035	17.702	18.550	20.168	22.268	24.280	16.380	17.393
Tanzania	36.000	37.000	50.000	67.000	77.200	48.170	89.310	125.990	126.000	125.000	78.167
Uganda	60.000	64.000	68.000	73.000	78.000	80.000	83.000	86.000	90.000	93.000	77.500

Yield (tonnes/ha)														
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	% of highest basin yield (excluding Egypt)	1998-2007 average area harvested (ha)
Burundi	2,60	2,44	2,40	2,73	2,80	2,80	2,61	2,70	2,63	2,67	2,64	11	16	10.050
DRC	4,63	4,63	4,63	4,63	4,64	4,63	4,63	4,63	4,63	4,63	4,63	19	27	19.706
Egypt	22,33	23,29	23,59	23,87	24,04	24,61	24,44	25,08	25,01	25,57	24,18	100		91.758
Eritrea	8,33	8,00	8,00	5,81	6,11	4,34	6,40	7,93	6,46	6,40	6,78	28	40	3.301
Ethiopia	7,60	7,65	7,70	9,22	10,49	9,33	9,86	7,28	7,28	7,19	8,36	35	49	53.371
Kenya	7,52	9,14	6,18	9,16	7,71	9,67	8,44	8,11	6,74	6,67	7,93	33	47	115.892
Rwanda	6,41	5,91	8,78	8,62	8,31	8,21	8,04	9,69	9,20	9,02	8,22	34	49	108.514
Sudan	24,68	13,28	16,74	11,77	16,57	16,66	16,66	17,29	18,63	16,67	16,89	70	100	17.393
Tanzania	6,94	6,89	7,00	6,72	8,26	2,93	8,19	5,17	5,24	5,20	6,25	26	37	78.167
Uganda	6,40	7,02	7,03	6,96	7,00	6,96	6,90	6,80	6,98	6,99	6,90	29	41	77.500
World Mean (Mitchell, D.O. *et al.*, 2008)											15,1			

Sweet Potatoes

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	100.000	112.000	110.000	120.000	124.000	125.000	125.000	142.000	125.000	125.000	120.800
DRC	51.066	49.092	47.296	45.566	43.889	44.540	44.791	45.851	46.520	47.198	46.581
Egypt	9.396	10.520	9.130	11.807	8.392	10.967	9.622	10.000	10.500	11.000	10.133
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	25.000	25.000	30.000	32.000	34.027	46.942	45.474	50.313	53.312	53.311	39.538
Kenya	49.320	51.320	59.740	66.520	60.410	58.770	60.701	24.294	74.937	61.111	56.712
Rwanda	148.850	179.941	174.663	192.727	195.370	147.130	163.070	148.526	135.725	140.000	162.600
Sudan	630	630	635	640	650	650	650	660	650	650	645
Tanzania	371.800	282.020	407.200	511.510	423.440	135.470	517.530	469.110	505.000	505.000	412.808
Uganda	544.000	539.000	555.000	572.000	589.000	595.000	602.000	590.000	584.000	578.000	574.800

Yield (tonnes/ha)														
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	% of highest basin yield (excluding Egypt)	1998-2007 average area harvested (ha)
Burundi	5,90	6,56	6,25	6,51	6,72	6,68	6,68	6,69	6,70	6,99	6,57	24	49	120.800
DRC	5,01	5,01	5,01	5,01	5,01	5,01	5,01	5,01	5,01	5,01	5,01	18	37	46.581
Egypt	24,01	24,05	27,33	26,65	27,70	28,05	28,12	30,00	29,05	29,55	27,45	100		10.133
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
Ethiopia	8,00	8,80	10,00	9,38	9,97	10,59	9,94	8,13	7,29	7,29	8,94	33	67	39.538
Kenya	8,06	10,58	8,84	8,30	7,20	10,47	9,41	9,50	9,67	13,28	9,53	35	71	56.712
Rwanda	5,05	4,79	5,91	6,00	6,61	5,90	5,57	5,96	5,73	5,71	5,72	21	43	162.600
Sudan	13,65	13,17	13,39	13,44	13,38	13,38	13,38	13,33	13,38	13,38	13,39	49	100	645
Tanzania	1,72	2,00	0,51	1,86	3,46	1,53	2,90	3,02	2,38	1,90	2,13	8	16	412.808
Uganda	4,00	4,37	4,32	4,40	4,40	4,39	4,40	4,41	4,50	4,50	4,37	16	33	574.800
World Mean (Mitchell, D.O. *et al.*, 2008)											11,6			

Cassava

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	70.000	70.000	73.000	80.000	82.000	82.000	82.000	89.000	75.000	75.000	77.800
DRC	2.102.580	2.033.522	1.966.847	1.902.359	1.839.985	1.841.825	1.842.559	1.845.510	1.877.355	1.849.203	1.910.175
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Kenya	57.094	66.467	60.273	78.332	81.967	53.635	57.916	38.218	68.502	53.610	61.601
Rwanda	76.314	118.492	120.463	136.238	130.457	134.146	133.876	115.694	118.860	120.000	120.454
Sudan	5.500	5.600	5.750	5.800	5.900	6.000	6.000	6.100	6.000	6.000	5.865
Tanzania	745.400	655.700	809.700	660.900	660.260	660.000	660.000	670.000	670.000	675.000	686.696
Uganda	356.000	375.000	401.000	390.000	398.000	405.000	407.000	387.000	379.000	371.000	386.900

Yield (tonnes/ha)													
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	1998-2007 average area harvested (ha)
Burundi	8,88	8,82	9,00	8,91	9,15	9,15	8,65	8,88	7,61	7,45	8,65	68	77.800
DRC	8,11	8,11	8,11	8,11	8,11	8,11	8,11	8,11	7,98	8,11	8,10	63	1.910.175
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			0
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			0
Ethiopia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			0
Kenya	8,06	10,21	6,95	7,77	7,34	7,90	11,10	9,10	9,59	7,42	8,54	67	61.601
Rwanda	2,47	2,67	6,82	5,79	7,90	7,48	5,72	6,76	4,95	6,67	5,72	45	120.454
Sudan	1,80	1,71	1,74	1,76	1,75	1,73	1,73	1,72	1,73	1,67	1,73	14	5.865
Tanzania	7,08	8,21	6,60	6,56	7,84	6,00	6,73	8,27	9,19	9,78	7,63	60	686.696
Uganda	9,00	13,00	12,38	13,50	13,50	13,46	13,51	14,41	13,00	12,01	12,78	100	386.900
World Mean (Mitchell, D.O. *et al.*, 2008)											10,1		

Bananas

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	295.000	295.000	295.000	300.000	300.000	300.000	320.000	325.000	300.000	300.000	303.000
DRC	85.192	84.292	83.489	83.674	83.859	83.993	83.883	84.017	84.150	284.284	104.083
Egypt	16.998	22.524	22.053	20.707	21.129	21.307	21.270	21.000	19.880	21.500	20.837
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	10.000	10.000	15.000	20.000	23.000	29.083	28.695	28.102	30.000	25.000	21.888
Kenya	37.751	37.643	37.154	38.788	39.078	39.799	40.000	40.000	82.518	77.356	47.009
Rwanda	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Sudan	2.100	2.100	2.200	2.300	2.300	2.300	2.300	2.300	2.300	2.300	2.250
Tanzania	334.700	252.960	303.500	289.620	370.630	394.050	316.100	322.040	480.000	480.000	354.360
Uganda	130.000	130.000	135.000	135.000	135.000	135.000	135.000	135.000	135.000	135.000	134.000

Yield (tonnes/ha)														
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	% of highest basin yield (excluding Egypt)	1998-2007 average area harvested (ha)
Burundi	4,74	5,12	5,13	5,16	5,34	5,33	5,31	5,29	5,33	5,33	5,21	13	16	303.000
DRC	3,74	3,74	3,74	3,74	3,74	3,74	3,74	3,74	3,74	1,11	3,47	9	11	104.083
Egypt	38,57	32,37	34,49	41,01	41,53	40,87	41,14	41,90	43,01	40,93	39,58	100		20.837
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
Ethiopia	8,10	8,10	6,67	6,50	6,09	6,02	6,34	7,52	7,60	8,00	7,09	18	22	21.888
Kenya	14,94	14,58	13,83	13,98	13,73	12,81	15,00	15,00	15,00	15,34	14,42	36	44	47.009
Rwanda	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
Sudan	33,57	33,81	32,73	31,74	31,96	32,17	32,17	32,61	32,17	32,17	32,51	82	100	2.250
Tanzania	2,50	2,96	2,31	2,60	5,95	4,82	7,87	6,23	7,31	7,29	4,98	13	15	354.360
Uganda	4,58	4,62	4,52	4,52	4,56	4,56	4,56	4,56	4,56	4,56	4,56	12	14	134.000
World Mean (Mitchell, D.O. *et al.*, 2008)											15,6			

Sunflower seeds											
Area harvested (ha)											
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
DRC	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Egypt	14.621	18.924	11.717	19.360	15.654	14.250	20.119	14.760	15.610	18.500	16.352
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Kenya	7.245	12.251	13.000	13.000	13.000	13.000	13.000	13.000	13.000	13.000	12.350
Rwanda	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Sudan	19.740	20.580	5.461	10.500	12.600	24.000	5.640	10.500	30.000	61.250	20.027
Tanzania	82.000	82.000	82.000	82.000	80.000	80.000	82.000	82.000	82.000	82.500	81.650
Uganda	66.000	72.000	79.000	78.000	124.000	145.000	149.000	157.000	165.000	173.000	120.800

Yield (tonnes/ha)														
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	% of highest basin yield (excluding Egypt)	1998-2007 average area harvested (ha)
Burundi	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
DRC	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
Egypt	2,32	2,38	3,84	2,28	2,26	2,34	2,35	2,34	2,42	2,38	2,49	100		16.352
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
Ethiopia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
Kenya	0,82	0,99	1,00	1,08	0,92	0,92	0,92	0,92	1,08	1,08	0,97	39	95	12.350
Rwanda	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
Sudan	0,51	0,39	0,73	0,38	1,51	0,75	1,24	1,14	1,47	1,19	0,93	37	91	20.027
Tanzania	0,34	0,34	0,34	0,34	0,34	0,34	0,34	0,34	0,34	0,34	0,34	14	33	81.650
Uganda	0,86	0,90	1,00	0,97	1,00	1,10	1,10	1,10	1,07	1,10	1,02	41	100	120.800
World Mean 2005/2007 (Bruinsma, 2009)											1,29			

Tea

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	7.500	7.500	8.500	9.150	8.900	8.900	8.900	8.900	8.900	9.000	8.615
DRC	4.823	3.600	2.723	2.341	2.013	3.000	4.216	4.243	4.757	5.351	3.707
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	3.300	4.000	4.000	4.000	4.000	4.500	4.500	5.000	5.000	5.000	4.330
Kenya	118.650	118.540	120.390	124.290	131.450	131.450	136.700	141.300	147.080	149.190	131.904
Rwanda	11.000	10.032	12.300	12.825	12.500	12.500	11.700	13.280	12.700	15.300	12.414
Sudan	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Tanzania	18.500	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	19.000	18.950
Uganda	20.000	15.213	15.701	15.761	22.000	20.000	20.000	20.100	19.100	20.000	18.788

Yield (tonnes/ha)													
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	1998-2007 average area harvested (ha)
Burundi	0,89	0,92	0,84	0,99	0,74	0,83	0,87	0,84	0,84	0,86	0,86	38	8.615
DRC	0,69	0,61	0,69	0,69	0,69	0,52	0,37	0,37	0,37	0,33	0,53	24	3.707
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Ethiopia	0,82	0,90	0,94	0,99	0,98	0,97	0,98	0,96	0,96	0,96	0,95	42	4.330
Kenya	2,48	2,10	1,96	2,37	2,18	2,23	2,37	2,32	2,11	2,48	2,26	100	131.904
Rwanda	1,35	1,29	1,18	1,39	1,19	1,24	1,24	1,24	1,26	1,24	1,26	56	12.414
Sudan	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Tanzania	1,18	1,32	1,24	1,34	1,30	1,45	1,58	1,62	1,59	1,65	1,43	63	18.950
Uganda	1,30	1,63	1,86	2,08	1,79	1,84	1,79	1,88	1,80	1,75	1,77	78	18.788
World Mean (Anon, 2002)											1,1		

Coffee

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	28.000	32.000	32.000	32.000	32.000	32.000	32.000	30.000	32.000	32.000	31.400
DRC	155.259	131.000	114.538	99.649	82.256	82.179	82.103	82.026	81.949	81.872	99.283
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	250.000	251.310	250.000	250.000	250.000	250.000	260.201	261.175	295.234	410.000	272.792
Kenya	178.500	170.000	170.000	170.000	170.000	170.000	170.000	170.000	170.000	170.000	170.850
Rwanda	21.000	26.728	23.000	26.000	28.000	20.000	29.000	26.000	30.000	27.000	25.673
Sudan	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Tanzania	110.000	116.000	115.000	130.000	92.000	136.894	120.000	120.000	100.000	120.000	115.989
Uganda	265.000	275.000	300.991	264.000	217.504	264.000	264.000	263.000	220.000	265.000	259.850

Yield (tonnes/ha)													
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	1998-2007 average area harvested (ha)
Burundi	0,60	0,91	0,58	0,49	1,13	0,63	1,13	0,26	0,97	0,47	0,72	87	31.400
DRC	0,36	0,37	0,41	0,35	0,39	0,39	0,39	0,39	0,39	0,39	0,38	46	99.283
Egypt	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Ethiopia	0,92	0,87	0,92	0,91	0,90	0,89	0,60	0,66	0,82	0,79	0,83	100	272.792
Kenya	0,30	0,40	0,59	0,30	0,31	0,33	0,28	0,27	0,28	0,31	0,34	41	170.850
Rwanda	0,68	0,70	0,70	0,71	0,69	0,69	0,69	0,72	0,70	0,70	0,70	84	25.673
Sudan	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Tanzania	0,35	0,40	0,42	0,45	0,41	0,45	0,27	0,45	0,34	0,46	0,40	48	115.989
Uganda	0,77	0,92	0,48	0,75	0,96	0,57	0,64	0,60	0,61	0,63	0,69	84	259.850
World Mean 2005/2007											?		

Sugar Cane

Area harvested (ha)

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
Burundi	2.600	2.700	3.000	3.000	2.508	3.200	2.500	2.500	2.500	2.500	2.701
DRC	36.000	36.000	36.000	36.500	43.000	42.000	39.344	36.627	37.922	40.000	38.339
Egypt	122.464	129.084	133.990	131.059	135.890	137.485	135.309	134.980	137.260	135.500	133.302
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	16.000	21.070	22.430	22.990	23.840	23.500	23.140	23.000	18.857	17.475	21.230
Kenya	50.111	51.833	57.243	47.794	54.010	50.468	54.191	56.537	54.621	59.201	53.601
Rwanda	1.000	1.300	1.300	2.000	2.300	2.300	2.300	2.300	3.300	33.000	5.110
Sudan	71.313	75.899	63.538	63.840	63.480	65.000	65.966	69.747	72.000	72.000	68.278
Tanzania	11.000	14.000	15.000	16.000	16.500	18.000	18.000	20.000	21.000	23.000	17.250
Uganda	14.000	20.000	20.000	19.705	25.000	17.043	23.357	24.536	19.500	20.000	20.314

Yield (tonnes/ha)													
Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean	% of highest basin yield	1998-2007 average area harvested (ha)
Burundi	73,26	64,81	66,67	66,67	70,18	71,88	72,00	72,00	71,01	72,00	70,05	59	2.701
DRC	48,09	47,22	46,36	42,74	37,29	37,60	39,41	41,56	39,41	38,75	41,84	35	38.339
Egypt	117,20	118,17	117,22	118,81	117,87	118,16	119,95	120,89	118,88	119,56	118,67	100	133.302
Eritrea	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a			
Ethiopia	103,13	99,02	97,04	97,09	93,63	104,51	106,06	106,52	85,12	63,88	95,60	81	21.230
Kenya	93,02	85,19	68,86	74,29	83,34	83,30	86,01	84,91	90,31	87,91	83,72	71	53.601
Rwanda	30,00	30,77	30,77	30,00	30,43	30,43	30,43	30,43	30,30	3,03	27,66	23	5.110
Sudan	80,51	70,10	78,41	86,20	94,52	100,00	105,87	103,03	104,17	104,17	92,70	78	68.278
Tanzania	89,45	90,64	90,33	93,75	106,06	111,11	111,11	115,00	116,67	119,57	104,37	88	17.250
Uganda	82,56	71,01	73,81	78,28	75,10	117,06	94,31	87,61	100,00	100,00	87,98	74	20.314
World Mean 2005/2007 (Bruinsma, 2009)											67,02		

Summary

All basin Countries

Country	Grains					Roots and Tubers			Others					
	Maize	Sorghum	Millet	Wheat	Barley	Potatoes	Sweet Potatoes	Cassava	Bananas	Sun-flower Seed	Tea	Coffee	Sugar-cane	Cotton
Burundi	14	22	70	13	n/a	11	24	68	13	n/a	38	87	59	
DRC	10	12	42	20	23	19	18	63	9	n/a	24	46	35	
Egypt	100	100	n/a	100	86	100	100	n/a	100	100	n/a	n/a	100	
Eritrea	5	9	20	6	17	28	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Ethiopia	24	23	65	22	40	35	33	n/a	18	n/a	42	100	81	
Kenya	21	14	37	35	100	33	35	67	36	39	100	41	71	
Rwanda	10	17	51	12	0	34	21	45	n/a	n/a	56	84	23	
Sudan	11	11	17	38	0	70	49	14	82	37	n/a	n/a	78	
Tanzania	22	15	51	22	78	26	8	60	13	14	63	48	88	
Uganda	21	25	100	27	n/a	29	16	100	12	41	78	84	74	

All basin Countries except Egypt

Country	Grains					Roots and Tubers			Others					
	Maize	Sorghum	Millet	Wheat	Barley	Potatoes	Sweet Potatoes	Cassava	Bananas	Sun-flower Seed	Tea	Coffee	Sugar-cane	Cotton
Burundi	59	87		34		16	49		16	n/a				
DRC	43	45		53		27	37		11	n/a				
Eritrea	21	36		17		40	n/a		n/a	n/a				
Ethiopia	100	91		59		49	67		22	n/a				
Kenya	90	57		93		47	71		44	95				
Rwanda	43	68		32		49	43			n/a				
Sudan	45	43		100		100	100		100	91				
Tanzania	93	60		58		37	16		15	33				
Uganda	89	100		72		41	33		14	100				

Annex 2: Area and weight conversions

1 ha = 10 000 m^2

1 fed (feddan) = 4 200 m^2

1 ha = 2.38 feddan

1 hg = 100 g

1 kg = 10 hg

1 q (quintal) = 100 kg

1 t = 10 quintal or 1 000 kg or 10 000 hg

A kantar is the official Egyptian weight unit for measuring cotton. It corresponds to the hundredweight, and is roughly equal to 99.05 pounds, or 45.02 kilograms. It is equal to either 157 kilograms of seed cotton or 50 kilograms of lint cotton.

Annex 3: Further details of agricultural production in the highland tropical farming system

Burundi

Agriculture in eastern Burundi remains principally at the subsistence level; with very little use of inorganic fertilizers, pesticides, selected seeds and a little mechanisation. Farmers do try to maintain/increase the productivity of their small farms by using manure to fertilize their fields, by installing affordable SWC structures[44] and by increasing the number of cropping cycle a year (average of two annual cultures, supplemented (where possible) by one culture in the marshes). In the past, farmers were encouraged to grow a monoculture, supposedly to increase productivity. However, experience has shown that there is often a shortfall between production and subsistence requirements in monocultures, thus farmers prefer to follow the traditional practice of inter-cropping, even on very small plots. This is a rational strategy which enables farmers to grow a range of cereals and tubers, diversifying to reduce the risk/impact of any crop failing.

The Burundian farmer also organizes his agriculture according to the often complex potentialities of the land and its microclimate, typically ranging from hilltops to valley bottoms, the latter often occupied by marshes. Table A1 outlines the cropping cycle arising from these agro-climatic potentialities.

From September to May/June, when the distribution of rainfall is regular, smallholders cultivate the fields on the sides and the top of the hills while from June to September, the dry period, cultivation shifts to low-lying marshes.

Table A1: Annual cropping patterns in the highland tropical farming system, Burundi

Cultural Season	Period	Crops Grown
1 st Cultural Season – A	September/October to January	Legumes (haricot beans and peas), maize, sorghum, sweet potatoes, Irish potatoes, manioc, coffee and tea.
2nd Cultural Season – B	February to June	Haricot beans, sorghum, sweet potatoes, Irish potatoes, manioc.
3rd Cultural Season - C	June/August to September	Legumes, sweet potatoes and maize. Cuttings of plants cultivated on hills.

Source: R. Gommes (FAO-FUL 96-1997)

[44] The terrain is undulating, with rates of erosion evaluated at 4t/ha/yr in the east and 18 t/ha/yr in central Burundi. Land parcels are becoming smaller, with the average cultivable plot currently between 0.4 and 05 ha.

- At the edge of banana plantations lie horticultural and forestry belts which farmers cultivate as home-gardens. Forest products, spices, medicinal plants and market-gardening species, (e.g., marrows, pineapple, lemons, yams, sweet potatoes, onions, vegetables) are grown there.
- The main cropping fields are located between the horticultural belt and the banana plantations.
- Relatively large fields of cassava and Chinese cabbages are to be found in the low-lying areas, which tend to be wet, with deeper laterite soils. The valley bottoms (marshes) are used in the dry season to grow beans, sweet potatoes and vegetables.
- The steep slopes, which are often rocky and not suitable for cropping, are used for grazing. Trees are very important components of this humid zone farming system. A great number of them are grown around dwellings and are also interplanted with arable crops and around marshes until they reach maturity.
- Livestock are kept by most smallholders. Sheep dominate, followed by goats and small animals including rabbits and poultry, with a small number of cattle. The system of pasture exploitation is based on mobile herds moving between available pastures, responding to the changing availability of grazing during the seasons and the distribution of water points.

Soil fertility is generally poor in Burundi, with more than 46 percent of soils acid, with aluminium toxicity, requiring organic amendments and calcium. These inputs are not readily available or affordable, thus limiting crop yields. Smallholders allow the fertility of their land to regenerate occasionally with short fallows. Frequency varies between smallholders according to their land holdings.

The principal problems of the system are: difficulties in accessing good-quality land for the growing number of smallholders; soil erosion following heavy rain; and wind erosion from surfaces which are bare of vegetation. Cropping therefore needs to be diversified to respond to soil and climatic conditions.

Drought is the principal long-term problem encountered by livestock keepers. Total rainfall is the principal factor which limits pastures in the dry areas, reducing productivity and the diversity of plant species – and also affecting forage quality and thus livestock nutrition.

In most provinces of Burundi, factors which limit production include shortage of agricultural inputs, climate change (notably warming of seasons A and B (see Table A1), when most of production takes place, plus increasing uncertainty as to the timing and duration of rains).

Phytosanitary problems include banana wilt, cassava mosaic virus, potato blight and ladybirds on wheat, which combine to seriously reduce crop yields. Appropriate agrochemicals could mitigate these problems, as could the substitution of disease- or drought-resistant varieties for the almost entirely local strains.

The unplanned exploitation of marshes is a further factor contributing to degradation of the land, particularly in northern Burundi.

The Democratic Republic of the Congo (DRC)

Water from the Nile basin is a major pillar of agricultural development in the north-east of the DRC. The rapid growth of the local population is accelerating demand for agricultural produce and livestock. However the area is vulnerable to drought, deforestation, floods and erosion. It has also been seriously affected by armed conflicts.

The Nile basin in DRC includes a wide variety of soils, which offer land users a broad range of agricultural possibilities. There is, howeverl, a severe lack of information, as much has been destroyed in the war which has affected the area since 1998.

Traditionally, agriculture in north-eastern DRC has focused on food production to meet subsistence needs, with any surplus being sold to make essential purchases. On average, households cultivate 0.5 to 1.5 ha and yields are poor as no fertilizers/pesticides are used and tillage follows traditional systems.

An intermediate system of management can be distinguished where farmers belong to producers' organizations or associations. Through them farmers can more easily access services that help improve production.

Soil preparation is poor, with over 60 percent of farmers not following recommended cultivation guidelines. Late soil preparation and use of traditional equipment limit production, which is also hampered by insufficient labour, which in turn makes it difficult to apply organic matter to improve soils.

Agro-economic factors also negatively affect crop sowing and planting as farmers frequently do not follow recommended seed density and spacing Lack of rains often delays planting dates and labour shortages limit timely weeding.

The traditional system is based on crop rotation with fallows to permit the restoration of soil fertility. However, socio-economic changes and population pressure are reducing the length of fallows, disrupting the environmental equilibrium, compromising soil fertility and exacerbating land degradation. Notably, the recycling of crop residues has been abandoned by many farmers.

Most of the agriculture in the Nile basin of DRC is rainfed and therefore dependent on the distribution of rainfall each growing season. Obviously, yields are particularly affected in seasons with irregular/showery rainfall. The impacts of climate change are already to be seen in this area, with more frequent dry periods, intensified storms and increased flooding. Despite great potential for irrigation, only 13 500 ha are currently irrigated (under sugar cane and rice) out of an estimated potential area of four million ha. There are no outgrower-type schemes using irrigation, although some individual smallholders have informal irrigation systems for their small plots. Currently, there is limited use of rainwater harvesting although it could help farmers to adapt to the increasingly challenging weather patterns brought by climate change.

The terrain of the Nile basin is very varied and broken, and many hilly areas require anti-erosion SWC protection.

The main food crops grown are cassava, rice, soya and haricot beans, groundnuts, bananas (cooking and sweet), vegetables, potatoes, sweet potatoes and sorghum. At national level the Nile basin is the leading producer of haricot beans, potatoes, sweet potatoes, peas and sorghum. It also supplies a wide range of other vegetables to other areas of the DRC.

Maize is the most important cereal crop grown in the basin area. Indeed the area under maize has increased significantly in recent years. The importance of maize at the national level is attributed to the introduction of high-yielding varieties in the 1980s. Maize is also preferred as it responds well to inorganic fertilizers, rotations and association with legumes.

The basin is climatically ideal for both rainfed and irrigated rice cultivation. Investment in the management of irrigation systems would bring benefits to communities, the private sector and specialist public services.

Groundnuts are grown (mainly by women) in all parts of the basin as a source of dietary protein and fat. Haricot beans and soya, although less important are also widely grown and figure largely in local diets. Surplus beans are sold in Rwanda, Kisangani and Kinshasa.

Three types of livestock-keeping are practiced:

- Traditional smallholder rearing;
- Semi-improved animal husbandry: adopted by a small number of innovative cattle farmers. The technical level of farms needs updating and the level of inputs use is inadequate;
- Organized animal husbandry: is only practiced by a small number of farmers scattered across the basin, including farms managed by missionaries.

Small ruminants and poultry are kept in rural and urban areas. Such animals are often not well-cared for and left to scavenge for feed, hence production is very poor.

The Nile basin (encompassing Ituri and North Kivu) has the biggest potential in the DRC to develop animal husbandry and the region is famous for its agro-pastoral sector. However, widespread poverty and imports of low-quality fish and offal (at prices of around one USD/kg) limit the potential for the development of animal husbandry. The current socio-economic crisis and the wars have harmed animal health, veterinary centres, the collective pastures and NERA, at Nioka, the most important animal research centre in the Nile basin.

Kenya

Historically crop farming has long been a major occupation for communities in the Lake Victoria basin (Kenya's Nile basin area). More than seven million people (1.4 million households) are dependent on this farming system. Land holdings are 0.2 ha-10 ha in size, the average being less than 2 ha. Many farms are so small that only by adopting high levels of intensification can farmers hope to meet subsistence requirements.

The farming system lies within sub-humid zone and receives rainfall ranging from 1 200 mm to 1 600 mm/year. This environment has potential for a wide range of crops. In most of the Nile basin in Kenya, farmers practice mixed farming with maize, sorghum beans and livestock as choice enterprises. The system is often referred to as the mixed farming zone, composed of cereals, pulses, roots and livestock. Vegetables and fruit are grown by many farmers. Although in some areas other crops would do better, most farmers prefer to grow traditional basic cereals and legumes to meet household demands. The choices depend on the level of humidity and rainfall, and other considerations including altitude and soils.

Cassava is a very important crop in both lake basin farming systems and acts as both a food and cash crop. Groundnuts are is the main cash crop followed by sweet potatoes and cassava, while maize forms the main staple food.

Fruit trees are not major crops in the faming system although in the last ten years several commercial fruits have been introduced - including improved mangoes, pawpaw, pineapples, oranges and avocado.

The details of production levels are presented for both food and industrial crops and the average over three years has been taken in order to internalize drought effects. Table A2 shows that in this traditional mixed system there is enormous scope to increase yields. For example the average current yield for groundnuts is only 0.3 t/ha, with the highest 0.6t/ha (100percent more) while the potential is 1.3 t/ha (or three as much). Similarly, the average yield for sweet potatoes is 9.3t/ha, with the highest attained 13.9 (50 percent more) while the potential is 25t/ha (169 percent).

These figures highlight the room there is for increasing the productivity of existing farmland, as opposed to expanding cropped areas into more marginal areas.

The farmers within this system are at subsistence level, mainly growing traditional crops regardless of whether they are profitable or not. Over 70 percent of total root crops and groundnuts produced in Kenya come from these farming systems. While most of these crops are now cultivated in monocultures, farmers traditionally interplanted them with other crops such as cereals and pulses. It may be appropriate to resume that strategy in the face of the predicted impacts of climate change. Many members of these communities also engage in petty trade in order to supplement their income.

The level of farm inputs, including fertilizer and certified seeds, is very low and often leads to declining yields with very little farm produce sold beyond the farm gate. This in most cases makes it difficult to attain food self-sufficiency, resulting in food shortage in some areas.

Livestock keeping among the communities is as important as crops due to its major role in the livelihood strategies of communities

Table A2: Production levels within the highland tropical farming systems of the lake basin in Kenya

Major Crops (t/ha)	Average Production in each Farming System	Highest Attained Production in each Farming System	Potential Production in each Farming System
Groundnuts	0.3	0.6	1.3
Sweet potatoes	9.3	13.9	25
Maize	1.2	1.3	3
Cassava	9.9	16	35

Source: NBI Country Report (2008)

within the basin. Farmers are also more closely involved in trade in this farming system than in other countries.

Tanzania

Four different sub-systems are described below. They are instructive as they explain variations within the farming system.

Bananas dominate the system on Bukoban sandstone in high rainfall areas, where the local Wahaya have developed a very intensive land-use system to provide sufficient food for the growing population. It is based on an intelligent adaptation of banana production to the difficult local natural conditions (low soil fertility, high leaching). Three different field types can be identified each having its own location-specific combination of cropping system components (e.g. soils, crops, fallow periods, weeds, pests and diseases):

- Kibanja: located around the homestead on deep soils; bananas are grown with beans, coffee and several other crops.
- Kikamba: located at the edge of the Kibanja.It may be fallow for short periods or cropped with bananas or annual crops (e.g. root crops, groundnuts).
- Rweya: located at some distance from the homestead on communal land. It may be fallow and grazed for long periods (5-10 years), then cultivated for short periods (1-2 years) with bambara nuts or cassava.

There are major differences in soil chemical qualities between these field types due to human management. The contrast between Kibanja and Rweya in the Bukoban high rainfall areas (1 500-2 100 mm) is huge. They have been modified over centuries and can be called man-made soils. Kibanja topsoils have changed considerably through accumulation of organic matter by adding cattle manure, household residues, mulch-grass and by the build-up of banana forest biomass containing large quantities of nutrients which are cycled rapidly between the banana biomass and the soil organic matter. Most Kibanja soils show medium soil fertility, with a fertility gradient ranging from high near the homestead and declining towards the periphery and Kikamba.

The Kibanja enrichment is the result of mining the fertility of the Rweya soil. As long as there were sufficient Rweya hectares to keep one hectare of Kibanja productive without causing irreversible Rweya degradation, the whole system could stay in balance sustaining a relatively high population density. However, during the last century population density increased to 161 people/ km^2 (NBI 2008 national report) and cattle numbers decreased to such levels that the system is no longer in balance. Consequently, the Rweya soils are strongly acid and have extremely low fertility, lacking almost every nutrient, except phosphorus.

Banana crops grown on Kibanja are thus increasingly confronted with a decline in soil fertility levels and an increase in the incidence of pests and diseases (e.g. banana weevil, nematodes, Panama disease). This is exacerbated by population growth which has reduced the area of cropped land per household to 0.67 ha/hh. The combined result is that food security is at risk among many households and this has provoked a continuous out-migration over the last decades.

The banana-dominated system on Bukoban sandstone in medium rainfall areas is quite similar to the one discussed for the high rainfall areas. However, in the former (1 000-1 500 mm annual precipitation), differences in soil qualities between Kibanja and Rweya field types are less extreme. This is attributed to the lower population densities (102 people/ km2), more recent settlement patterns and lower nutrient leaching rates. Rweya soils in the medium rainfall areas are less depleted of organic matter and nutrients. They are still moderately acid and have very low soil fertility ratings. Although topsoils of Kibanja have also been changed, their organic matter content has only been raised to the medium level. Consequently, banana growing on Kibanja is more productive and when combined with lower population densities, more land of higher quality is available for cropping (0.73 ha/hh) – resulting in better food security. As a consequence, out-migration (although already taking place) is less common.

The banana-dominated system on Karagwe-Ankolean parent rock differs from the Bukoban sandstone system, as the soils derived from the Karagwe-Ankolean rocks are more fertile. Population densities are much lower than the systems on Bukoban sandstone. (The Farming Systems Research project (1995) recorded a district average of 46 people/km^2 for Karagwe, while Lorkeers (1995) reported 34 people/km^2 for the Karagwe-Ankolean system in Bukoba district.) However, it should be noted that there is considerable variation within the system and certain districts have higher population densities[45].

Perennial and annual crop production is essentially limited to the Kibanja and Kikamba field types. In contrast to Bukoban sandstone systems, where bambara, groundnuts and cassava are grown on Rweya following long fallow periods, the Rweya plots on the Ankolean-Karagwe system are only composed of Eucalyptus plantations. The absence of a real Rweya field type is due to the higher inherent soil fertility and better physical characteristics (depth, texture), making the system's soils more suitable for continuous crop production. In addition, most areas covered by this system have a shorter duration of continuous soil exploitation compared to the Bukoban systems. The degeneration of Rweya land through nutrient transportation to Kibanja land is far less accentuated; its use is mainly restricted to extensive livestock keeping and cutting of grasses for mulching.

Although the agricultural potential of the volcanic soils in the Tarime highlands is reasonable, available information is scanty. The soils of the undulating-to-rolling plateaus and plains (altitude: 1 500-1 800 m) have developed on lava and granites, hence their soil fertility appears to be reasonable.

The general trend in this system is to move away from the traditional extended family production system with large cattle herds, towards more "modern" small, independent units operating mixed production system. Farm sizes are small, due to the high population density and cultivation is continuous as there is not sufficient land to allow fallows. This demands careful management of soil fertility. Livestock keeping is directed towards supplying manure and draught power. The agro-climatic situation and the reasonable access to nearby markets through a permanent road system favour production intensification.

[45] Notably, there has been confusion on the classification of communal grazing lands (whether to included then in the village area or not), so variations may not be genuine – some standardization of terminology is recommended.

Maize is the principal crop in the system, used as a food and cash crop. It is often chosen as it is less laborious to cultivate than finger millet and does not have the bird pest problems of sorghum. Although these traditional food crops will remain in the system, maize is expected to gain in importance, due to market demand and high prices.

In parts of the area coffee is the major cash-earner. However, the general appearance of coffee fields is poor and institutional constraints are important.

In addition, weed infestations pose a serious problem, especially in coffee fields without shade from trees.

In recent years the system has become a major banana producing area, as the agroclimate is ideal and farmers are improving their level of husbandry steadily. Being a less laborious and capital-intensive crop than coffee, bananas are a good alternative cash crop for the smaller farmers. However, passable feeder roads are essential for a further expansion of this crop.

As similar farming systems have developed across the border in Kenya, extrapolation and exchange of research information will be relevant. The Mogabiri Farm Extension Centre and the Kisii Regional Research Centre should therefore be in close contact.

Annex 4: Further details of agricultural production in the commercial farming system

Sudan

The total area cropped under "semi-mechanized" rainfed crop production in the Sudan is estimated to be about 7.1 million ha. In terms of location the system is confined to the eastern and western regions of the country, covering areas of the savannah belt. The system includes about 10 000 "big" farmers with farms of 450 – 900 ha and a few large companies with holdings of 9 000 – 90 000 ha.[46]

The system is termed semi-mechanized as only land preparation and seeding are mechanized while weed control and harvesting are still largely manual. Of the sub-sector's annually cropped area of 3.1 -5.4 million ha, sorghum occupies 80 - 85 percent, sesame 14-16 percent and cotton, sunflower and pearl millet and guar combined 1-2 percent. This subsector produces about 70 percent of the country's sorghum, 40 percent of its sesame and almost all of its sunflower and guar.

There are many crops that could potentially be grown on the semi-mechanized farms as part of the Government's diversification policy for this farming system. The system is fully market-oriented and to meet consumer demand it mostly grows local varieties of sorghum and sesame, an improved variety of cotton, introduced varieties of guar, and hybrids of sunflower selected to adapt to the range of local agro-ecosystems.

Table A3 shows the performance of the major crops grown under semi-mechanized agriculture during the period 1999/2000-2002/2003 (the most recent data found). This data shows that the area under sorghum increased 33 percent over the period despite the fluctuations in annual rainfall. However, the average sorghum yield remains disappointing (0.36 to 0.48 t/ha – whereas the national average is 0.63 t/ha – see Annex 1).

The area under sesame declined tremendously during 1999-2003, as the crop area in the 2002-2003 season was only 21 percent of the crop area in 1999-2000. However, this decrease is highly likely to be attributable to a number of external factors, notably the low rainfall and the poor sesame prices the previous year. As a result, sesame production declined from about 242 000 tonnes in 1999/2000 to about 61 000 tonnes in 2000/2003 – but yields showed some improvement.

The area under sunflower ranged from 21 000 ha in 1999-2000 to only 3 000 ha in 2002-2003, with widely-ranging yields (0.33 t/ha in 1999-2000; 0.53 t/ha in 2000-2001) – at all

[46] The farms are allotted to private farmers on a rental basis.

Table A3: Major crops performance in semi-mechanized agriculture (1999-2003) Areas ('000s ha), production ('000s t) and yields (t/ha), Sudan												
Season	1999-2000			2000-2001			2001-2002			2002-2003		
Crop	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Sorghum	2 063	746	0.36	2 064	880	0.43	2 803	1 342	0.48	2 741	1000	0.36
Sesame	1 404	242	0.17	1 298	225	0.17	908	165	0.18	301	61	0.20
Sunflower	21	7	0.33	4	2	0.53	11	4	0.38	3	1	0.40

Source: adapted from Department of Agriculture Statistics, General Administration for Planning & Agricultural Economics, Ministry of Agricultural & Forestry (2004).

times with a large gap between the achieved yields and the national average yields (0.93 t/ha in the 1999-2007 period, see Annex 1).

A range of different livestock systems are followed by farmers in the commercial sector in the Sudan:

- Commercial herds that use natural pastures on a year-round basis, with water being transported by tankers or available from privately developed watering facilities to meet dry-season requirements. Sheep are the most important type of livestock in this system and supplementary feed may be provided.
- Commercial herds that use natural pastures for wet-season grazing, then return to irrigated land to feed on crop stubble and residues in the dry season. Cattle and sheep are equally important in this system, where limited supplementary feed may be provided during the dry season.
- Fattening operations near urban centres utilize weaned calves and young bulls from traditional rainfed production areas[47], which are subsequently fed a mix of crop residues, urea and molasses; plus cottonseed cake, sorghum grains or wheat bran and salt; also processed concentrates.
- Commercial herds (cattle and sheep) kept in irrigated land and fed fodder sorghum and alfalfa.
- Modern, large-scale dairy production systems which are completely closed, efficiently-run and obtain relatively high levels of productivity. They keep exotic breeds fed on irrigated fodder (forage sorghum, maize, alfalfa and Rhodes grass) and concentrates.
- Relatively intensive and modern, more or less closed, small-scale dairy production systems, where cattle are kept in a courtyard or fenced site and fed purchased fodder plus concentrates; common around urban centres with varying levels of productivity.
- Open, traditional mixed crop-livestock production systems.
- Commercial ranching is a recent trend in the Sudan, either with group ranching initiated by a government department, or

[47] Agropastoral and/or dryland farming systems.

under a project. The Rural Development Department took the initiative of establishing group ranches in Kordofan but has had very limited success in the north and failed in the west

In modern systems, the animals are kept in a loose housing system made of a solid building with high walls on three sides, concrete floors and a roof. Between every second pen there are high walls and no contact between the animals. An example of this system is Azaheir farm, where cows are milked 2-3 times a day by machine in a parlour. The animals are fed in stone troughs positioned outside along the sides of the pens, and reachable at all times. This avoids consumption of feed from the ground as in the other two systems. It is important from a hygienic perspective and in the prevention of diseases. In this type of system, milk production is estimated at 15-23 litres per day/cow. It is, however, lower than would be expected in temperate regions so genetic potential is not fully exploited. Climatic stress is probably one factor; others could be high disease pressure and low nutrient content in the fodder.

In the small-scale systems group, there is greater diversity between farms. Common to them is their urban location, their production of milk for sale and the fact that milking is done manually twice a day. Milk yields range from five to 11 litres per day/ cow. The crossbreeds used have different proportions of exotic breed, but their genetic production potential is probably higher than achieved. The feeding of roughage on the ground in relatively modern systems and traditional systems is identified as a risk factor for transmission of diseases. This includes internal parasites as well as many other pathogens.

Traditional systems remain in many rural villages, where animals are kept according to traditional practices in often well-integrated crop-livestock systems, but with very few modern technical aids. Milking is done manually twice a day and yields range from five to nine litres/day and cow. Most of the time animals are housed in walled pens while sometimes there are no walls and animals are kept tethered. Some pens provide shading roofs, especially for the calves. All animals in the main groups (post weaning) are allowed out to pasture once or twice daily, when the herds often mix. After harvest, the pastures used are fields with crop residues.

Even though there is very little control of the breeding in this system, production capacity by the cows is probably much higher than the level reported by farmers. In this system, the growth of calves is slow, leading to high ages at first calving. This is a clear loss for the owners, as heifers cost money to keep when not productive. The many reasons for low productivity in traditional systems include poor nutrition, lack of water and water hygiene, and climatic stress in combination with little protection against sun and heat. In addition very little is done to prevent disease transmission.

Animals are mostly grazed in this system. The quality of the pastures differs between seasons. During the dry season, the amount of fodder is generally limited and the quality poor in arid and semiarid areas. The energy content is probably lower than in many other fodder types. One of the effect of high ambient temperatures is that feed intake decreases. This has to be compensated by additional feeding or by grazing during less hot hours of the day or during the night. Cattle are kept in pens at night, and since little additional feeding is given, at least in the wetter season, their feed intake is probably not optimal. All farmers in traditional systems reported that additional feeding of concentrates is given, at least to lactating cows.

The poor quality of the water in the irrigation canals used as the main source of drinking water for animals, and also its restricted availability, affects the health, welfare and production of these animals. The shores of the canals were the greenest parts of the pastures, which of course increased the amount of grazing there. Where cattle graze, they also defecate leading to a high pressure of, for example, internal parasites. Fewer than half of the farmers in this system considered the water quality to be poor or a potential cause of disease while some did mention the risk of infection from grazing near irrigation canals. But the truth is they do not have much choice as to their water source.

The traditional system is not the only way for farmers to make a living in rural areas. By combining cropping with livestock production they can make money even during the dry season. Hence people depend on their animals and they obviously try to care for them as best they can. However, economic factors, location and lack of knowledge combine to limit production. Many of these problems could be mitigated by extension activities. Increased knowledge could help the farmers to develop their livestock holdings without necessarily increasing costs. Simple innovations possibly coupled with some economic investment could increase production and enable the investment to be recovered through higher income.

In the past, development projects aimed to improve productivity through large-scale dairy systems with imported high-grade cattle, but such schemes often failed (NBI Sudan report, 2008). Since the mid-nineties efforts have therefore focused on smallholder systems to promote sustainable rural development. That approach is supported by the results of a study on the small-scale dairy management systems in Abu Elkelik, where the introduction of a set of fairly simple measures has shown large potential for improvements (including increased milk production). This would contribute to meeting increasing urban demand while also improving living conditions for the farmers.

Egypt

Livestock production activities are an integral part of crop production as there are almost no independent natural pastures in Egypt. However, with the increase of agricultural mechanization, the role of animal draught power has declined and today livestock are considered to be of secondary importance as sources of farm income. The private sector (mainly small farmers) is responsible for this activity.

Livestock are raised in several production systems but are here classified into two broad categories: the mixed production system and the commercial production system. In terms of animal units, about 93 percent of the total livestock population is included in mixed (crop/livestock) production systems, thus the mixed system produces the majority of animal products.

In the mixed production system, farmers own and raise livestock and grow crops. The livestock are well integrated under the cropping system, feeding on crop residues and thus helping recycle nutrients to maintain soil fertility while also providing additional income in the form of milk and/or meat. The complementarities between crops and livestock are critical to the ecological and economic stability of mixed systems, where human populations and demand for food are increasing, while technology and inputs are not always readily available.

The dominant animals kept include buffaloes, Baladi cows, crossbred cows, purebred animals (predominantly Friesian or Holstein), sheep, goats, donkeys and poultry. Generally, farmers replaces the older stock mainly from their own young females. Animal housing may be sufficient, while herd management is not technically efficient. Animal productivity in this system is still low, while productivity of crops is satisfactory

This production system is characterized by herd sizes of two to 15 animal units, and also features poultry keeping (flocks of over 20 birds). The system is highly dependent on family labour, as in general women take care of animals and home processing of milk into traditional milk products. Animals are fed on fodder, stubble, industrial by-products and concentrates. In this system, input usage is relatively low, but with intense husbandry it can achieve medium levels of production.

In this traditional arrangement, animals are kept under a system used by Egyptian farmers over centuries. They are fed mainly on forage and crop residues produced on-farm. In the winter and spring months (October-April), farmers feed their animals mainly on multi-cut berseem plus variable quantities of concentrates/bran, wheat straw and corn silage. In the summer and autumn months (May-September), animals are fed wheat straw and concentrates/ bran and small amounts of summer green fodder (mostly darawa). Feed quality varies between seasons and is characterized by a shortage of green forage as the land is mainly occupied with the two summer crops of maize and rice. The productivity and fertility of animals responds directly to the variations in feed supply.

In parts of southern Egypt, farmers use a large proportion or their land to cultivate perennial crops such as sugar cane, wich provides three feed by-products: green tops, molasses and bagasse, all of which are commonly-used fodder. Sugar cane tops are used as fresh forage, and silage. Molasses are supplemented by urea as a source of non-protein nitrogen, minerals and vitamins and is highly recommended to farmers. Bagasse is used to a limited extent as a source of energy in feedlots, in combination with other fodders.

Milk production is the main objective of livestock raising; both fresh of processed it is either sold or used for family consumption. This system produces about 75 percent of the total domestic milk output (NBI Egypt report, 2008). Sheep and goat meat plays a minor role compared to cattle and buffaloes. Beef is produced from culled cows and fattening calves.

The Commercial Production System is also common in the Nile valley, including the Nile Delta and its desert fringes. It aims to produce milk and/or meat. Most farmers keep exotic breeds, especially Friesians and Holsteins. Such farms are managed by highly-experienced staff and often manufacture their own feedstuffs. Commercial farms represent about three percent of the total cattle and buffalo population but produce about 25 percent of the marketable milk in Egypt. Within the commercial production model there are two types of production systems, modern and peri-urban.

The main features of the modern production system are good husbandry and management, leading to highly efficient production. The farmers adopt the concepts and management procedures practiced in the source countries of these exotic breeds, for example a small number of farmers keep buffalos in highly managed systems, with good commercial returns. Dairying and beef production are also common activities. Most farmers in this production system cultivate berseem as winter green forage (available in October-May). While in summer months sorghum and green maize are available (June-October). This ensures the availability of green forage all year round. Dairy concentrates are often manufactured on-farm and are also available all year.

Annual milk yield, as an indicator for the relationship between milk production and calving intervals, is estimated at 6 680 - 10 899 kg.

In commercial feedlot farms, average daily weight gain is estimated at 1.11-1.17 kg. The corresponding value of feed conversion (kg of dry matter intake per kg body weight gain) is estimated at 9-10 kg. Feeding costs accounts for 86-87 percent of the total variable costs.

Fattening lambs and kids are common all over the country. Grains are the main ingredients in their rations. Lamb and kid fattening are profitable with economic returns of up to 37 percent. They are sometimes exported to the Gulf countries and are also fattened for special religious and social occasions.

The peri-urban production system is located in and around cities and towns to meet the high demand for milk. It is defined as a "flying herd system": intensive feeding regimes are applied to buffaloes to produce high-fat milk that is delivered directly to consumers in the cities through unofficial channels. Milk is the main product from such herds, where young animals are sold for fattening. Agro-industrial by-products available in the cities (e.g. brewery wastes, oilseed cakes, residual bread..., etc.) are the main feedstuffs together with green forage or crop residues. The dairy buffaloes are slaughtered after one or two milking season regardless of their genetic value, which represents a loss to the national buffalo herd. Sheep, goats and poultry are also raised commercially in peri-urban areas. Despite the relative economic importance of this system, little quantitative data exist about it as it is highly informal. More attention should focus on it.

Eritrea

Sesame is the second most important crop grown in the area. It is grown as a cash crop for export. Sesame is mainly cultivated by all parastatal and private farmers.

Kenya

The main challenge facing the farmers in this system is inadequate infrastructure. Many farmers in some areas have invested heavily in cash crops such as sugar cane, tea, coffee, pyrethrum and cotton. These crops require heavy application of inputs such as fertilizer and pesticides for economic returns. Although farmers get advances to buy some of these inputs from the contracted processing and marketing companies, they are often forced to sell off their inputs at a throwaway price either to buy food or meet other immediate household needs.

Poverty is rampant in this typology. Sales and marketing are done seasonally and there is a time-lag between the farmers selling their produce and getting paid. At times payments may take one year or more, forcing farmers to borrow money from farmers' cooperatives. By the time they are paid they may well have spent more than their annual sales. This leads to more borrowing from their cooperatives, fuelling a vicious cycle of poverty. The majority of farmers growing these cash crops lead a miserable life and many end up leasing their farms for very long periods in order to repay their debts.

The main areas of intervention include building the capacity of farmers in management skills. Other areas include diversification, growing other short-term crops or developing alternative sources of income, including small ruminants, to generate cash quickly.

The main opportunity is formation of marketing groups to reduce transaction costs and also to ensure farmers are part of the value chain. There are new policies and rgulations related to coffee, pyrethrum, sugar and cotton, which farmers could take advantage of to increase production and profits. There are also new market opportunities as a result of regional integration. Farmers can take up this opportunity through close collaboration with the Kenya National Federation of Agricultural Producers (KENFAP).

Tanzania

Due to the high and increasing population pressure around Mwanza town, households are under continuous pressure to intensify agricultural production. As little grazing land is left, the cattle population has declined and access to ox-ploughing has become difficult for the majority of households. Seedbed preparation is now mainly done by hoe. During the last decade, however, tomato production has increased rapidly, especially among young farmers, for whom it has become a major source of income. With Mwanza lying nearby, tomatoes can be easily transported to this large market on bicycles. ICRA (1990) reported that 75 percent of households grew tomatoes with an average area of 0.125 ha.

Tomato cropping mainly takes place on lower slopes and valley bottoms (close to shallow, hand-dug wells) during the dry season, when sufficient labour is available to irrigate the plots using buckets. Local tomato production is highly intensive, using fungicides and fertilizer or manure. For non-cattle owners, the main problem is the maintenance of soil fertility. Access to manure is becoming increasingly difficult and many non-cattle owners must buy manure to sustain the tomato production system.

Uganda

Urban and peri-urban agriculture (UPA) is practiced in the country's capital city, but also in municipalities, towns and in the countryside within easy reach of urban centres. The farmers concentrate on short-term and high-value activities, including: vegetable production, poultry and pig raising, zero-grazing of dairy cattle for milk production, plus tree nurseries/woodlots. The importance of this type of agriculture is growing in parallel to urbanisation (some 30 percent of the population is estimated to be living in urban areas).

A number of challenges have been cited by both practitioners and policy makers, including:

- Limited space (ranging from a few m^2 to about 1.5 ha) in peri-urban areas to practice UPA, hence use of gunny/plastic bags filled with soils or rice husks;

- Limited access to quality seed;
- Poor quality planting materials and livestock breeds;
- High incidences of natural calamities, pests and diseases;
- Theft;
- Lack of extension and advisory services that substantially constrain the system's output.

Some urban planners, engineers and health officers in certain municipalities are said to be against the practice of farming within municipal boundaries as it may compromise urban development. UPA is further disadvantaged as agricultural research concentrates on technologies for rural areas rather than UPA.

Urban agriculture Is currently a low-input and low-output system. The limited use of fertilizers is the main factor limiting crop yields to among the lowest in the world. Frequently, lack of adequate moisture to enhance plants' uptake of fertilizers exacerbates the problem.

Roaming livestock are a notable concern as the owners lack adequate fodder and thus leave them to scavenge. Low milk yields and lean carcass output characterize the livestock system, particularly during the dry season and in drought-prone areas due to limited pasture and the long distances covered by animals in search of water. Both indigenous and exotic breeds are affected.

Deforestation for fuel and building timber, and lack of development and/or maintenance of a "green belt" have led to widespread environmental degradation.

Annex 5: Major crops performance in traditional agriculture (1999-2003), Sudan

Table A3: Major crops performance in semi-mechanized agriculture (1999-2003) Areas ('000s ha), production ('000s t) and yields (t/ha), Sudan

	1999-2000			2000-2001			2001-2002			2002-2003		
Crop	Area (ha)	Production (t)	Yield (t/ ha)	Area (ha)	Production (t)	Yield (t/ha)	Area (ha)	Production (t)	Yield (t/ha)	Area (ha)	Production (t)	Yield (t/ha)
Sorghum	2 111 765	1 022 000	0.48	1 704 202	706 000	0.41	2 251 681	2 587 000	1.15	1 739 496	958 000	0.55
Millet	2 310 084	465 000	0.20	2 144 538	458 000	0.21	2 805 042	558 000	0.20	2 371 008	554 000	0.23
Sesame	768 908	86 000	0.11	583 193	57 000	0.10	680 672	104 000	0.15	605 042	79 000	0.13
Groundnut	1 401 261	826 000	0.59	1 352 941	742 000	0.55	1 487 395	882 000	0.59	1 381 513	769 000	0.56

Source: FAO Nile Country Report:Sudan (2008)

Annex 6: Comparison of crop yields and costs under existing and improved management in the farming systems of Ethiopia

Farming System	Crop	Yield in t/ha (under existing practices)	Cost in USD/t (under existing practices)	Yield in t/ha (under improved management)	Cost in USD/t (under improved management)
Pastoral/Agropastoral	maize	1.5	120.37	4	71.50
Forest-based	maize	1.5	120.37	4	71.50
Riverside	maize	1.5	120.37	4	71.50
	sorghum	1.5	127.31	2	143.00
	sesame	0.7	371.36	0.8	442.13
Forest-based	coffee	0.7	238.10	0.9	231.48
	maize	1.5	213.89	4	113.74
	sorghum	1.5	203.70	2	222.28
Dryland Farming	sorghum	1.5	127.31	2	149.36
	teff	0.8	363.72	1.5	231.56
	millet	1	150.46	1.5	148.07
	sesame	0.7	371.36	0.8	506.37
	cotton	0.7	416.67	1.5	289.89
Highland, temperate	teff	0.9	300.15	2	173.67
	maize	2	103.13	4	74.65
	barley	1.1	160.77	1.8	138.05
	wheat	1.3	140.85	3.1	82.18
	pulses	0.9	277.78	1.2	243.06
Highland, cold	barley	1.1	160.77	1.8	126.48

(Continued)

(Continued)						
Farming System	**Crop**	**Yield in t/ha (under existing practices)**	**Cost in USD/t (under existing practices)**	**Yield in t/ ha (under improved management)**	**Cost in USD/t (under improved management)**
Irrigation (small-scale traditional)	maize	3	181.10	4	154.69
	pepper	4	301.10	6	218.31
	tomato	15	77.84	25	45.47
	potato	13	74.23	20	49.47
	rice	2	194.50	3	131.75
	teff	1.2	385.61	1.2	393.61
	oil crops	0.7	425.93	1	353.24

Crop	Yield in t/ha (under existing practices)	Cost in USD/t (under existing practices)	Yield in t/ha (under improved management)	Cost in USD/t (under improved management)
maize	3	181.10	4	154.69
pepper	4	301.10	6	218.31
tomato	15	77.84	25	45.47
potato	13	74.23	20	49.47
rice	2	194.50	3	131.75
teff	1.2	385.61	1.2	393.61
oil crops	0.7	425.93	1	353.24

Table ** (b): Average Crop Yields for Ethiopia (from Annex 1)

crop	t/ha
maize	1.83
sorghum	1.32
millet	1.02
wheat	1.42
barley	1.14
potatoes	8.36
sweet potatoes	8.94
coffee	0.83

Source: FAOSTAT

Annex 7: The Kenana Sugar Company, Sudan

The Kenana Sugar Estate is located on the eastern bank of the White Nile, 250 km south of Khartoum. The rich alluvial soils of the Blue Nile floodplain, close to the course of the White Nile with its abundant surface water, are ideal for the cultivation of sugar cane which is grown from 40 000 ha of irrigated land. Production of sugar at Kenana increased steadily from 107 000 tonnes in 1980/81 to more than 600 000 tonnes in 2006/07 . Since 1990, in addition to supplying the domestic market, Kenana has been exporting sugar to the markets of the Middle East and Africa, providing substantial export earnings for the company.

Today the Kenana estate, linked by road, rail and air with the country's national networks, encompasses a main township complete with a mosque, a Christian church, primary and secondary schools and a modern 80-bed hospital. In addition there are a number of satellite villages with primary health-care facilities and a vocational training centre with modern equipment and teaching aids, plus a university.

The Kenana Sugar Company employs over 12 000 people, drawn from all regions of the Sudan, with a further 4 000 workers hired on a seasonal basis. Service industries for Kenana have sprung up in the immediate Rabak/Kosti area, making it one of the most prosperous in the country. Nearly 100 000 people are estimated to be dependent on the project.

Apart from sugar production, a new generation of environmentally-friendly Kenana products are being developed from timber planted on over 4 200 ha within the estate. For example Kenana charcoal has been innovatively created from a by-product of sugar production, bagasse. The company's website also notes that the estate manufactures processed dairy products and cattle feed, which has substantial export markets in the Gulf due to its high nutritional value.

Other projects in various stages of development include ethanol, floriculture, yeast, industrial alcohol and paper while research has led to the commercial production of crops such as sunflower seeds, sesame seeds, sorghum, maize and peanuts. Kenana's experience and expertise - from initial feasibility studies to the commissioning of plant -has also been assisting other sugar projects both in the Sudan other African countries.

One of the key differences appears to lie in the scheme management's ability to plan and manage both on-farm production and scheme operations. The good transport links, diversification and socioeconomic benefits also contribute to creating an environment where it is possible to attain and sustain high crop yields and avoid the various problems which hamper production in traditional systems

There are many reasons for the difference in yields of Kenana and government companies and the gap can probably never be fully closed. According to the Director of the Sugar Cane Research Centre in Gunied, which is the research station for all of the government companies, the reasons are not due to better soils or climate. The main differences are:

- Kenana has a better irrigation system and field layout because it was the last sugar company developed in the Sudan and its design benefits from experience acquired in the earlier projects
- Kenana's equipment is newer and also better because design improvements were made between the time the equipment in the first factory was installed and the time when Kenana's factory equipment was completed. This allows higher yields because, for example, better harvesters have lower cane losses which increase yields per hectare
- Kenana benefits from being operated as a single private company because it can implement technological improvements more rapidly than can the four government companies. It also has more capital to implement technological improvements without needing authorization from government authorities
- Kenana exports to world markets and gains from the contact with other companies and sugar industry professionals
- Kenana's larger size gives it better economies of scale, which improves performance in many areas including research, where it has 20 cane researchers compared to seven for the government's research centre
- Kenana has better factory performance according to several commonly used metrics, which further contributes to its lower costs compared to the government companies. A commonly used measure of factory performance is the tonnes of cane required to produce a tonne of sugar (TC/TS ratio). Kenana required 9.4 tonnes of cane to produce a tonne of sugar in 2000-05 compared to 10.6 for the government factories. While there could be many contributing factors for this difference, the main ones include the quality of factory equipment, management, cane quality, harvesting and transport.