Water Use for Agriculture in Priority Rivers Basins

CONTENTS

1 IWMI PROJECTIONS FOR AFRICA SOUTH OF THE SAHARA

Using the IWMI base scenario (Molden 2000) described in the Section 1 (see under 2.2 Water supply and demand), the regional projections for Africa south of the Sahara are presented here, followed by an assessment of the various river basins in the region. Projections for individual countries within the river basins are also given.

Table 1.1 IWMI projections for Africa south of the Sahara

Factor	**Units**	**1995 value**	**2025 projection**	**Annual growth 1995–2025** (%)
Population	million	583	989	2.1
Cereal demand	m mt	87	178	2.4
Cereal production				
- Total	m mt	79	150	2.1
- Irrigated	m mt	8	16	2.4
- Rain-fed	m mt	71	134	2.1
Growth in total irrigated area	m ha	9	14	1.3
Primary water supply	km^3	51	74	1.2
PWS, % of PUWR	%	2	4	
Water diversion				
- Total	km^3	66.9	103.2	1.5
- Irrigation	km^3	56.4	76.8	1.0
- Domestic	km^3	7.3	18.3	3.1
- Industrial	km^3	3.3	8.1	3.1
Water-scarcity level	Economic water scarcity (Total PWS <60% of PUWR, but total growth in PWS >25%			

Source: Molden 2000
PUWR = Potential utilizable water resource
m mt = million metric tonnes
m ha = million hectares

The major conclusions of IWMI for Africa are:

- The cereal production deficit will widen from 9 per cent of total demand in 1995 to 15 per cent of total demand in 2025
- The African region still contains substantial renewable water resources not yet developed for human use. Even if the projected increase of 45 per cent in primary water supply is realized, this will mean that just 4 per cent of PUWR is used. The main problem in Africa will be to secure the financial and human resources required to develop the water resources. The major exception will be the Republic of South Africa, which will have to develop 62 per cent of its PUWR by 2025 to meet projected water requirements
- Irrigation is a small contributor to total food needs. There is scope for expanding irrigation, but much effort is required in designing sustainable irrigation practices suited to African conditions.

Important issues for the region are:

- Most countries in the region can be categorized into the high potential/high need areas. Only the Republic of South Africa will experience physical water scarcity. It has to be kept in mind though, that IWMI data concern a country as a whole and that regional, in-country differences exist.
- Despite low productivity, rain-fed agriculture will be the major contributor to total cereal production (>75%).
- There is scope for productivity improvements through supplemental irrigation in marginal rain-fed land.
- Innovative smallholder water and land management systems may offer solutions for poor smallholder farmers, especially if the institutional arrangements for land/water rights are adequately understood.
- Groundwater development opportunities.
- Concerns for environment and human health.

2 THE NIGER RIVER BASIN

2.1 Introduction

The Niger River Basin, located in western Africa, covers 7.5 per cent of the continent and spreads over ten countries (see Figure 2.2 and Table 2.1).

Table 2.1 Niger River Basin, areas and rainfall by country

Country	Total area of the country (km^2)	Area of the country within the basin (km^2)	As % of total area of basin (%)	As % of total area of country (%)	Average annual rainfall in the basin area (mm)		
					min	max	mean
Guinea	245,857	96,880	4.3	39.4	1,240	2,180	1,635
Côte d'Ivoire	322,462	23,770	1.0	7.4	1,315	1,615	1,465
Mali	1,240,190	578,850	25.5	46.7	45	1,500	440
Burkina Faso	274,000	76,621	3.4	28.0	370	1,280	655
Algeria	2,381,740	193,449	8.5	8.1	0	140	20
Benin	112,620	46,384	2.0	41.2	735	1,255	1,055
Niger	1,267,000	564,211	24.8	44.5	0	880	280
Chad	1,284,000	20,339	0.9	1.6	865	1,195	975
Cameroon	475,440	89,249	3.9	18.8	830	2,365	1,330
Nigeria	923,770	584,193	25.7	63.2	535	2,845	1,185
For Niger Basin		2,273,946	100.0		0	2,845	690

Source: FAO 1995

Algeria and Chad together cover about 9 per cent of the total Niger River Basin, but there are almost no renewable water resources in these areas.

The area of the Niger River Basin in Guinea is only 4 per cent of the total area of the basin, but the sources of the Niger River are located in this country. The quantity of water entering Mali from Guinea ($40km^3/yr$) is greater than the quantity of water entering Nigeria from Niger ($36km^3/yr$), about 1,800km further downstream. This is due, among other reasons, to the enormous reduction in runoff in the inner delta in Mali through seepage and evaporation, combined with almost no runoff from the whole of the left bank in Mali and Niger.

Mali, Niger and Nigeria contain the largest surface areas of the Niger Basin (25% in each of these three countries). Mali and Niger are almost entirely dependent on the Niger River for their water resources. In the case of Niger, nearly 90 per cent of its total water resources originate outside its borders (the Niger River and tributaries from Burkina Faso and Benin).

2.1.1 Rivers and discharges

The Niger River, some 4,100km long, is the third-longest river in Africa, after the Nile and the Congo/Zaire Rivers, and the longest and largest river in West Africa.

The upper Niger River system

The source of the Niger River farthest away from the mouth lies in the mountains of Guinea near the border with Sierra Leone. Together with several tributaries, it traverses the interior plateau of Guinea flowing north-east towards the border with Mali. Just after the border it is joined by another tributary which also originates in Guinea. The total annual flow entering Mali from Guinea is estimated at 40 km^3.

The river then flows north-east towards the inner delta in Mali, where it is joined at Mopti by an important tributary, the 1,100-km long Bani River, the sources of which are in Côte d'Ivoire and Burkina Faso.

The inner delta

The total area of the inner delta – a network of tributaries, channels, swamps and lakes – can extend to some 30,000km^2 in the flood season. The swampy nature of the delta, with its sandy soils, means that the river loses nearly two-thirds of its potential flow between Ségou (900km from its source) and Timbuktu (1,500km) due to seepage and evaporation, the latter being aggravated by the fact that the river here touches the southern flanks of the Sahara desert. All the water from the Bani tributary, which flows into the Niger River at Mopti (1,150km from source), does not compensate for the losses in the inner delta, as the total flow further downstream still decreases rather than increases (Figure 2.1). The average loss is estimated at 31km^3/year, but varies considerably according to the years: it was 46km^3 during the wet year of 1969 and about 17km^3 during the dry year of 1973.

The middle Niger River system

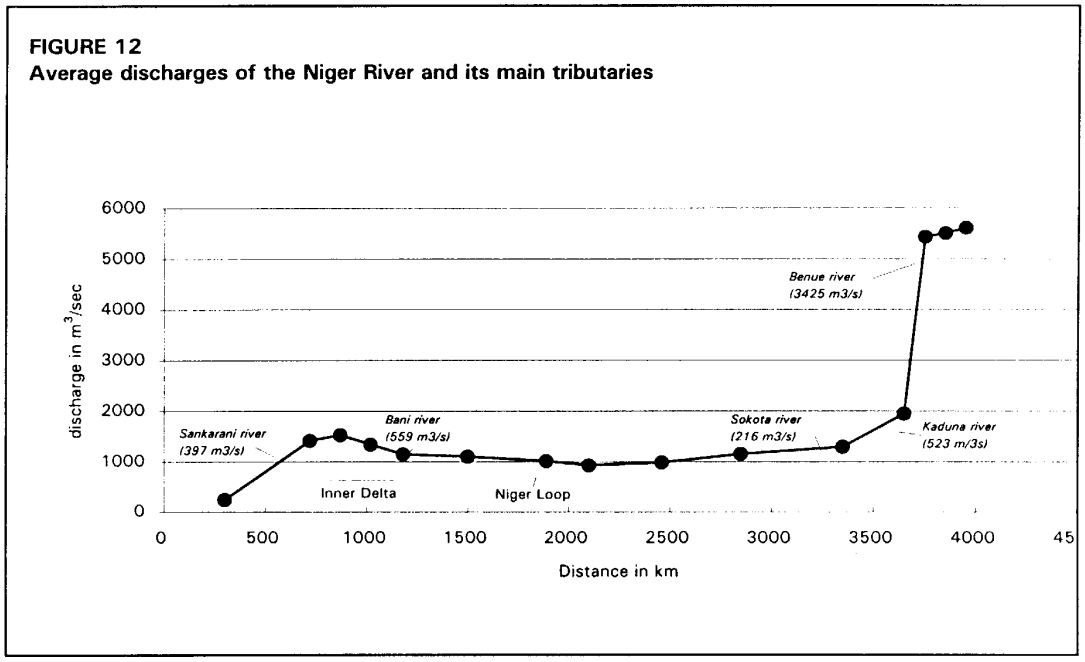
From the inner delta the river continues to flow north-eastwards before turning south-east to form a great bend, the Niger Loop. After meandering through arid areas it enters Niger. In the Niger Loop another 4km^3/year of water disappears between Diré and Ansongo. As in the inner delta, these losses are mainly caused by evaporation, but they are much reduced because of the smaller area inundated during and after the floods. Losses from infiltration are limited.

Within Niger, the river receives water from six tributaries originating in Burkina Faso (the Gouroual, Dargol, Sirba, Gouroubi, Diamangou, and Tapoa). The total annual discharge leaving Burkina Faso is estimated at about 1.4 km^3.

Further downstream the river becomes the border between Niger and Benin, from where three main tributaries enter the river (the Mekrou, Alibori, and Sota) with a total annual discharge of around 3km^3.

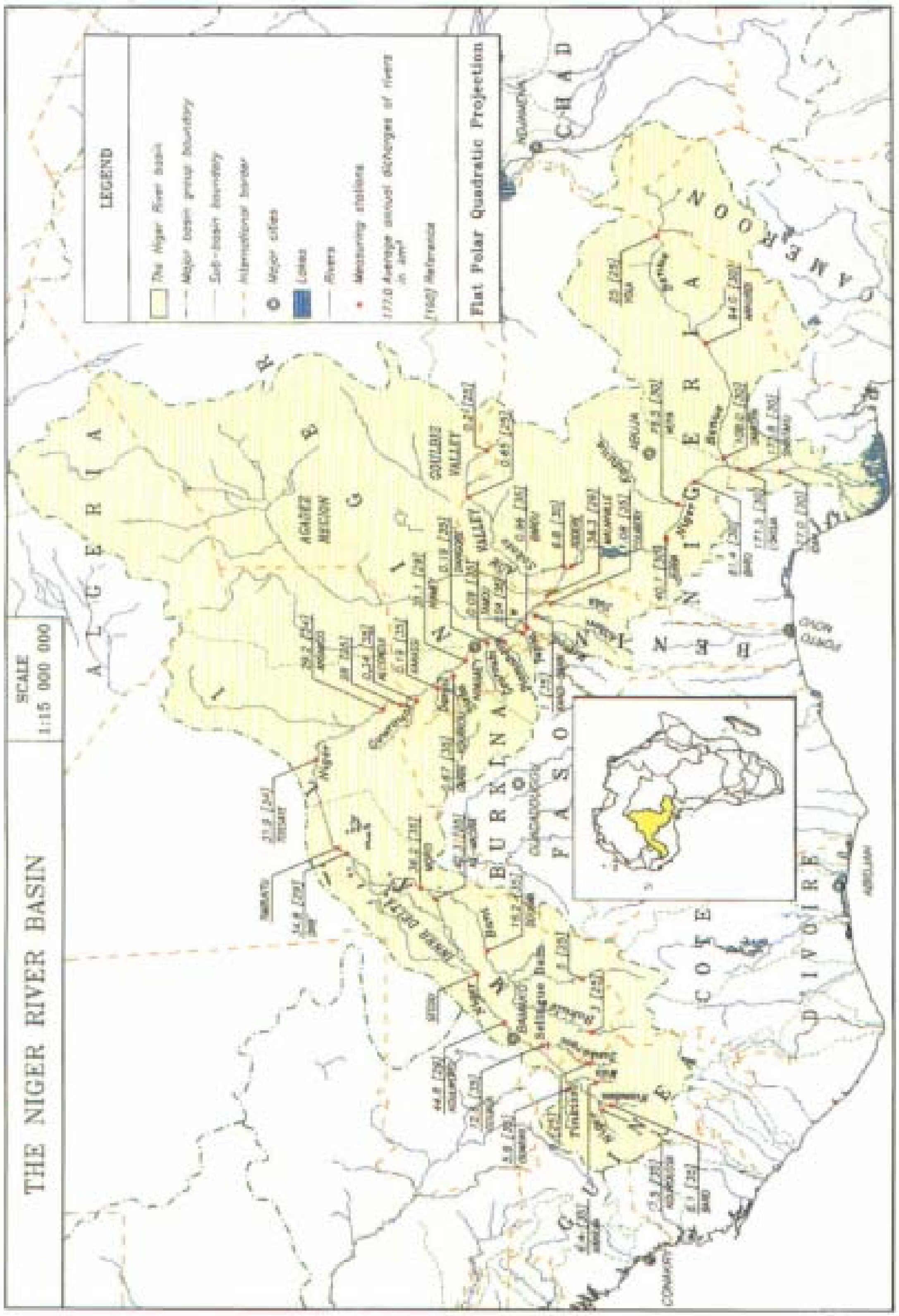
At Gaya in Niger or Malanville in Benin, just upstream from the border with Nigeria, the average annual discharge has been estimated at about 36km^3, but only about 18km^3 was measured in 1986.

Figure 2.1 Average discharges of the Niger River and its main tributaries



Source: FAO 1995

Figure 2.2 The Niger River Basin (source: FAO 1997)



The lower Niger River system

Leaving the border between Niger and Benin, the river enters Nigeria, where it is joined by numerous tributaries. The most important is the Benue which merges with the river at Lokoja in Nigeria. The Benue itself rises in Chad, although there are almost no surface water resources in its uppermost part. In Cameroon it receives water from several tributaries. The slope in Cameroon is considerable and the discharge there has important seasonal variations. The quantity of water entering Nigeria was estimated at 25km^3/year before the 1980s and at 13.5km^3/year during the 1980s. In Nigeria itself, the Benue is joined by several tributaries, of which the ones on its left bank originate mainly in Cameroon. The Benue reaches its flood level in September, begins to fall in October and falls rapidly in November, continuing slowly over the next three months to reach its lowest level in March and April. From the confluence with the Benue, the Niger heads southwards and empties into the Gulf of Guinea through a network of outlets that constitute its maritime delta.

2.1.2 Irrigation potential and water requirements

Rainfall and hydrological conditions in **Guinea** make it possible to exploit – with good chances of success for an annual rain-fed crop – the alluvial plains of the Niger River and its tributaries. However, to be able to grow crops all year round, irrigation is necessary. The irrigation potential in this region is estimated at 185,000ha, of which 100,000ha would be relatively easy to develop, though dams would need to be built to store water. To date, only about 6,000ha of rice are irrigated.

The irrigation potential for the whole of **Côte d'Ivoire** has been evaluated at 475,000ha, though without details of location. It is estimated that of this figure, 50,000ha are located in the Niger Basin.

In **Mali** there are four climate zones in the basin area and rainfall ranges from 1,500mm in the south to less than 50mm in the north.

The water in the Niger River is partially regulated through dams. The Sélingué dam on the Sankarani River is mainly used for hydropower, but also permits the irrigation of about 60,000ha under double-cropping. Two diversion dams, one at Sotuba downstream of Bamako, and one at Markala downstream of Ségou, are used to irrigate the area of the 'Office du Niger', which covers about 54,000ha. However, double-cropping in this area would only be possible if the Fomi Dam, planned on the Niandan River in Guinea, were constructed to provide a supplementary and regular amount of water. The effects on the environment that would be caused by the construction of this dam seem to be acceptable (Ramsar 2000)

Several irrigation projects have been identified, relating in particular to the construction of the Talo dam on the Bani River and the dam at Tossaye on the Niger River. However, the drying up of several watercourses during the low-flow period in the dry years 1983–1985 requires a careful re-examination of these projects, with recent hydrological figures being taken into consideration. If the Bani had an ample supply, sufficient water to meet the needs of downstream farmers could be released during the dry season. However, as the Talo dam is proposed precisely because of the Bani's dwindling water supply, the proposed dam is unlikely to help at the height of the dry season. Although the African Development Bank states that only 6 per cent of the Bani River will be diverted annually for irrigation in the target area, a hydrological analysis by Cultural Survival, a US-based NGO, found that up to 20 per cent of the river will be diverted while the reservoir is filling during the rainy season.

In Mali, irrigation potential has been estimated at 556,000ha. At present, about 187,000ha are equipped for irrigation in the Niger Basin. However, of this 57,000ha are already abandoned and of the remaining 130,000ha actually irrigated, more than 60 per cent needs to be rehabilitated.

In **Burkina Faso** most of the area under irrigation is located outside the Niger Basin. About 850ha of the basin are irrigated, while the potential is estimated at about 5,000ha.

In **Benin** the irrigation potential has been evaluated at 300,000ha for the whole country, of which an estimated 100,000ha are in the Niger Basin. The actual equipped area here is 1,090ha, of which 740ha are cultivated.

The Niger River crosses the south-western part of **Niger** over a distance of about 550km, with the final 150km forming the border between Niger and Benin. There are no important tributaries in Niger, but there are two fossil valleys, the Dallols, where there is no permanent flow but where the water resources are quite important. Three other zones are considered as being part of the Niger Basin: the Ader-Doutchi-Maggia valley, the Goulbis valley and the Agadez region. They are in fact valleys or depressions situated at a considerable distance from the Niger River, with no streams reaching the river:

The total irrigation potential of Niger has been estimated at 222,000ha, of which 140,000ha lie in the Niger River valley, with the remaining 82,000ha spread over the other zones. At present, about 54,000ha benefit from irrigation, of which 16,000ha are in the Niger River valley. Irrigation of the 140,000ha in the river valley and its tributaries on the right bank would only be possible through construction of the Kandadji Dam to the north, downstream of the border with Mali. The volume of the resulting reservoir would be in the order of 1.6km^3. Without this dam it would be possible to irrigate only 15,000ha. For further information see section 2.4.2 on irrigation development in Niger.

The irrigation potential in the Niger Basin for **Cameroon** has been estimated at 20,000ha. The Lagdo dam on the Benue River, built primarily for hydroelectricity, regulates the flow of the river and could also be used for irrigation purposes.

Irrigation in **Nigeria** can be divided into three categories:

- public irrigation schemes, which are government-run schemes
- farmer-owned and operated irrigation projects (improved floodplains, termed *fadama*)
- residual *fadama*.

About 275,000ha of public schemes are planned under the existing water infrastructure, but only 40,540ha have been completed and irrigated. As far as the *fadama* is concerned, crop production has depended traditionally on rainfall in the wet season and on residual moisture after flood recession in the dry season. In areas with easily accessible shallow groundwater or surface water, water-lifting devices help to get water onto the land. The existing forma1 *fadama* area has been evaluated to cover some 79,000ha, with a further 550,000ha of residual *fadama* cultivation in the Niger Basin.

Estimating irrigation potential is rather difficult, despite the considerable data available on surface water resources, because of the potential of large areas to be irrigated either by surface

water or shallow *fadama* aquifers, two sources that are hydraulically connected. Table 2.2 shows the irrigation potential as identified in the country's National Water Resources Master Plan.

Table 2.2 Irrigation potential in the Niger River Basin in Nigeria

Region in Niger River Basin	Potential of public schemes (ha)	Potential of *fadama* development (ha)	Total irrigation potential (ha)
Niger North	146,590	299,000	445,590
Niger Central	183,140	34,000	217,140
Upper Benue	435,430	320,000	755,430
Lower Benue	61,230	140,000	201,230
Niger South	59,120	0	59,120
Total	**885,510**	**793,000**	**1,678,510**

Source: FAO 1995

Table 2.3 summarizes the irrigation potential of the Niger Basin, per country and for the basin as a whole.

Table 2.3 Niger River Basin: irrigation potential, water requirements and availability, and irrigated areas

Countries with areas within the Niger Basin	Irrigation potential	Gross irrigation water requirement		Actual flows		Flows after deduction for irrigation and losses		Area already under irrigation
	(ha)	per ha (m^3/ha/year)	Total (km^3/yr)	Inflow (km^3/yr)	Outflow (km^3/yr)	Inflow (km^3/yr)	Outflow (km^3/yr)	(ha)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Guinea	185,000	23,500	4.35	0.00	40.40	0.00	36.05	6,000
Côte d'Ivoire	50,000	23,500	1.18	0.00	5.00	0.00	3.83	0
Mali	556,000	40,000	22.24	45.40	29.20	39.88	6.96	187,500
Burkina Faso	5,000	7,000	0.04	0.00	1.40	0.00	1.37	850
Benin	100,000	18,500	1.85	0.00	3.10	0.00	1.25	740
Niger	222,000	37,000	8.21	33.70	36.30	9.58	3.96	57,520
Cameroon	20,000	18,500	0.37	0.00	13.50	0.00	13.13	2,000
Nigeria	1,678,510	10,000	16.79	49.80	177.00	17.09	670000	1,678,510
Sum of countries	2,816,510		55.02			Rest to sea		924,610
Total for Niger Basin	≤2 816 510							

Source: FAO 1995

Notes:

For the sake of simplicity, the study has assumed that where a certain quantity of water is abstracted upstream, this same quantity is subtracted from the resource downstream, except in cases where more information was available.

Mali:

(4) Equal to the sum of the water entering from Guinea (40.40) and Côte d'Ivoire (5.00).

(5) Equal to the water leaving Mali, which is less than the water entering, among others, due to losses in the inner delta.

(6) Equal to the water entering (45.40) minus potential water requirement in Guinea (4.35) and Côte d'Ivoire (1.18).

(7) Equal to the water leaving the country (29.20) minus potential water requirement in Mali (22.24). Potential requirements in Guinea and Côte d'Ivoire are not included, because it is supposed that it is included in the 'losses' in the inner delta. For this reason, part of the 22.24km^3 also should not be included.

Niger:
(4)&(5) Outflow (36.30) minus inflow from Mali (29.20), Burkina Faso (1.40) and Benin 3.10 is equal to 2.6km^3, which is less than the potential water requirement (8.21). In fact, Niger needs more water than 'produced' within the country.
(7) Equal to the water leaving the country (36.30) minus potential water requirements in Mali (22.24), Burkina Faso (0.04), Benin (1.85) and Niger (8.21).

Nigeria:
(4) Equal to inflow from Niger (36.30) plus inflow from Cameroon (13.50).

The countries with the largest water requirements are Mali, Niger and Nigeria. Water problems may arise in the Niger Basin if the entire potential is developed. The effect of water abstraction upstream of the inner delta on the quantities that disappear within the inner delta has not been studied.

In Nigeria, of the 177km^3 which flows to the sea each year, 36km^3/year enter from Niger and 25km^3/year from Cameroon. The rest is 'produced' internally. More than 1 million ha of its irrigation potential of nearly 1.7 million ha is located in the basin of the Benue tributary.

Throughout the entire basin, water storage works for the development of irrigation are necessary. Navigation and hydropower problems are likely to arise if more water is abstracted for agricultural purposes.

2.2 Ecoregions in the Niger River Basin

Three of WWF's Global 200 Ecoregions are located in the Niger River Basin: Guinean Moist Forests; Sudd-Sahelian Flooded Grassland and Savannas; and the Niger River Delta.

Guinean Moist Forests
Along with the far larger and more intact Congolese rainforests, the moist forests that lie along coastal West Africa from Guinea through Sierra Leone, Liberia, Côte d'Ivoire, and Ghana, with pockets in Togo and Benin, form the most species-rich habitats in West Africa. Separated from the Central African forests to the east by the Dahomey Gap in Togo, Benin, and eastern Ghana, where savannas and woodlands extend to the coast, the two blocks of forest have evolved plant and animal species that are highly distinctive within the Afrotropical region. Many species have restricted ranges within the forests of this region.

General threats: Lowland rainforest in West Africa has been severely reduced by logging, clearing for agriculture, and mining activities. Intensive hunting has significantly reduced wildlife populations.

Sudd-Sahelian Flooded Grasslands and Savannahs
A series of disjunct seasonally flooded grassland areas – including wetlands associated with Lake Chad – and perennial swamps comprise this ecoregion which covers parts of Cameroon, Chad, Ethiopia, Mali, Niger, Nigeria, Sudan, and Uganda. It supports large populations of mammals, including areas that witness seasonal migrations of mammals as water levels change.

General threats: The rich biodiversity of the western blocks, including both the Lake Chad and Inner Niger delta flooded savannas, is threatened by large-scale plans to divert water for agricultural and industrial uses.

Niger River Delta

The Niger River delta, the point at which Africa's third-largest river flows into the Gulf of Guinea, extends over 50,000km^2. One of the largest deltas in the world, it is considered a biogeographical crossroads between the Nilo-Sudan and Guinea-Congo ichthyo-faunal areas. The Niger's relatively nutrient-rich, silt-laden white waters converge with the black and clear waters of its numerous tributaries to form an ecosystem that supports nearly 200 species of fish. These include several endemic or near-endemic fish families, including *Denticipidae* and *Phractolaemidae*. The delta provides habitat for hippopotamus (*Hippopotamus amphibius*), the vulnerable pygmy hippo (*Choeropsis liberiensis*), and West African manatee (*Trichechus senegalensis*).

General threats: The delta is highly threatened by oil pollution. Other threats include population growth and attendant coastal urbanization, oil and gas exploration and exploitation, industrialization, domestic and industrial waste discharges, the menace of introduced water hyacinth (*Eichhornia crassipes*), coastal erosion, and problems associated with aquaculture.

2.3 Mali

Mali covers a surface area of 1.24 million km^2, of which 43.7 million ha, 35 per cent of the total area, is suitable for agriculture. At present only 2.6 million ha (6 per cent of the cultivable area) is in use.

The agricultural sector contributes 57 per cent of GNP, engages 83 per cent of the active population, and provides 75 per cent of the country's export earnings.

2.3.1 Climate and water resources

Mali's weather is marked by a dry and a wet season. The dry season lasts five months in the south of the country and nine months in the north, and starts around September/October. Average rainfall in the south is 1,400mm decreasing to less than 100mm in the north. Rainfall distribution is very irregular and shows large inter-annual fluctuations.

Table 2.4 Water demand forecast for Mali

IWMI Characteristics	**Units**	**1995**	**2025**	**Annual growth** (%)
Population	million	9.9	20.5	2.4
Total cereal consumption	m mt	2.2	5.4	3.0
Cereal production	m mt	2.2	6.0	3.5
Irrigated cereal area	m ha	0.12	0.16	1.0
Rain-fed cereal area	m ha	2.75	4.32	1.5
Total cereal area	m ha	2.87	4.48	1.5
Net irrigated area	m ha	0.1	0.1	1.0
Gross irrigated area	m ha	0.2	0.2	1.0
Primary irrigation supply	km^3	0.9	1.2	29
Total water withdrawals	km^3	1.18	1.56	0.9
Total primary water supply	km^3	1.0	1.3	Total growth
Total PWS as % of PUWR	%	1.3	1.7	35%
Scarcity level	Economic			

Source: Molden 2000
m mt = million metric tons
m ha = million hectares

2.3.2 Irrigation development

In Mali irrigation development is restricted to areas where water can be made available, although a much larger area is topographically suitable for irrigation development. Thus, only 560,000ha – 1 per cent of the total cultivable area – have the potential to be developed for irrigation. In 1994, 191,469ha were equipped for one form of irrigation or another; however, it was estimated that 50,000ha were abandoned, reducing the total irrigated area to less than 130,000ha, or 23 per cent of the potential irrigated area.

Large irrigation systems (>100ha) make up 80 per cent of the area laid out for irrigation. Taking double-cropping practices into account, the total irrigated area amounted to approximately 274,000ha in 1987. Rice occupies 70 per cent of the irrigated areas, followed by sorghum on flood recession areas.

2.3.3 Agriculture

Traditional food crops of sorghum and millet, as well as the main cash crop, cotton, are grown under rain-fed conditions. Crops grown under irrigation are rice, sugarcane, wheat, and vegetables (see also Table 2.8).

Table 2.5 Irrigation data for Mali

Irrigation potential		2000	**560,000ha**
Irrigation			
1 Area equipped for irrigation		1994	78,620ha
- surface irrigation		1994	78,520ha
- sprinkler irrigation		1989	100ha
- micro-irrigation		1989	0ha
% of area irrigated from groundwater		1989	2.6%
% of area irrigated from surface water		1989	97.4%
% of equipped area actually irrigated		1989	-
2 Spate irrigation			-
3 Equipped wetland and inland valley bottoms			-
4 Other cultivated wetland and inland valley bottoms		1989	3,826ha
5 Flood recession cropping areas		1989	109,023ha
Total water managed area (1+2+3+4+5)		1994	191,469ha
- as % of cultivated area		1989	7.4%
- increase over the last 10 years		1989	-
- power irrigated area as % of water-managed area			4.9%
Full or partial control schemes	Criteria		
Large schemes	>100 ha	1994	63,119ha
Medium schemes			
Small schemes	<100 ha	1994	15,501ha
Total number of households in irrigation			-
Irrigated crops			
Total irrigated grain production		2000	748,713T
As % of total grain production		2000	32%
Harvested crops under irrigation		2000	299,700ha
- rice		2000	213,000ha
- sorghum in flood recession areas		1987	73,700ha
- sugarcane		2000	4,000ha
- wheat		2000	4,000ha
- other		2000	5,000ha

Source: FAO 1997b, FAOSTAT 2000

Table 2.6 Irrigated area per river basin in Mali

River Basin	Bagoe	Bani	Baoule	Fawara	Kankelaba	Ngora Laka	Niger	Senegal	Mali
Irrigated Area (ha)	2,256	2,308	2,152	874	298	1,270	181,490	822	191,469

Source: FAO 1995

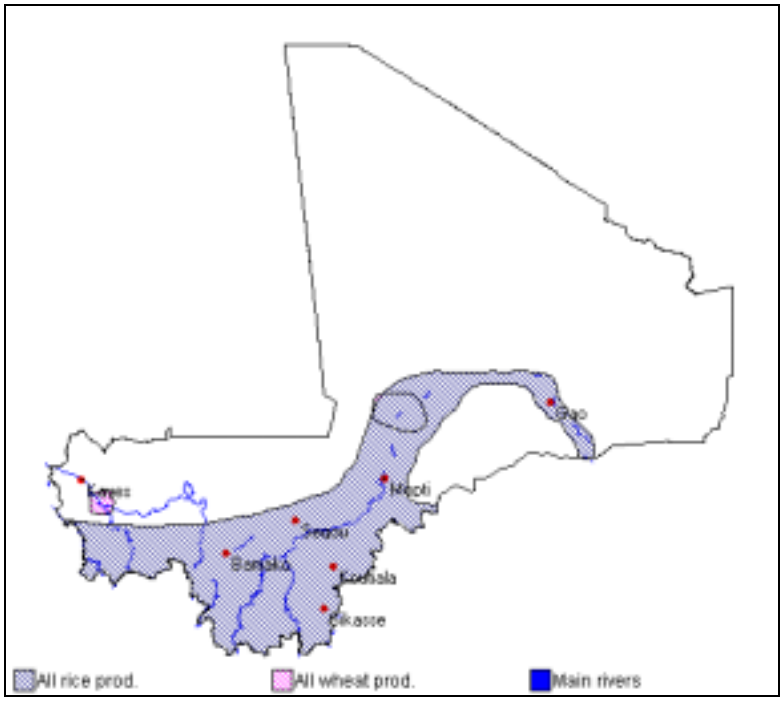
Rice

FAO and Riceweb statistics indicate that the average production of rice in Mali is around 425,000 tonnes per year from about 245,000ha. The average yield is about 1,600kg/ha.

Rice is grown in a variety of ecosystems in Mali: rain-fed upland, rain-fed lowland, irrigated lowland, and flood prone areas with no or only partial water control. In the southernmost region, where rainfall is most abundant, most of the rice is produced in rain-fed lowlands (8% of national rice area) in the form of seasonally flooded valley bottoms and river floodplains. The remainder is grown in irrigated lowlands (4%), which implies land development providing varying degrees of partial water control (e.g. bunding, derivation irrigation), with small amounts reportedly grown in the uplands.

The other principal production zone is along the Niger River, including the inland delta. Much of the rice area is defined by the annual flooding of the river. In this zone, rice is grown in deep-water, shallow flooded, or flood recession environments, depending on the depth of flooding. These flooded ecosystems, which have no water control structures, account on average for over half (56%) of the national area under rice, although the actual figure in any given year varies enormously depending on the quality of flooding, both in terms of extent and timing. Some production also occurs in large-scale public polders which provide partial control of flooding (12% of area). The remainder is grown in irrigation schemes, both large-scale public schemes (19% of national area) and pump-irrigated small-scale village perimeters (2%), located along the river.

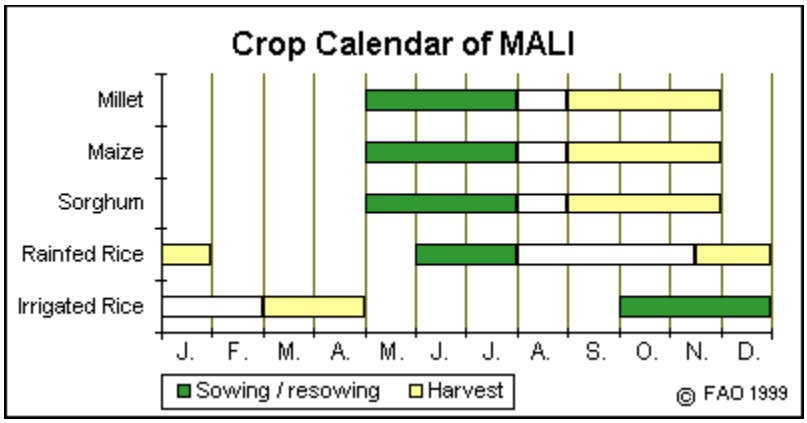
Figure 2.3 Rice and wheat cultivation areas in Mali



Source: FAO GIEWS

Figure 2.3 shows the location of the major rice production zones in Mali: Kayes (3.9%), Koulikoro (4.7%), Sikasso (10.8%), Ségou (7.0%), Mopti (59.2%), Timbuktu (7.8%), and Gao (6.5%).

Figure 2.4 Mali crop calendar



Source: FAO GIEWS

CROPWAT, a decision support system developed by the Land and Water Development Division of FAO, has been used to calculate crop water requirements for different crops in a number of locations during both the wet and dry seasons.

Rice is grown along the entire Niger River, with the major area in the inland delta. Sugar is grown in the south of the country, where rainfall conditions are more favourable. Wheat is a typical dry-

season crop, as lower temperatures are required for a successful harvest. Since no rainfall occurs during the dry season, irrigation requirements are more or less the same for the entire country.

Table 2.7 Water requirements for major irrigated crops in Mali

Crop	**Location**	**(Trans)planting date**	**Total cultivation requirements** (mm)	**Irrigation requirements** (mm)
Rice	Bamako	1/7	917	376
	Gao	1/7	1,359	1,150
	Mopti	1/7	1,006	650
	Ségou	1/7	1,015	570
	Timbuktu	31/7	1,313	1,168
	Bamako	15/11	126	1,120
	Gao	15/11	1,206	1,205
	Mopti	15/11	1,067	1,066
	Ségou	15/11	1,184	1,180
	Timbuktu	15/11	1,258	1,257
Sugarcane	Sikasso	15/6	2,151	1,524
Wheat	Timbuktu	15/12	836	836
Vegetables	Bamako	1/12	589	589
Groundnut	Bamako	1/7	552	183

Source: FAO CROPWAT

Table 2.8 Irrigated crop area in Mali

Irrigated area (1,000 ha)		**Crop area as % of the total area equipped for irrigation, by month**											
		J	F	M	A	M	J	J	A	S	O	N	D
Wheat	4	2	2	2	2	2						2	2
Rice	213												
Rice-one		56	56	56								56	56
Rice-two							56	56	56	56	56		
Millet	12						6	6	6	6	6		
Sorghum	12						6	6	6	6	6		
Sugarcane	4	2	2	2	2	2	2	2	2	2	2	2	2
Vegetables	3	2	2	2								2	2
Groundnut	2	1	1	1								1	1
All irrigated crops	250	63	63	63	4	4	70	70	70	70	70	63	63
Equipped for irrigation	191												
Cropping intensity	131												

Source: FAO AQUASTAT

Table 2.9 Agricultural water withdrawal in Mali

Total renewable water resources (TRWR)	100km^3
Irrigation water requirements	2.06km^3
Water use efficiency percentages	30%
Water withdrawal for agriculture	6.87km^3
Water withdrawal as % of TRWR	7%

Source: FAO AQUASTAT

Table 2.10 Water requirement per crop in Mali

Crop	Location	Season	Area (ha)	CWR (mm/ha)	Efficiency (%)	Total crop (million m^3)
Rice	north	wet	1,500	1,100	30	55.0
	centre	wet	9,200	600	30	184.0
	north	wet/dry	9,950	1,100	30	392.0
Wheat	north	dry	4,000	840	30	112.0
Sugarcane	south	wet/dry	4,000	1,500	30	200.0
Groundnut	south	wet	2,000	200	30	13.3
Vegetables	south	dry	3,000	590	30	59.0
					Total	**1,182.3**

Table 2.10 shows that rice cultivation is the major water consumer in irrigated agriculture in Mali. If climatic conditions were to permit the replacement of the dry-season rice crop with wheat, the water savings would be in the order of 30 per cent, or 93 million m^3 of water.

2.4 Niger

Niger covers 1,267,000km^2, of which around 15 million ha (some 12%) are suitable for agriculture. The area under cultivation is 3.8 million ha, or 3 per cent of the total area and 25 per cent of the total cultivable area.

In 1998, the agricultural sector accounted for 38 per cent of GNP and provided employment for 85 per cent of the active population. The share of agricultural products in export earnings dropped from about 90 per cent in the 1960s to about 15 per cent in the 1990s.

2.4.1 Climate and water resources

Average annual rainfall is about 180mm/year, but varies from zero in the north to 800mm/year in the south-west. In the Sudan-Sahelian zone, average rainfall is 300mm/year. The rainy season is from June to September, with generally no rainfall in the other months.

Table 2.11 Water demand forecast for Niger

IWMI Characteristics	Units	1995	2025	Annual growth (%)
Population	million	9.2	21.2	0.3
Total cereal consumption	m mt	2.5	6.9	3.4
Cereal production	m mt	2.3	5.6	3.0
Irrigated cereal area	m ha	0.03	0.05	2.1
Rain-fed cereal area	m ha	6.94	10.83	1.5
Total cereal area	m ha	6.97	10.89	1.5
Net irrigated area	m ha	0.1	0.1	1.5
Gross irrigated area	m ha	0.1	0.1	2.1
Primary irrigation supply	km^3	0.6	1.1	73
Total water withdrawals	km^3	0.99	1.96	2.3
Total primary water supply	km^3	0.7	1.3	
Total PWS as % of PUWR	%	2.4	4.6	90
Scarcity level	Economic			

Source: Molden 2000
m mt = million metric tons
m ha = million hectares

2.4.2 Irrigation development

Agricultural activities are concentrated in the south of the country in a 200-km wide strip along the border with Nigeria. Cereals occupy 80 per cent of the total area under cultivation.

Total irrigation potential is estimated at 270,000ha, of which 140,000ha are located in the valley of the Niger River. The areas equipped for irrigation cover 78,000ha, or 2.1 per cent of the total cultivated area. Full irrigation control is only present on 12,000ha and these areas are cultivated by cooperatives supported by the 'Office National d'Aménagements Hydro-Agricoles' (ONAHA). The main crops are rice, cotton, and wheat.

The area under traditional irrigation (partial irrigation) is estimated at 55,000ha, while 11,000ha are subject to uncontrolled flooding.

Development of water resources management

The majority of farmers consider irrigation as a means to diversify their agricultural activities rather than a way of substantially increasing yields per hectare. If rainfall is satisfactory, farmers tend to let irrigated plots lay idle and concentrate activities on rain-fed land. Other constraints to the expansion of sustainable irrigation are a general lack of participation by farmers in the development and design of irrigation schemes, cost and the availability of technical assistance.

High investment costs make the full irrigation option an expensive alternative to rain-fed food crop production, particularly since there is still potential to increase yields under rain-fed agriculture. Soil and water conservation measures provide interesting possibilities to take better advantage of precipitation, and are less expensive than full irrigation schemes.

Table 2.12 Irrigation data for Niger

Irrigation potential	1990	270,000ha
Irrigation		
1 Area equipped for irrigation	1989	66,480ha
- surface irrigation		-
- sprinkler irrigation		-
- micro-irrigation		-
% of area irrigated from groundwater		-
% of area irrigated from surface water		-
% of equipped area actually irrigated		-
2 Spate irrigation		-
3 Equipped wetland and inland valley bottoms		-
4 Other cultivated wetland and inland valley bottoms		-
5 Flood recession cropping areas	1989	12,000ha
Total water managed area (1+2+3+4+5)		78,480ha
- as % of cultivated area		2.1%
- increase over the last 10 years		-
- power irrigated area as % of water managed area		-
Full or partial control schemes Criteria		
Large schemes		-
Medium schemes		-
Small schemes		-
Total number of households in irrigation		-
Irrigated crops		
Total irrigated grain production	2000	71,399T
As % of total grain production		3.3%
Harvested crops under irrigation		
Rice	2000	30,000ha
Cotton	1989	3,000ha
Wheat	2000	3,000ha
Sugarcane	2000	6,000ha
Groundnuts	2000	32,000ha
Vegetables	2000	12,000ha

Source: FAO 1997b, FAOSTAT 2000

Table 2.13 Irrigated areas per (sub)basin in Niger

Region	**Diffa**	**Dosso**	**Maradi**	**Niamey**	**Tahoua**	**Zinder**	**Niger**
Irrigated area (ha)	5,250	1,280	5,210	16,170	31,490	3,710	66,480

A major dam has been planned for the Niger River, 187km upstream of Niamey. The dam will be located at Kandadji and have an estimated reservoir volume of 1.6 km^3 (5–8% of the annual flow). It is expected that by the year 2034 this dam will allow for the irrigation of an additional 31,000ha of land (according to the feasibility study by the 'Haut Commissariat au Barrage de Kandadji'). Low-lying areas will be developed for rice cultivation, while higher areas will be laid out for sugarcane, vegetables, groundnut, and cotton. The average water demand per hectare will be around 12,500m^3, with the minimum flow during the dry season maintained at 120m^3/s.

The dam will be equipped with a fish lock to facilitate fish migration. The main ecological concern is possible infestation of the reservoir with water hyacinth (*Eichhornia crassipes).* Downstream, the minimum flow of 120m^3/s is expected to have a beneficial effect on the self-purifying capacity of the river in areas suffering heavy pollution from riverbank agglomerations (e.g. Niamey city).

2.4.3 Agriculture

Crops under traditional irrigation are tobacco, groundnut, millet, cassava, sweet potatoes, and fruit trees. Sugarcane is generally grown in the wettest lowlands, while tobacco is grown in flood recession areas, as are many vegetables. The irrigation schemes along the Niger River supported by ONAHA grow rice, wheat, and cotton.

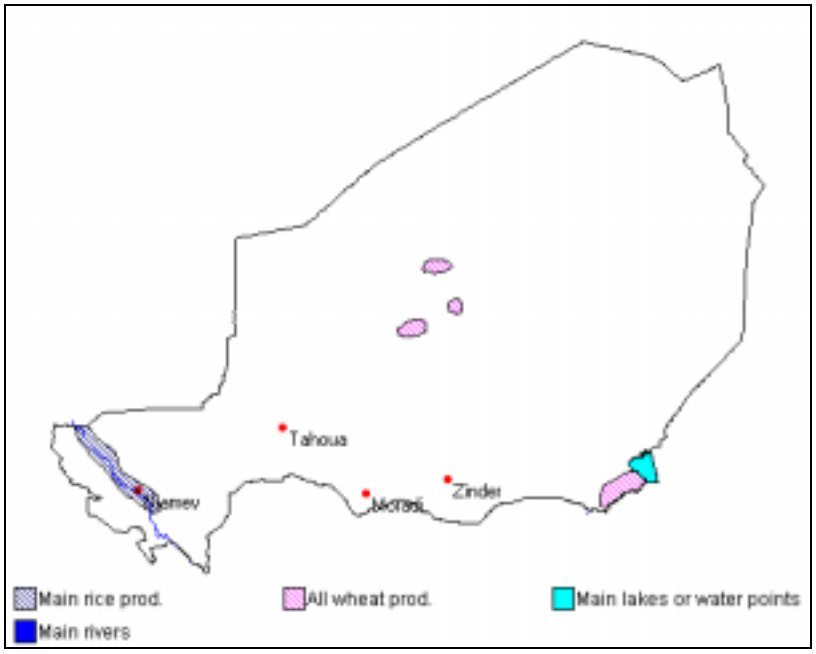
FAO and Riceweb statistics indicate that the average production of rice in Niger is around 60,453 tonnes per year, with an average yield 2,300kg/ha. Abernethy (2000) carried out a detailed study of four irrigation schemes along the Niger River and found an average yield of 4,500kg/ha for wet and dry seasons combined, with the yield for the dry season slightly higher than for the wet season. Cropping intensity (surface of irrigated crops/surface laid out for irrigation) was close to 133 per cent. The major rice production zones are located around Dosso (73.5%) and Tillabery (26.5%). The majority of rice is grown under flooded conditions (53.3%).

Table 2.14 Water requirements for major irrigated crops in Niger

Crop	**Location**	**(Trans)planting date**	**Total cultivation requirements** (mm)	**Irrigation requirements** (mm)
Rice	Tillabery	15/7	1,180	832
	Niamey	15/7	1,105	732
	Tillabery	1/11	1,305	1,303
	Niamey	1/11	1,337	1,336
Cotton	Niamey	15/6	1,089	752
Wheat	Agadez	15/11	726	726
	Niamey	15/11	803	803
Sugarcane	Niamey	15/7	2,843	2,467
Groundnut	Niamey	15/7	741	451
Vegetables	Niamey	15/7	696	696

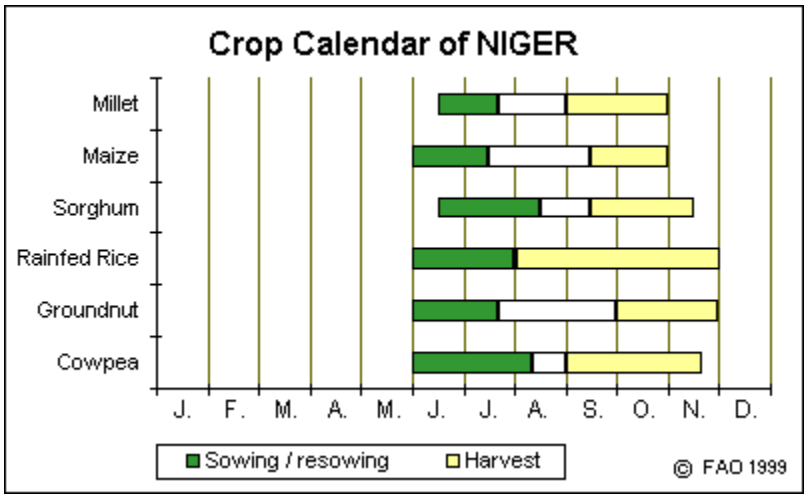
Source: FAO CROPWAT

Figure 2.5 Rice and wheat cultivation areas in Niger



Source: FAO GIEWS

Figure 2.6 Niger crop calendar



Source: FAO GIEWS

FAO's CROPWAT system has been used to calculate water requirements for the major irrigated crops during both wet and dry seasons.

Table 2.15 Irrigated crop area in Niger

Irrigated area (1,000ha)		**Crop area as % of the total area equipped for irrigation, by month**											
		J	F	M	A	M	J	J	A	S	O	N	D
Wheat	3	5	5	5	5	5						5	5
Rice	30												
Rice-one		23	23	23								23	23
Rice-two							23	23	23	23	23		
Sweet potatoes	2	3	3	3								3	3
Sugarcane	6	9	9	9	9	9	9	9	9	9	9	9	9
Vegetables	12	18	18	18								18	18
Groundnut	32						48	48	48	48	48		
Cotton	3	5	5	5	5	5						5	5
All irrigated crops	88	62	62	62	18	18	80	80	80	80	80	62	62
Equipped for irrigation	66												
Cropping intensity	133												

Source: FAO AQUASTAT

Table 2.16 Agricultural water withdrawal in Niger

Total Renewable Water Resources (TRWR)	34km^3
Irrigation water requirements	0.62km^3
Water use efficiency percentages	30%
Water withdrawal for agriculture	2.08km^3
Water withdrawal as % of TRWR	6%

Source: FAO AQUASTAT

Table 2.17 Water requirement per crop in Niger

Crop	**Location**	**Season**	**Area** (ha)	**CWR** (mm/ha)	**Efficiency** (%)	**Total crop** (million m^3)
Rice	n/a	wet	15,000	800	30	400.0
	n/a	dry	15,000	1,300	30	650.0
Wheat	n/a	dry	3,000	726	30	72.6
Sugarcane	n/a	wet/dry	6,000	2,467	30	493,4
Groundnut	n/a	wet	32,000	451	30	481.1
Vegetables	n/a	dry	12,000	696	30	278.4
Cotton	n/a	wet	3,000	842	30	84.2
						Total 2,469.7

When considering Table 2.17, it should be noted that irrigated groundnut is most likely grown under flood recession irrigation and would thus not fall into the same category as the other crops, which are raised under the full control type of irrigation.

As in Mali, the dry-season rice crop consumes the most water, followed by sugarcane. The same observation holds concerning the replacement of the dry-season rice crop by wheat, with water savings per hectare in the order of 55 per cent.

2.5 Nigeria

Nigeria is located in the tropical zone of West Africa and has a surface area of 923,770 km^2. The total cultivated area is estimated at 70 million ha – 76 per cent of the total area. The net cultivated

area is about 22.6 million ha, which is 37 per cent of the cultivable area and 24 per cent of the total area. Wetlands represent 2.6 per cent of the country's surface.
Agriculture employs about 54 per cent of the labour force and in 1998 contributed 39 per cent of GDP.

2.5.1 Climate and water resources

Nigeria's climate is seasonal with distinct wet and dry periods, except for the coast where it rains all year round. Rainfall is concentrated in the period June–September when the south of the country receives 50–60 per cent of its rainfall and the north 90 per cent. Rainfall varies between 500mm in the north-east and 3,000mm on the coast.

Table 2.18 Water demand forecast for Nigeria

IWMI characteristics	**Units**	**1995**	**2025**	**Annual growth** (%)
Population	million	99.0	178.7	2.0
Total cereal consumption	m mt	21.0	43.7	2.5
Cereal production	m mt	19.9	38.8	2.2
Irrigated cereal area	m ha	1.06	1.43	1.0
Rain-fed cereal area	m ha	16.75	26.41	1.5
Total cereal area	m ha	17.81	27.84	1.5
Net irrigated area	m ha	1.0	1.2	0.6
Gross irrigated area	m ha	1.3	1.8	1.0
Primary irrigation supply	km^3	4.4	5.7	32
Total water withdrawals	km^3	8.29	14.56	1.9
Total primary water supply	km^3	5.0	7.6	Total growth
Total PWS as % of PUWR	%	3.1	4.8	53%
Scarcity level	Economic			

Source: Molden 2000
m mt = million metric tons
m ha = million hectares

A total of 142 dams (60 large ones to a height of >15m and 82 small to medium ones) have been constructed or are under construction, with a total projected capacity of 30.3$km^{3.}$ The large-scale dam projects are concentrated in the five northern and central areas of Nigeria for perennial storage of wet-season runoff to be released later for dry season irrigation. The country's water resources are mobilized for multi-purpose uses such as domestic water supply and irrigation, and their allocation is a function of many variables, among which availability and government play a dominant role.

Water allocation from reservoirs is shared as follows: 10.9 km^3 (36%) for irrigation, 0.8 km^3 (3%) for domestic purposes and 18.6 km^3 (61%) for hydropower.

Environmental issues
Under natural hydrological conditions the rivers deposit rich sediments in the *fadama* (floodplains) when in flood. These areas help to mitigate the downstream effect of flooding and help to recharge the shallow aquifers. In addition, the natural vegetation supports wildlife populations. Floodplain use is subject to conflicting interests between local people, who use them for agriculture, fishing, grazing or hunting, local planners who wish to intensify production through development of irrigation and river control, and conservationists, who are concerned about the environmental role of wetlands.

2.5.2 Irrigation development

Irrigated crops represent about 8 per cent of the value of the country's total agricultural crop output and 4 per cent of the cultivated area. The combined use of surface water and shallow *fadama* aquifers makes the assessment of irrigation potential particularly difficult. According to the National Water Resources Master Plan Study, total irrigation potential would be about 3.14 million ha: 1.10 million ha for public irrigation projects, and 2.04 million for formal *fadama* irrigation projects. Other sources estimate total irrigation potential to be about 2–2.5 million ha.

Estimates of irrigated land and irrigated crops also vary greatly from one source to another. The total area of managed water is estimated to be about 2,646,200ha, but it is not clear if this includes double-cropping.

Irrigation systems can be divided as follows:

Category	**Distribution**		**1991**	**1993**
Formal irrigation (public irrigation projects)	Full or partial control	Equipped Actually irrigated	118,621ha 62,086ha	119,350ha 69,000ha
Informal irrigation (farmer-owned and operated irrigation projects)	Full or partial control Equipped wetlands	Lift or shallow tube-well Flood control (improved *fadama*)	101,000ha 13,200ha	161,700ha 18,500ha
Residual *fadama*	Flood plains		723,714ha	724,000ha

Source: FAO/Investment Centre 1992, Japanese Cooperation Agency 1993

Public irrigation projects are schemes under government control (formal irrigation). It is estimated that only 57 per cent of the area of public irrigation schemes is actually irrigated. Farmer-owned and operated irrigation projects receive assistance from the government in the form of subsidies and training. About 75 per cent of the total water managed areas are residual *fadama*, where no government aid is supplied. The part of the equipped area actually irrigated by pumping (from rivers or groundwater) is 13 per cent of the total water managed area. Sprinkler irrigation is practised on 3,570ha.

Trends in water resources management

At the current low levels of technology, Nigeria's population already exceeds the carrying capacity of its land resources. Key factors for increasing productivity are seen as fertilizers and improved irrigation systems, which together can increase land productivity by between three and seven times, especially in the north of the country.

A number of problems exist in the irrigation sub-sector. Large public projects are hampered by the very high cost of irrigation development, the inadequacy of planning and design of irrigation control areas (e.g. differences in water distribution between the head and the tail-end, poor maintenance of systems, setting up of irrigation rotation schedules), and the poor state of the existing irrigation canal system. Combined with slow progress in achieving target yields, this leads to poor financial returns for small-scale farmers involved in large-scale irrigation projects. In small, public projects lack of training in new techniques and modern practices is considered a major constraint to achieving target incomes, together with the unreliable supply of agricultural inputs.

Traditional, informal, irrigation suffers from the changing conditions in the floodplains resulting from the construction of dams and other structures upstream. Reservoir construction also generates social problems, due principally to their implicit displacement of populations.

The floodplain of the Niger River is considered the greatest untapped potential for future irrigation development in Nigeria.

Table 2.19 Irrigated areas per (sub)basin in Nigeria

Basin	Coast East	Coast West	Niger South	Lower Benue	Upper Benue	Niger Central	Niger North	Lake Chad	Nigeria
Irrigated area (ha)	1,820	4,220	9,860	20,410	31,370	32,760	56,970	142,940	300,350

Only about 57 per cent of large irrigation schemes are actually put into use, while no more than 60 per cent of small-scale schemes succeed in reaching operational status. While the large-scale schemes are government controlled, small-scale schemes are mostly farmer-owned, with some assistance from government in terms of subsidies and training. Meanwhile, about 76 per cent of the total area of managed water is residual, where no government aid is supplied.

The portion of the equipped area irrigated by pumping from rivers or groundwater is 121,161ha, representing about 13 per cent of the total water managed area, while sprinkler irrigation is carried out on 3,570ha.

Table 2.20 Irrigation data for Nigeria

Irrigation potential		**2000**	**3,137,000ha**
Irrigation			
1 Area equipped for irrigation		2000	233,000ha
- surface irrigation			-
- sprinkler irrigation			3,570ha
- micro-irrigation			-
% of area irrigated from groundwater			13%
% of area irrigated from surface water			-
% of equipped area actually irrigated		2000	57%
2 Spate irrigation			-
3 Equipped wetland and inland valley bottoms		1993	18,500ha
4 Other cultivated wetland and inland valley bottoms			-
5 Flood recession cropping areas		2000	2,400,000ha
Total water managed area (1+2+3+4+5)		2000	2,646,200h
- as % of cultivated area		2000	4.3%
- increase over the last 10 years			-
- power irrigated area as % of water managed area			13.4%
Full or partial control schemes	Criteria		
Large schemes	> -ha		-
Medium schemes	< -ha		-
Small schemes			-
Total number of households in irrigation			-
Irrigated crops			
Total irrigated grain production		2000	3,401,000T
As % of total grain production		2000	15%
Harvested crops under irrigation		2000	2,960,000ha
- rice		2000	10,000ha
- vegetables		2000	152,000ha
- wheat		2000	50,000ha
- potatoes		2000	5,000ha
- sugarcane		2000	26,000ha
- maize		2000	19,000ha

Source; FAO 1997b, FAOSTAT

2.5.3 Agriculture

Nigeria contains six ecological zones, ranging from a belt of mangrove swamps and tropical forests along the coast, to open woodland and savanna on the low plateau which extends through much of the central part of the country, to the semi-arid plains in the north and highlands to the east. The principal food crops are yams, cassava and maize in the south, and millet, sorghum and cowpeas in the drier north. Cocoa, rubber, oil palm, groundnuts, and cotton are the main cash crops, which are generally destined for export.

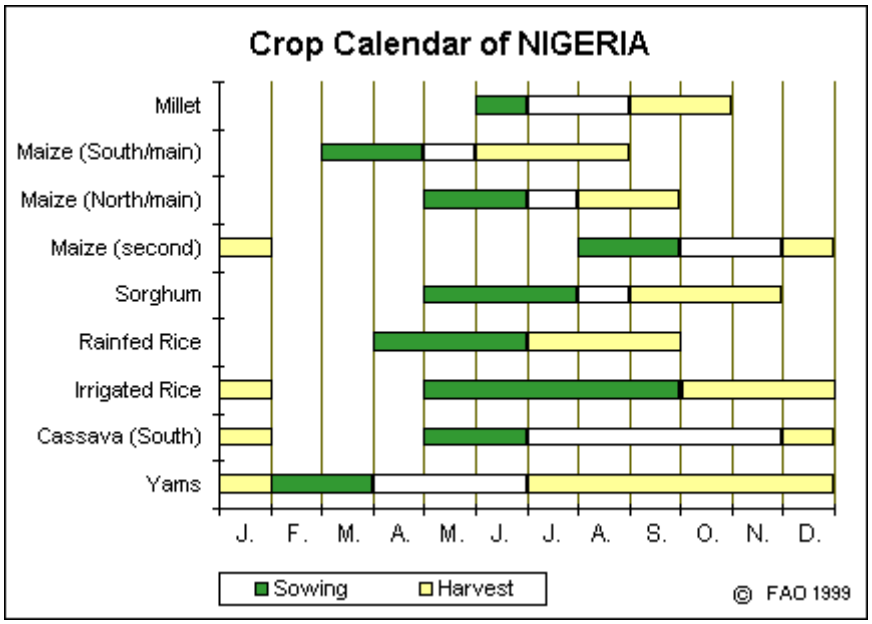
The main irrigated crops in order of significance are rice, vegetables, wheat, potatoes, and tobacco.

Between the arid north and the moist south lies the Guinea Savanna Zone, sometimes referred to as the middle belt. This area produces staples such as yams, sorghum, millet, cassava, cowpeas, and corn, with rice an important crop in some places. The middle belt's southern edge represents the lower limits of the northern grain-dominated economy. The most significant commercial crop of the middle belt is sesame (or benniseed).

Rainfall is heaviest in the south, where the rainforests and woodlands benefit from abundant precipitation and relatively short dry seasons. Root crops are the staples in the south, including cassava, yams, taro (*cocoyams*), and sweet potatoes. The main cash crops in the south are trees, which in general are grown on large plantations that include cacao, oil palm, and rubber. However, almost 85 per cent of Nigeria's current palm oil production is from unorganized wild groves.

The northern third of Nigeria experiences a dry season of five to seven months, and lies mostly in the Sudan and Sahel Savanna zones. Staples in the north are millet, cowpeas, and a drought-resistant variety of sorghum known as guinea corn. Sorghum is Nigeria's most widely cultivated grain, accounting for more than 45 per cent of the total area. Sorghum cultivation spans the north of the country to the middle belt, where precipitation and soil moisture levels are low. Maize is also cultivated, as well as rice, in suitable lowland areas. Wheat is a lowland crop, irrigated along broad valley bottoms in the north, especially in the Lake Chad Basin. The north's principal commercial crops are cotton and groundnuts.

Figure 2.7 Nigeria crop calendar

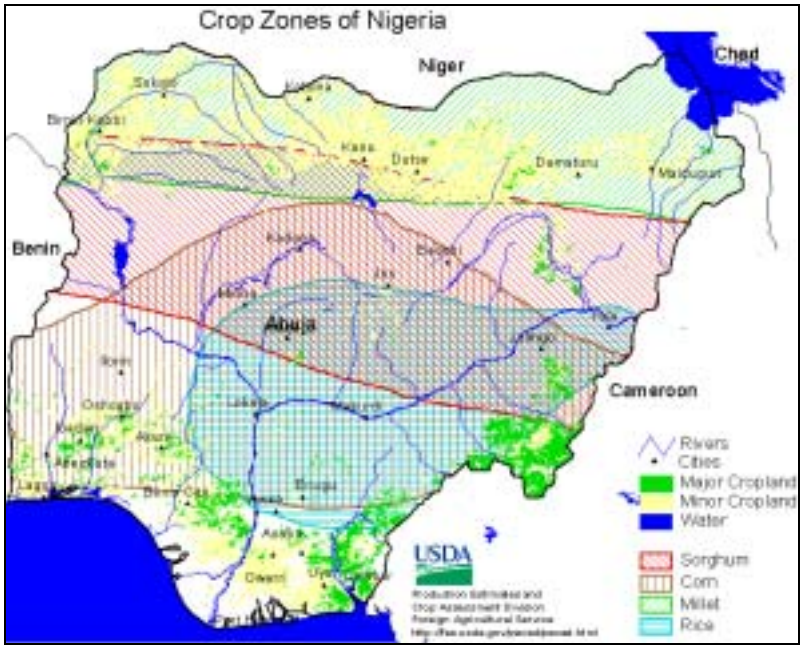


Source: FAO GIEWS

Nigeria is nearly self-sufficient in sorghum and it is West Africa's largest rice producer. Rice cultivation is widespread in Nigeria, extending from the northern to southern zones, with most rice grown in the eastern and middle belt of the country.

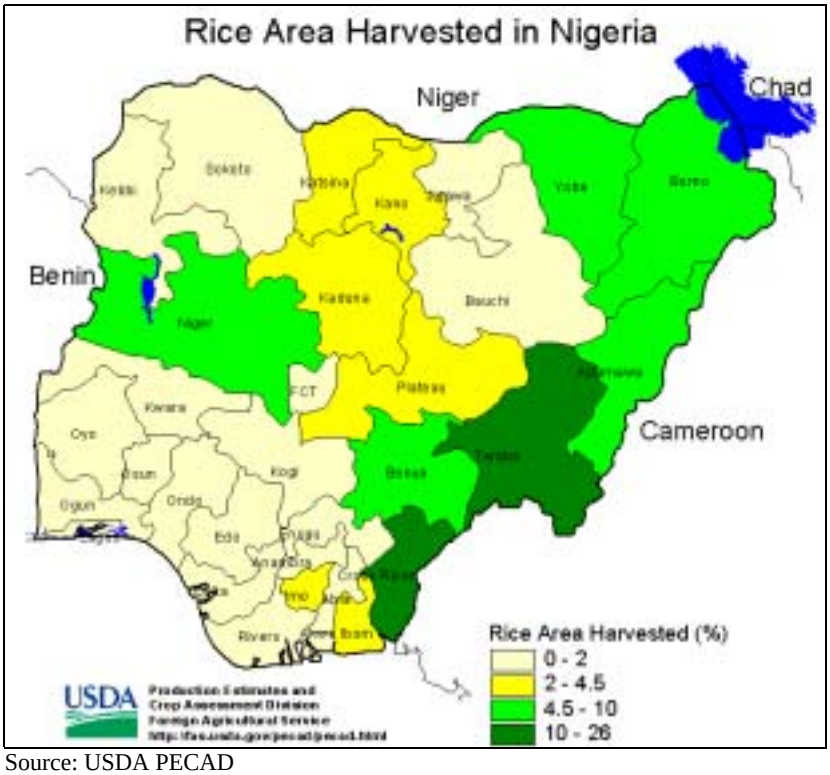
In 2000, the harvested rice in Nigeria covered 2,199,000ha, with an average yield of 1.5 tonnes/ha. Major production zones were Cross River (26%), Taraba (11%), Niger and Adamawa (8%), and Benue (6.5%). Yobe (6%) falls in the same category but takes it water from the Lake Chad Basin.

Figure 2.8 Crop zones of Nigeria



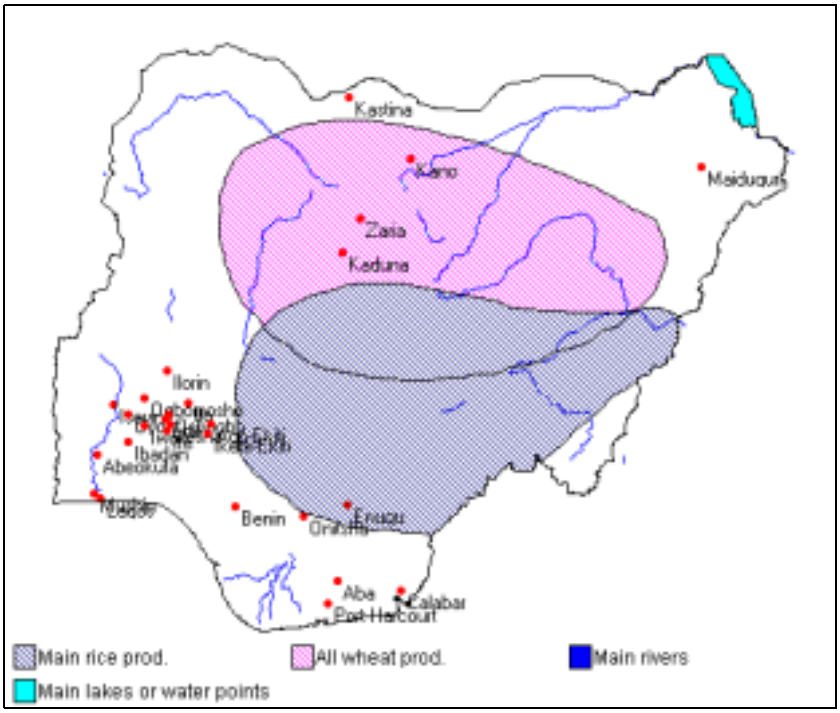
Source: USDA PECAD

Figure 2.9 Rice production areas in Nigeria



Source: USDA PECAD

Figure 2.10 Rice and wheat cultivation areas in Nigeria



Source: FAO GIEWS

Rice-growing environments in Nigeria are usually classified into five rice ecosystems: rain-fed upland, rain-fed lowland, irrigated lowland, deep-water, and mangrove swamp. The mangrove swamp ecology is the least important in terms of area, accounting for less than 1 per cent of total rice area. Another 8 per cent of the rice area is generally estimated to fall in deep-water environments, although this figure is most likely an overestimate given the physical limits to area expansion within this environment and reports that water control projects have reduced the potential suitable area. Irrigated systems, which include large-scale irrigation schemes in the north and small-scale developed inland valley bottoms in the south, account for 16 per cent of total rice area. Rain-fed upland systems (25%) and rain-fed lowland systems (25%) account for the remainder. The latter, which include the broad inland valley bottoms in the north and the floodplains along the Niger and Benue River systems, appear to have been a major source for the rapid increase in paddy-field production in recent years.

Table 2.21 Rice production ecologies and their potential

Type of ecology	**% of cultivated rice area**	**Potential yield** (t/ha)	**Percentage of national rice supply**
Upland	25	0.8–2	30–35
Inland or shallow swamp	50	2–8	44
Irrigated	16	2–4	10–12
Deep water or floating	8	<1	10–14
Tidal or mangrove	<1	1	-

Source: Riceweb

CROPWAT has been used to calculate crop water requirements for different crops in different locations, both during the wet and dry seasons.

Table 2.22 Water requirements for major irrigated crops in Nigeria

Crop	Location	(Trans)planting date	Total cultivation requirements (mm)	Irrigation Requirements (mm)
Rice	Makurdi (Benue)	30/6	748	202
	Minna (Niger)	30/6	770	202
	Yola (Adamawa)	30/6	833	334
	Potiskum (Yobe)	30/6	890	437
	Makurdi (Benue)	1/11	884	825
	Minna (Niger)	1/11	1000	957
	Yola (Adamawa)	1/11	1130	1104
Wheat	Maiduguri (Borno)	1/11	541	541
	Kano (Kano)	1/11	661	661
Potatoes	Jos (Plateau)	1/6	403	-
	Kano (Kano)	1/6	647	170
Vegetables	Bauchi (Bauchi)	1/11	619	619
	Kano (Kano)	1/11	533	533
Tobacco	Bauchi (Bauchi)	1/6	453	-

Table 2.23 Irrigated crop area in Nigeria

Irrigated area (1,000ha)		Crop area as % of the total area equipped for irrigation, by month											
		J	F	M	A	M	J	J	A	S	O	N	D
Wheat	50	17	17	17	17								17
Rice	10												
Rice-one		2	2	2								2	2
Rice-two							2	2	2	2	2		
Maize	19						2	2	2	2	2		
Potatoes	5	2	2	2	2								2
Sugarcane	26	9	9	9	9	9	9	9	9	9	9	9	9
Vegetables	152	51	51	51	51								51
All irrigated crops	262	81	81	81	79	9	13	13	13	13	13	11	81
Equipped for irrigation	300												
Cropping intensity	87												

Source: FAO AQUASTAT

The figure for irrigated rice area in Nigeria requires some consideration. In 1989, it was estimated at 714,000ha (FAO 1995). CORIFA (Country Rice Facts, FAO) gives the total areas as 1,208,000ha in 1990 and 2,061,000ha in 2000. CORIFA also estimates that, over the period 1975–2000, of the total area under rice cultivation, 50 per cent was in a rain-fed lowland environment and 26 per cent in a rain-fed upland environment. This would leave around 500,000ha under irrigation. If double-cropping was practised, this would leave 250,000ha in each of the dry and wet seasons. In view of the fact that Nigeria is West Africa's largest rice producer, this seems a more reasonable figure which could thus be maintained for calculations on crop water requirements.

However, if 250,000ha of rice were to be irrigated in each season, the total cropped areas as given in Table 2.23 would exceed the total area equipped for irrigation in the dry season by 202,000ha. Even taking into account the fact that irrigation data for Nigeria are not clear, this area is too large to be acceptable.

The area under vegetable cultivation probably combines modern, full control irrigation with the more traditional *shadouf* systems. There is a proposal to divide the area in 100,000ha under full control and 52,000ha under traditional systems.

The crop areas which will be used for calculating crop water use are given in Table 2.24.

Table 2.24 Proposed irrigated crop areas in Nigeria

Crop	**Wet season** (ha)	**Dry season** (ha)	**Total** (ha)
Wheat		50,000	50,000
Rice	250,000	124,000	374,000
Sugarcane	26,000	26,000	26,000
Vegetables		100,000	100,000
Maize	19,000		19,000
Potatoes	5,000		5,000
Total		**300,000**	**574,000**

Table 2.25 Agricultural water withdrawal in Nigeria

Total Renewable Water Resources (TRWR)	286km^3
Irrigation water requirements	1.65km^3
Water use efficiency percentages	30%
Water withdrawal for agriculture	5.51km^3
Water withdrawal as % of TRWR	2%

Source: FAO AQUASTAT

Table 2.26 Water requirement per crop in Nigeria

Crop	**Location**	**Season**	**Area** (ha)	**CWR** (mm/ha)	**Efficiency** (%)	**Total crop** (million m^3)
Wheat	north	dry	50,000	600	30	1,000.0
Rice	n/a	wet	250,000	800	30	6,666.7
	n/a	dry	124,000	1,000	30	4,133.3
Potatoes	north	wet	5,000	500	30	83.3
Sugarcane	n/a	wet/dry	26,000	1,495	30	1,295.7
Vegetables	north	dry	100,000	533	30	1,776.7
						Total 14,955.7

If the proposed crop areas given in Table 2.24 are maintained, water requirement per crop would be as shown in Table 2.26. Irrigated wet-season rice is the largest water consumer, followed by the dry-season rice crop. However, this in only because of the difference in area; if the area cultivated in the dry season remained of the same order in the wet season, the dry-season rice crop would be the largest water consumer, which is in line with the observations made for the other countries in West Africa.

The total figure given in Table 2.26 – of almost 15 million m^3 – does not tally with the figure for 'water withdrawal for agriculture' given in Table 2.25. However, total water withdrawal for agriculture would increase from 2 to 5 per cent of total renewable water resources, which in itself is a large increase but does not draw heavily on the total available resources.

3 THE LAKE CHAD BASIN

3.1 Introduction

The Lake Chad Basin, located in northern Central Africa, covers almost 8 per cent of the continent and spreads over seven countries (see Table 3.1).

Table 3.1 Lake Chad Basin: areas and rainfall by country

Country	Total area of the country (km^2)	Area of the country within the basin (km^2)	As % of total area of basin (%)	As % of total area of country (%)	Average annual rainfall in the basin area (mm)		
					min.	max.	mean
Nigeria	923,770	179,282	7.5	19.4	285	1,330	670
Niger	1,267,000	691,473	29.0	54.6	0	635	105
Algeria	2,381,740	93,451	3.9	3.9	0	135	20
Sudan	2,505,810	101,048	4.2	4.0	70	1,155	585
Central Africa	622,980	219,410	9.2	35.2	760	1,535	1,215
Chad	1,284,000	1 046,196	43.9	81.5	0	1,350	400
Cameroon	475,440	50,775	2.1	10.7	365	1,590	1,010
For Lake Chad Basin		2,381,635	100.0		0	1,590	415

Source: FAO 1995

About 20 per cent of the total area of the Lake Chad Basin, or 427,000km^2, is called the Conventional Basin (42% in Chad, 28% in Niger, 21% in Nigeria and 9% in Cameroon), which is under the mandate of the Lake Chad Basin Commission. The commission was created in 1964 by the four member states with the objective of ensuring the most rational use of water, land and other natural resources, and to coordinate regional development.

3.1.1 Rivers and discharges

The Lake Chad Basin is a terminal depression with the seven countries grouped around, while the shores of Lake Chad itself are touched by the four member states of the Lake Chad Basin Commission.

In **Nigeria**, two sub-basins drain into the lake:

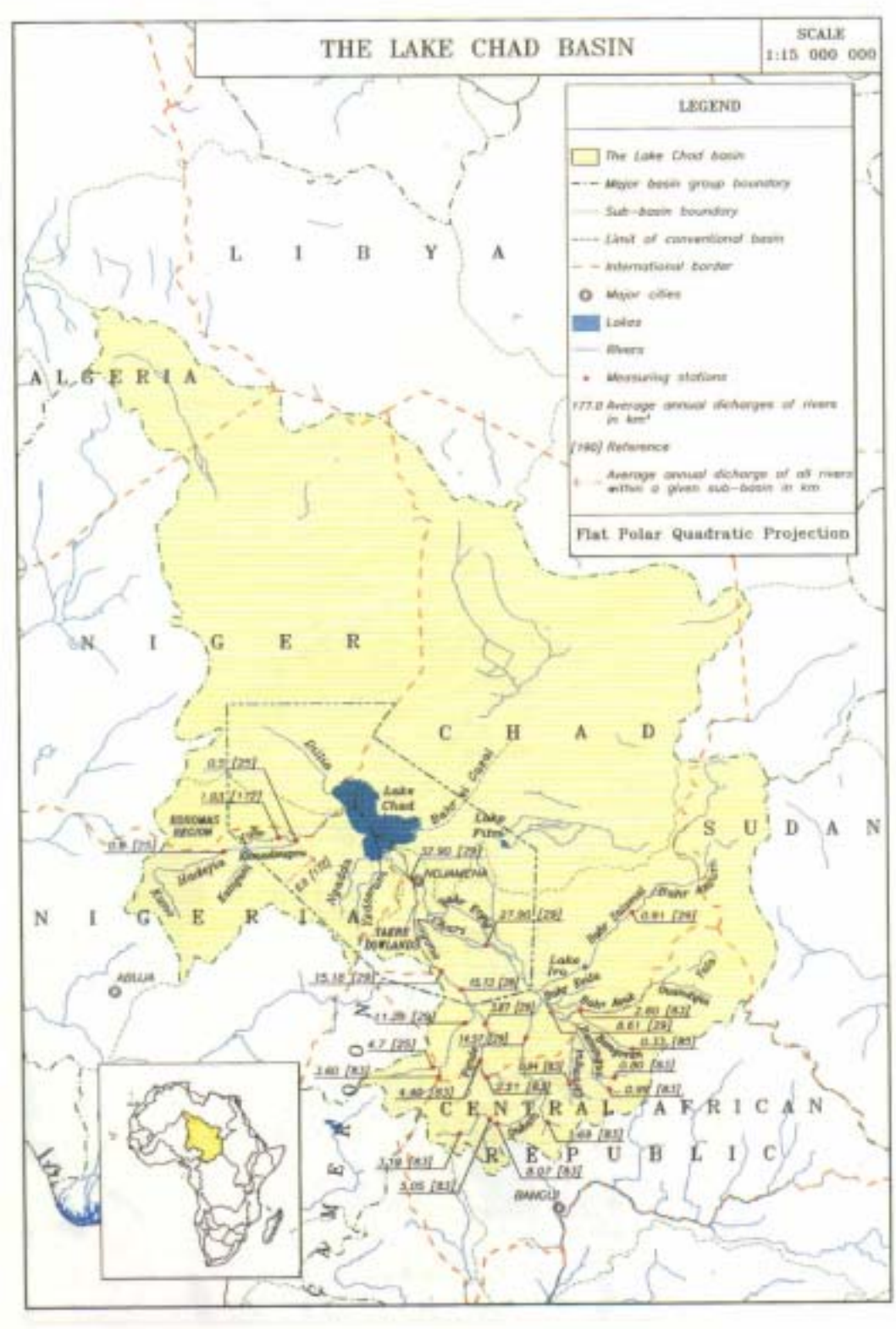
- the Yedseram/Ngadda sub-basin to the south
- the Hadejia/Jama'are/Komadougou/Yobe sub-basin to the north.

The Yedseram River and its tributaries rise in the Mandara hills and 'loses' most of its water while flowing northwards through a 7km-wide floodplain. Further downstream, together with the Ngadda River, it forms an 80km^2 swamp with no definable water course to the lake.

The Komadougou/Yobe River forms the border between Nigeria and Niger over the last 300km. Upstream of the confluence of the Hadejia and Jama'are rivers, the Hadejia-Nguru wetlands start. These cover a total area of about 6,000km^2 and a water surface area of about 2,000km^2. However, dam construction and increasing water abstraction for irrigation purposes upstream since the 1980s have contributed to large areas of the floodplains becoming increasingly dry. All rivers crossing this area lose flow as a result of evaporation and evapotranspiration, and infiltration to

recharge the groundwater. The inflow varies between 1 and 1.8km^3/year, the outflow between 0.6 and 0.7km^3/year. When inflow is more than 2km^3/year, outflow gradually increases to 1.2km^3/year. Upstream, peak flow occurs at the end of August and rises and falls rapidly, reflecting the sporadic nature of heavy rainfalls and the largely impermeable strata. Downstream, peak flow occurs in January. Water flow into Lake Chad amounts to about 0.5 km^3/year.

Figure 3.1 Lake Chad Basin



Source: FAO 1995

In **Niger**, in addition to the bordering Komadougou/Yobe River, there are the Koramas in the south of the country close to the border with Nigeria. These are seasonal rivers and their flow does not reach Lake Chad.

To the north, **Algeria** lies far from Lake Chad and possesses few renewable water resources.

To the east is **Sudan,** with Wadi Kaya and Wadi Azum. Both wadis are seasonal, with spate flows that originate on the western slopes of the Jebel Marra. Their alluvial aquifers may deliver about 0.08km^3/year of water of excellent quality to the Lake Chad Basin.

To the south is the **Central African Republic**, a humid country with enormous water resources. The sources of the Chari-Logone Rivers are located here and the quantity of water leaving the country to Chad was about 33km^3/year in the period prior to the 1970s, but this fell to 17km^3/year during the 1980s.

The amount of water crossing the border from **Cameroon** to Chad varies between 3 and 7km^3/year. In the north of the country the Logone River forms the border with Chad as far as N'Djamena, where it joins the Chari River which then continues north to the lake. These rivers have a tropical regime with a single flood occurring at the end of the rainy season, from August to November. They are characterized by irregular inter-annual flows and by their large water 'losses', estimated at about 5km^3 /year, through flooding of the adjacent Yaéré lowlands in Chad and Cameroon. The largest area flooded covers about 8,000km^2 and is used for pasture, fishing, flooded rice production, and flood recession cropping. In order to expand the Yaéré area, two sites for regulatory dams have been identified on upstream branches of the Logone in Cameroon and Chad. However, this would be to the detriment of water uses for hydroelectric power generation and for irrigation outside the Yaéré lowlands.

The rivers outside the Chari-Logone basin in Chad, such as the Batha River, have flash floods during heavy rains and negligible flows the rest of the time. This regime seriously limits irrigation development.

The Chari-Logone Rivers contribute about 95 per cent of the total inflow into Lake Chad, amounting to 38.5km^3/year. In recent times, the area of Lake Chad has varied considerably between 3,000 and 25,000km^2, with variations in level of 8m and in volume of between 20 and 100km^3. The total inflow in recent times has varied between 7km^3/year (1995/96) and 54km^3/year (1955/56). Due to the lowering of the lake level, one proposal was put forward to replenish the lake with water from the Congo/Zaire basin through the construction of a 2,400km-long canal, but for the time being this is impractical on technical, economic and political grounds.

3.1.2 Irrigation potential and water requirements

In **Nigeria** irrigation planned under the existing water management system is estimated at 185,000ha, of which only about 32,000ha have been completed and irrigated. The total identified potential has been evaluated at 356,000ha. However, even the complete development of the first 185,000ha would result in water shortages. In addition, Nigeria plans the development of 146,000ha of *fadama*, of which 20,000ha lie in the upper part of the country, 27,000ha in the middle, and 99,000ha in the lower part.

In **Niger** irrigation potential in the Koramas sub-basin has been estimated at 8,000ha, and in the downstream Kadougou/Yobe River valley and around Lake Chad at 40,000ha. In the northern part of the country there are a number of oases, but no information on them is available.

The irrigation potential in the **Algerian** part of the basin is estimated at zero, while in **Sudan** potential is put at about 4,000ha.

The irrigation potential for the whole of the **Central African Republic** is estimated at 1.9 million ha, but no details are available on location. About one-third of the country is situated in the Lake Chad Basin, the remaining two-thirds being in the Congo/Zaire basin. A first approximation of the potential in the Lake Chad Basin is estimated at 500,000ha. This would require 8.25km^3/year of water, equal to between a quarter and half of the total quantity of water leaving the country to Chad, depending on the period of reference.

For **Chad,** the irrigation potential has been estimated as per Table 3.2.

Table 3.2 Irrigation potential and water requirements in the Lake Chad Basin in Chad

Region	**Irrigation potential** (ha)	**Water requirement** (km^3/year)
Sudanese and western Sahelian zone:		
- Logone River system	100,000	1,500
- Chari River system	400,000	6,000
- Lake Chad	200,000	3,000
Central and eastern Sahelian zone	135, 000	2,025
Total	**835,000**	**12,525**

Source: FAO 1995

In addition, there are an estimated 90,000ha of oases in the Saharan zone, but most probably these have to be irrigated by non-renewable groundwater.

The irrigation potential for **Cameroon** is estimated at about 100,000ha in the Lake Chad Basin.

Table 3.3 summarizes the figures for the whole of the Lake Chad Basin and for the Conventional Basin.

Table 3.3 Lake Chad Basin: irrigation potential and water requirements in the basin countries

Country	**Irrigation potential in whole Lake Chad Basin** (ha)	**Irrigation water requirement** (km^3/year)	**Irrigation potential in the conventional Lake Chad Basin** (ha)	**Irrigation water requirement** (km^3/year)
Nigeria	502,000	5.020	300,000	3.000
Niger	48,000	0.936	40,000	0.780
Algeria	0	0		
Sudan	4,000	0.030		
CAR	500,000	8.250		
Chad	535,000	12.525	700,000	10.500
Cameroon	100,000	1.250	80,000	1.000
Total	**1,989,000**	**28.011**	**1,120,000**	**15.280**

At present, out of a potential of over 1.1 million ha in the Conventional Basin, fewer than 100,000ha are actually irrigated. However, due to the lowering of the level of Lake Chad in

recent history, every new irrigation development has to be studied very carefully. Already in 1980, maximum development was estimated by a UNDP study to be less than 400,000ha. The recently prepared master plan for the Conventional Basin proposes to concentrate future developments on small-scale projects.

Taking all the above aspects into consideration, the total potential for the whole of the Lake Chad Basin is presented in Table 3.4.

Table 3.4 Lake Chad Basin: irrigation potential, water requirements and areas under irrigation

Country	Irrigation potential			Gross irrigation water requirement		Area under irrigation
	within	outside	within whole basin	per ha	Total	
	Conventional basin					
	(ha)	(ha)	(ha)	(m^3/ha/year)	(km^3/year)	(ha)
Nigeria	204,000	100,000	304,000	10,000	3.040	82,821
Niger	3,000	8,000	11,000	19,500	0.215	2,000
Algeria		0	0	18,000	0.000	0
Sudan		4,000	4,000	7,500	0.030	500
Centr. Afr. Rep.		500,000	500,000	16,500	8.250	135
Chad	142,500	135,000	277,500	15,000	4.163	14,020
Cameroon	46,700	20,000	66,700	12,500	0.834	13,820
Total	**396,200**	**767,000**	**1,163,200**		**16.531**	**113,296**

Source: FAO 1995

3.2 Ecoregions in the Lake Chad Basin

There are two WWF 200 Ecoregions in the Lake Chad Basin. Around Lake Chad the region is characterized as Sudd-Sahelian Flooded Grasslands and Savannahs. The southern regions of Chad and the northern part of the Central African Republic form part of the Sudanese Savannas ecoregion.

Sudd-Sahelian Flooded Grasslands and Savannas
See above under section 2.2 Ecoregions in the Niger River Basin.

Sudanese Savannas
Comprised of expanses of woodland areas, which are mainly deciduous in the dry season, these areas are also characterized by an understorey of grasses, shrubs, and herbs. The ecoregion occupies a portion of a larger area identified as a centre of plant diversity, and hence is important for plant conservation. Given the pronounced dry season, there is a large seasonal migration of fauna, particularly large vertebrates, within the ecoregion, in addition to large numbers of migrant birds using the Afrotropical-Palaearctic flyway.

General threats: Significant loss of original wooded savanna habitats has occurred in the ecoregion, but large blocks of relatively intact habitat remain even outside protected areas. Threats include seasonal 'shifting' cultivation, overgrazing by livestock, cutting trees and bushes for wood, burning woody material for charcoal, and uncontrolled wild fires. Climatic desiccation is a further threat, exacerbating the impacts of human activities, as the ability of the ecosystem to recover from overuse is reduced when there is little rainfall. The main threats to wild species are overgrazing and, in the case of larger animals, over-hunting for meat or poaching for trophies.

3.3 Chad

Chad is a land-locked country in the centre of Africa with a surface area of around 1.3 million km^2. Total population is around 6 million with a concentration towards the south of the country. The cultivated area is estimated at 2 million ha, or 1.6 per cent of the total area. Eighty-five per cent of the population engages in agricultural activities for a living. The rural sector contributes 80 per cent of GNP.

3.3.1 Climate and water resources

Average rainfall is estimated at 348mm/year, but shows large variations in total annual rainfall as well as geographical uniformity. Droughts occur frequently and the cultivated area and yields per hectare depend heavily on rainfall.

Three major climatic zones can be distinguished:

- The Sudan zone with annual rainfall over 600mm. The zone covers 32 million ha (25% of the total area) and is home to 47 per cent of the population.
- The Sahel zone with rainfall between 300–600mm, covering around 36 million ha. Almost half the population lives in this zone (51%).
- The Sahara zone, where rainfall is lower than 300mm/yr. It covers 47 per cent of the total area and is inhabited by 2 per cent of the population.

Water resources fall into two categories:

- Rivers, both permanent and seasonal. The Logone, originating in Cameroon, and the Chari, which has its source in the Central African Republic, are the major water courses in the south of the country and supply water to Lake Chad.
- Lake Chad, located in the west of the country, together with small lakes of minor importance (Lake Fitri, Lake Léré).

All water resources depend heavily on rainfall and thus show large variations in availability. In northern Chad some fossil groundwater is the only available water source.

A treaty with Cameroon on water withdrawals from the communal Logone River limits water withdrawal to $10m^3/s$ in December and to $5m^3/s$ from January to April. This limits the irrigated rice area in the dry season to around 3,000ha for both countries.

Table 3.5 Water demand forecast for Chad

IWMI Characteristics	**Units**	**1995**	**2025**	**Annual growth** (%)
Population	million	6.7	13.5	2.4
Total cereal consumption	m mt	1.0	2.4	2.9
Cereal production	m mt	1.0	2.2	2.8
Irrigated cereal area	m ha	0.00	0.00	1.1
Rain-fed cereal area	m ha	1.51	2.37	1.5
Total cereal area	m ha	1.51	2.37	1.5
Net irrigated area	m ha	0.0	0.0	1.0
Gross irrigated area	m ha	0.0	0.0	1.0
Primary irrigation supply	km^3	0.1	0.1	33
Total water withdrawals	km^3	0.17	0.32	2.0
Total primary water supply	km^3	0.1	0.2	Total growth
Total PWS as % of PUWR	%	0.5	0.8	61
Scarcity level	Economic			

Source: Molden 2000
m mt = million metric tons
m ha =- million hectares

Table 3.6 Irrigation data for Chad

Irrigation potential	1994	335,000ha
Irrigation		
1 Area equipped for irrigation	1988	14,020ha
- surface irrigation	1988	10,820ha
- sprinkler irrigation	1988	3,200ha
- micro-irrigation		0ha
% of area irrigated from groundwater		
% of area irrigated from surface water		
% of equipped area actually irrigated	1988	92%
2 Spate irrigation		
3 Equipped wetland and inland valley bottoms		
4 Other cultivated wetland and inland valley bottoms	1988	21,400ha
5 Flood recession cropping areas	1988	78,000ha
Total water managed area (1+2+3+4+5)	1988	113,420ha
- as % of cultivated area	1988	5.7%
-power irrigated area as % of water managed area	1988	5.3%
Full or partial control schemes		
Large schemes	1988	9,250ha
Medium schemes		
Small schemes	1988	4,770ha
Total number of households in irrigation		
Irrigated crops		
Total irrigated grain production		71,828T
As % of total grain production		6%
Harvested crops under irrigation		
- rice	2002	27,430ha
- sugar cane	2002	3,000ha
- vegetables	2002	3,000ha
- sorghum in flood recession areas	1988	78,000ha
- wheat	2002	2,000ha

Source: FAO 1997b

3.3.2 Irrigation development

According to estimates by CILSS (‘Comité permanent inter-états de lutte contre la sécheresse dans le Sahel’), the area that can be developed for irrigation is around 335,000ha, of which 200,000ha are located in the Sahel zone and 135,000ha in the Sudan zone. Other estimates for

potential irrigation arrive at 935,000ha, but these figures seem to be less realistic as they involve dam construction, do not take into account the environmental impacts on Lake Chad, and tend to overestimate the irrigation potential of the oases in the Sahel zone.

Table 3.7 Different irrigation methods and types of management

Water control	Irrigation method	Major crop	Irrigated area (ha)
Full control	Pump (State)	Rice	500
	Pump (NGO)	Rice	230
	Pump	Vegetables, wheat	500
	Polder with pumping	Vegetables, wheat	250
	Pivot	Sugarcane	3,200
	Gravity with pump	Wheat and date palms	2,000
	Shadouf	Vegetables, fruit trees	2,040
		Sub-total	**8,720**
Partial control	Gravity	Rice	1,900
	Traditional systems	Rice	3,400
		Sub-total	**5,300**
Flood recession areas	Flood recession	Sorghum, tomatoes	70,000
	Flood recession	Maize	8,000
		Sub-total	**78,000**
Fadama	Traditional systems	Rice	21,400
			Total 113,420

Source: FAO 1997b

In the rice schemes with full control, double-cropping is possible, but is practised on only 28 per cent.

Development of water resources management

At the start of irrigation development, large schemes were laid out for cereal production. However, most of these schemes have broken down and are in need of rehabilitation. Recent irrigation development has concentrated on the construction of small schemes with a higher degree of farmer participation. Special emphasis has been laid on the development of methods to increase the productivity of shallow wells in the Sahel zone.

3.3.3 Agriculture

Millet, sorghum, rice, wheat and maize are the main cereal crops in Chad and occupy around 90 per cent of the cultivable area. The remaining area is used for the production of cash crops such as sugarcane and cotton. The major agricultural activities are located in the south of the country.

Under the irrigation schemes with full control, 4.5t/ha of paddy rice can be achieved, with a reduction to 3t/ha for schemes with partial control. Under the traditional schemes 2t/ha can be obtained under favourable conditions, while 0.5 to 0.8t/ha are more common.

Figure 3.2 Chad crop calendar

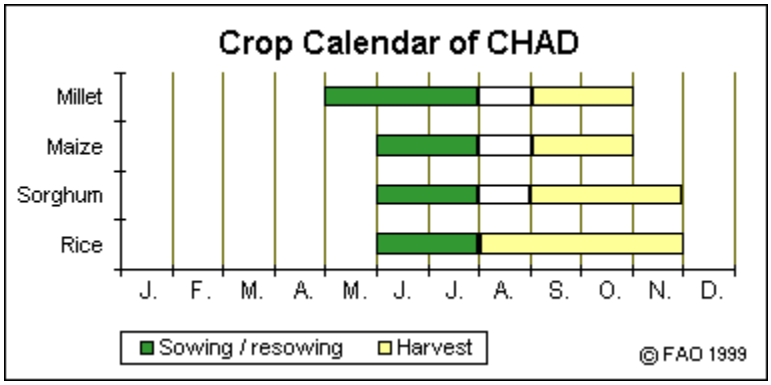


Figure 3.3 Rice and wheat cultivation areas in Chad

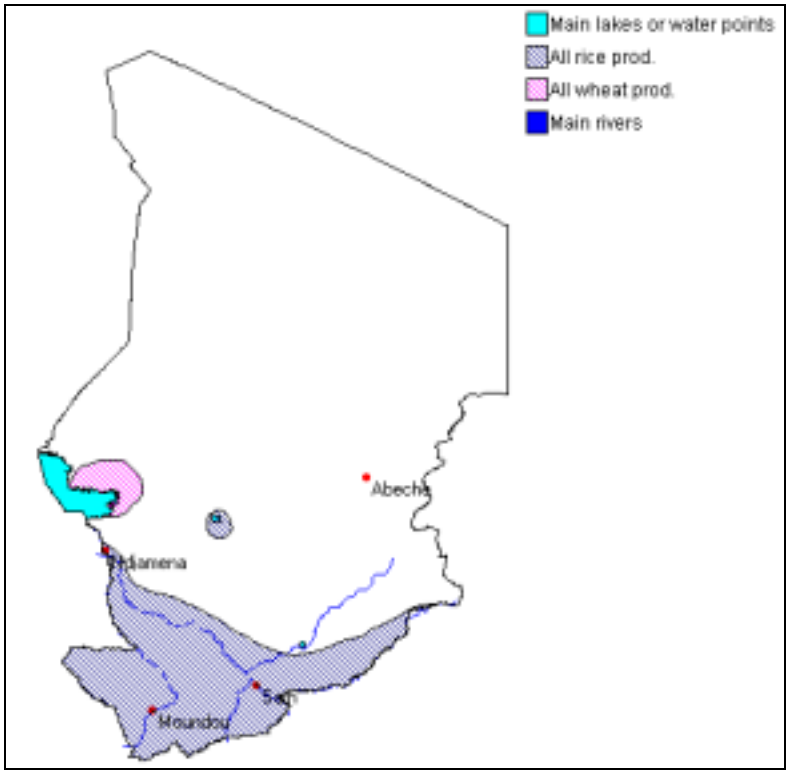


Table 3.8 Water requirements for major irrigated crops in Chad

Crop	**Location**	**(Trans)planting date**	**Total cultivation requirements**	**Irrigation requirements** (mm/ha)
Rice	N'Djamena	15/7	901	547
	Moundou	15/7	781	281
	Sarh	15/7	853	320
	N'Djamena	1/12	961	957
	Moundou	1/12	898	876
	Sarh	1/12	1,007	986
Sugar	Moundou	15/6	1,693	1,127
Wheat	N'Djamena	15/12	549	549
Vegetables	N'Djamena	1/12	453	453

Table 3.9 Irrigated crop area in Chad

Irrigated area (1,000 ha)		**Crop area as % of the total area equipped for irrigation, by month**											
		J	F	M	A	M	J	J	A	S	O	N	D
Wheat	2	14	14	14	14	14							
Rice	10						71	71	71	71	71		
Sugarcane	3	21	21	21	21	21	21	21	21	21	21	21	21
Vegetables	3	21	21	21	21								21
All irrigated crops	18	57	57	57	57	36	93	93	93	93	93	21	43
Equipped for irrigation	14												
Cropping intensity	129												

Table 3.10 Agricultural water withdrawal in Chad

Total Renewable Water Resources (TRWR)	43km^3
Irrigation water requirements	0.07km^3
Water use efficiency percentages	35%
Water withdrawal for agriculture	0.19km^3
Water withdrawal as % of TRWR	0%

Source: FAO AQUASTAT

Table 3.11 Water requirement per crop in Chad

Crop	**Location**	**Season**	**Area** (ha)	**CWR** (mm/ha)	**Efficiency** (%)	**Total crop** (million m^3)
Wheat	n/a	Dry	2,000	549	35	31.4
Rice	n/a	Wet	10,000	850	35	242.9
Sugarcane	n/a	wet/dry	3,000	1,127	35	96.6
Vegetables	n/a	Dry	3,000	453	35	38.8
Total						**409.7**

4 CONCLUSIONS FOR THE NIGER RIVER AND LAKE CHAD BASINS

4.1 Irrigated agriculture

WWF's Living Waters Programme is working on two major river basins in West Africa: the Niger River Basin and the Lake Chad Basin. This study has assessed which countries are situated in these basins and their respective surface areas in each of the basins. Data were collected (from FAO's AQUASTAT system) on major irrigated crops, their water requirements in the wet and dry seasons, and the area under cultivation in the wet and dry seasons. Calculations were then carried out to establish the total water requirement per crop, using FAO's CROPWAT system. Total areas for irrigated crops in West Africa were assembled from individual country data (FAO AQUASTAT)(see Table 4.1).

Table 4.1 Irrigated crop areas in West Africa

Country		Wheat	Rice	Sugarcane	Vegetables	Fruits	Millet	Sorghum	Groundnut	Cotton	Maize
Benin			10	1							
Burkina Faso			21	4	6	2					
Cameroon			12		15	5					
Chad		2	10	3	3						
Côte d'Ivoire			14	20	4	6					
Gambia			2								
Ghana			12								
Guinea			65		20						
Liberia					2						
Mali		4	213	4	3		12	12	2		
Niger		2	30	6	12				32	3	
Nigeria		50	10	26	152						19
Senegal			34	8	9	8					5
Sierra Leone			19	2	9						
Togo			2	1	3	1					
Total	**(000ha)**	**58**	**454**	**75**	**238**	**22**	**12**	**12**	**34**	**3**	**24**
	(%)	**6.2**	**48.7**	**8.0**	**25.5**	**2.4**	**1.3**	**1.3**	**3.6**	**0.3**	**2.6**

Source: FAO AQUASTAT

Rice is the main irrigated crop, in both the wet and dry season (48.7%), followed by vegetables (25.5%), which are cultivated mainly in the dry season. Sugarcane comes third (8%), followed by wheat (6.2%).

Table 4.2 Water consumption by four major crops in the Niger River Basin

	Rice		Vegetables		Sugarcane		Wheat	
	ha	million m^3	ha	million m^3	ha	million m^3	ha	million m^3
Mali	2,800	631.0	3,000	59.0	4,000	200.0	4,000	112.0
Niger	30,000	1,050.0	12,000	278.4	6,000	493,4	3,000	72.6
Nigeria	374,000	10,800.0	100,000	1,776.7	26,000	1,295.7	50,000	1,000.0
Total	**406,800**	**12,481**	**115,000**	**2,144.1**	**36,000**	**1,989.1**	**57,000**	**1,184.6**

Nigeria, Chad and the Central African Republic are the main countries in the Lake Chad Basin from a surface runoff point of view. For Nigeria, however, no specific data are available for the crops cultivated in the Lake Chad Basin. Some of the water withdrawals in the Niger River Basin are actually withdrawals from the Lake Chad Basin, but for the purposes of this study more detailed information on actual volume was unavailable. In the Central African Republic irrigation development occurs mainly on the Oubangui River, which drains towards the Zaire River. An estimate of the total withdrawals from the Lake Chad Basin are presented in Table 4.3.

Table 4.3 Water consumption by four major crops in the Lake Chad Basin

	Rice		Vegetables		Sugarcane		Wheat	
	ha	million m^3	ha	million m^3	ha	million m^3	ha	million m^3
Chad	10,000	242.9	3,000	38.8	3,000	96.6	2,000	31.4

When considering these figures for the two river basins, it should be kept in mind that in Africa south of the Sahara agriculture is still mainly rain-fed (80%) and that increases in irrigated area, although apparently substantial in terms of surface area, are in fact relatively small when compared to rain-fed cultivated area (see also Table 4.4).

4.2 Future water demand

IWMI Working Paper No.32 *Water for Rural Development* was used to collect information on the probable future water situation. The general conclusion for the West Africa region is that there will be economic water scarcity – i.e. primary water supply (PWS) less than 60 per cent of potential utilizable water resources (PUWR) – with a requirement to increase PWS by more than 25 per cent over current levels.

Table 4.4 Water demand forecasts for four West African countries

	Irrigated cereal area (million ha)	**PWS** (km^3)	**Rain-fed cereal area** (million ha)	**PUWR** (km^3)
Mali				
1995	0.12	1.18	2.75	76.5
2025	0.16	1.56	4.32	
Increase (%)	33%	35%	57%	
Niger				
1995	0.03	0.7	6.49	28.2
2025	0.05	1.3	10.83	
Increase (%)	66%	90%	67%	
Nigeria				
1995	1.06	5.0	16.75	158.3
2025	1.43	7.6	26.41	
Increase (%)	35%	53%	58%	
Chad				
1995	0.00	0.17	1.51	25
2025	0.00	0.32	2.37	
Increase (%)		54%	36%	

Source: Molden 2000

5 THE ZAMBEZI RIVER BASIN

5.1 Introduction

The Zambezi Basin is the fourth-largest river basin of Africa, after the Congo/Zaire, Nile, and Niger Basins. Its total area represents about 4.5 per cent of the entire continent and spreads over the eight countries listed in Table 5.1. The Zambezi River flows eastwards for about 3,000km from its sources to the Indian Ocean.

Table 5.1 The Zambezi Basin: areas and rainfall by country

Country	Total area of the country (km^2)	Area of the country within the basin (km^2)	As % of total area of basin (%)	As % of Total area of country (%)	Average annual rainfall in the basin area (mm)		
					min.	max.	mean
Angola	1,246,700	235,423	17.4	18.9	550	1,475	1,050
Namibia	824,900	17,426	1.3	2.1	545	690	630
Botswana	581,730	12,401	0.9	2.1	555	665	595
Zimbabwe	390,760	213,036	15.8	54.5	535	1,590	710
Zambia	752,610	574,875	42.5	76.4	600	1,435	955
Tanzania	945,090	27,840	2.1	2.9	1,015	1,785	1,240
Malawi	118,480	108,360	8.0	91.5	745	2,220	990
Mozambique	801,590	162,004	12.0	20.2	555	1,790	905
For Zambezi Basin	1,351,365		100.0		535	2,220	930

Source: FAO 1997b

5.1.1 Rivers and discharges

The Zambezi River rises in the Kalene hills in north-western Zambia and flows northward for about 30km. It then turns west and south to run for about 280km through Angola and re-enters Zambia with an annual discharge of nearly $18km^3$. It then flows southwards through marshy plains. In the south-west of Zambia the river forms the border between Zambia and the Eastern Caprivi Strip of Namibia for some 130km.

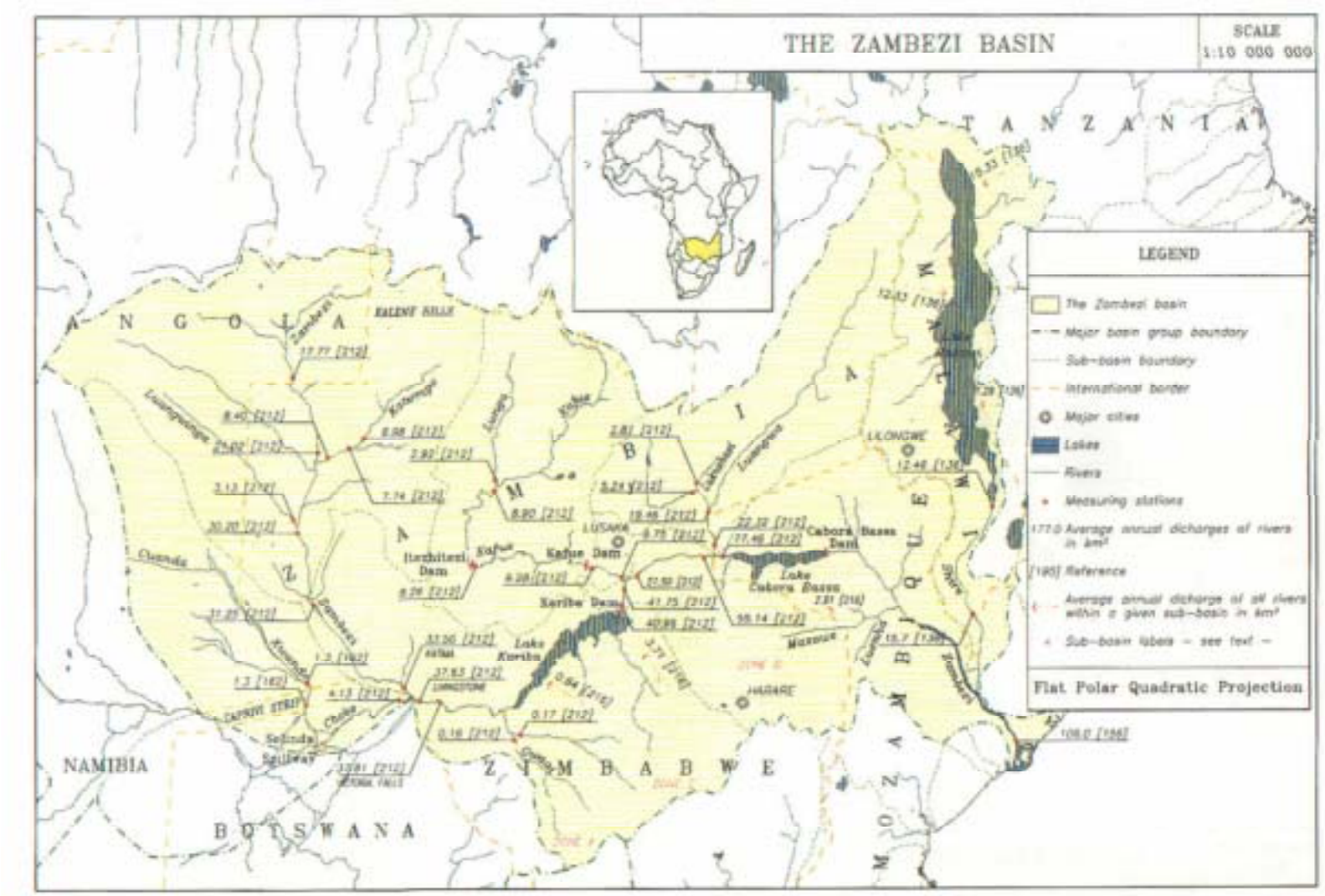
The Chobe tributary originates in Angola, crosses the Caprivi Strip with an annual discharge of about $1.3km^3$, then forms the border between Namibia and Botswana and enters Botswana to flow southwards for about 75km until it meets the Selinda spillway, along which runoff from the Okavango Delta occurs in high flood years. The Chobe then turns east again, forming the border between Namibia and Botswana, flowing through a swampy area into the Zambezi River at the border point between Namibia, Botswana, Zimbabwe, and Zambia. Its annual discharge is about $4.1km^3$. At this point the annual discharge of the Zambezi River is 33.5 km^3.

The Zambezi then forms the border between Zambia and Zimbabwe, here reaching its greatest width at more than 1.3km before its waters plunge over the Victoria Falls. It continues to form the border between Zambia and Zimbabwe until it enters Mozambique.

There are two major man-made lakes on the Zambezi River: Lake Kariba on the border between Zambia and Zimbabwe, and Lake Cabora Bassa in Mozambique.

Downstream of Lake Kariba the Kafue River, a major tributary originating in the north of Zambia, flows into the Zambezi River with a discharge of about $10km^3$/year.

Figure 5.1 The Zambezi River Basin



Source: FAO 1997

Further downstream, at the border with Mozambique, the Luangwa River flows into the Zambezi with an annual discharge of over 22km^3. This tributary originates in the north-east of Zambia. The total discharge entering Lake Cabora Bassa from Zambia is estimated at 77.5km^3/year.

Leaving the lake, the Zambezi River flows south-eastwards and at this point takes in water from its last great tributary, the Shire, which has an annual discharge of nearly 16km^3. The Shire drains Lake Malawi (also called Lake Nyasa) about 450km to the north. The northern part of Lake Malawi forms the border between Tanzania and Malawi, and the southern part the border between Mozambique and Malawi. The total flow into the lake is estimated at about 29km^3/year, 53 per cent of which comes from Tanzania, 43 per cent from Malawi, and 4 per cent from Mozambique. Total outflow from the lake along the Shire River in the south is 12.5km^3/year. The level of the lake has fluctuated by 6m since the 1900s, the lowest level occurring in 1917 and its highest level in 1980.

At its mouth, the Zambezi River splits into a wide, flat, marshy delta. The annual discharge flowing to the sea is estimated at 106km^3.

Annual rainfall in the basin decreases from almost 1,800mm in the north to less than 550mm in the south. Both Botswana and Namibia are rather dry countries and only 2 per cent of each of these countries is situated in the basin. However, rainfall in these parts, at around 600mm/year, is higher than the countries' average, which is 400mm/year for Botswana and only 280mm/year for Namibia.

5.1.2 Irrigation potential and water requirements

For **Angola** the irrigation potential has been estimated at 700,000ha.

The irrigation potential for **Namibia** has been estimated at between 45,000 and 50,000ha, of which 10,000ha is allocated to a sugarcane project in the Caprivi Strip. Flood-recession cropping is evaluated at 1,000ha in this area.

For **Botswana,** irrigation potential in the Zambezi Basin ranges from 80ha, based on identified soil types and excluding the need for major water development works, to 11,080ha, including the need for major water development works. Of this, 10,000ha are located in the Padamatenga plains outside the Zambezi Basin in the north-east, where there is a plan to transfer water from the Chobe tributary. For the purposes of this study, 1,080ha of this has been retained as irrigation potential.

According to the irrigation sub-sector review in **Zimbabwe**, of the total internal surface water resources of 13.1km^3/year, 3.6km^3 is already committed annually for domestic, industrial, mining, and irrigation use. Of the remaining 9.5km^3, at least 3.0km^3 is reported to be inaccessible. Of the remaining 6.5km^3, about half is considered as potentially available for irrigation development, of which 1.94km^3 occurs in the Zambezi Basin. In addition, there is the flow of the Zambezi River.

The Zambezi Basin in Zimbabwe has been divided into three hydrological zones. In the western and eastern zones, suitable soil is the limiting factor, while in the middle zone, water is the limiting factor. At present, 70,045ha have been developed or planned for irrigation. Based on available land and water resources, and assuming (for the purposes of this study) an irrigation water requirement of 10,500m^3/ha per year, it would be possible to irrigate another 95,355ha, bringing the total up to 165,400ha. However, assuming a water requirement of 18,000m^3/ha per

year, as proposed in the irrigation sub-sector review, this would reduce the potential to 131,000ha.

In **Zambia,** irrigation potential is estimated at 523,000ha. However, of this total no details on location are available for 168,000ha, comprised of 100,000ha of *dambo* (wetlands), 60,000ha irrigated by renewable groundwater, and 8,000ha of commercial farms. The irrigation potential in the Zambezi Basin is estimated at 422,000ha, as shown in Table 5.2.

Table 5.2 Irrigation potential in the different Zambezi sub-basins in Zambia

Types of irrigation	Upper Zambezi River Basin (ha)	Kafue River Basin (ha)	Luangwa River Basin (ha)	Total for Zambezi River Basin (ha)
Located	112,000	165,000	14,000	291,000
Groundwater	15,000	15,000	15,000	45,000
Commercial	2,000	2,000	2,000	6,000
Dambos (wetlands)	30,000	20,000	30,000	80,000
Total	159,000	202,000	61,000	422,000

Source: FAO 1997b

In view of the rugged, very steep terrain of the southern highlands of **Tanzania** draining to Lake Malawi, no real possibilities for irrigation development exist and consumptive water use would be limited to domestic and industrial water supply. The relatively small volumes involved would not change the mean annual flow into the lake from Tanzania.

Malawi has abundant land where soil and topography are suitable for irrigation, but only limited areas that coincide with easily obtainable water from perennial streams. A feature of the flat lake shore and the Shire River valley are large areas of marsh, swamps and lagoons, which are poorly drained and flood susceptible areas. The irrigation potential for the whole of Malawi has been estimated at 100,000ha plus 61,900ha of *dambos*. An estimated 160,900ha of this total are located in the Zambezi Basin.

The irrigation potential of 2 million ha given in the literature for **Mozambique** includes the whole Zambezia province, part of which lies outside the Zambezi Basin. The area lying within the basin is estimated at 1.7 million ha. Table 5.3 summarizes the figures for the whole basin.

Table 5.3 Zambezi Basin: irrigation potential, water requirements and areas under irrigation

Country	Irrigation potential (ha)	Gross potential irrigation water requirement		Area under irrigation (ha)
		per ha (m^3/ha per year)	total (km^3/year)	
Angola	700,000	13,500	9,450	2,000
Botswana	1,080	5,500	0,006	0
Malawi	160,900	13,000	2,092	28,000
Mozambique	1,700,000	11,000	18,000	20,000
Namibia	11,000	5,000–25,000	0,255	6,142
Tanzania	0	11,000	0,000	0
Zambia	422,000	12,000	5,064	41,400
Zimbabwe	165,400	10,500	1,737	49,327
Sum of countries	**3,160,380**		**37,303**	**146,869**

Source: FAO 1997b

For the Zambezi Basin as a whole, the water requirements for irrigated agriculture are far less than the amount of water available. Attention has to be paid, however, to the Chobe tributary, originating in Angola and shared by Angola, Zambia, Namibia and Botswana. The Zambezi River entering Zambia from Angola in the north has an annual discharge of 18km^3, which is twice the volume needed to irrigate the 700,000ha potential of Angola. The Chobe tributary, however, has an annual discharge of only 1.3 km^3 when leaving Angola, so if a large part of the land with irrigation potential in Angola is utilized, or if part of the irrigation potential of 159,000ha in the upper Zambezi Basin in Zambia is located in this sub-basin, problems of water scarcity may arise for Namibia and Botswana, even though irrigation potential there is very limited compared to the other countries.

Further downstream, no particular problems are expected in terms of water resources. However, water regulation would be necessary for full development of the potential.

5.2 Ecoregions in the Zambezi River Basin

Five of WWF's Global 200 Ecoregions are located in the region: Central and Eastern Miombo Woodlands; Zambezian Flooded Savannahs; Southern Rift Montane Woodlands; East African Mangroves; and Rift Valley Lakes.

Central and Eastern Miombo Woodlands
Covering much of central and southern Africa, taking in parts of Angola, Malawi, Mozambique, Zambia, and Zimbabwe, the ecoregion is dominated by the Central African Plateau. However, portions of the ecoregion are characterized by flat or rolling hills with local areas of higher relief. Important in terms of species richness, species found here are typical of miombo woodlands, and in the southwest, baikiaea woodlands. In particular, there is a high diversity of large mammals, including populations that make up the well-known East African savanna mammal fauna. In addition, some areas support relatively undisturbed natural communities of these plants and animals.

General threats: Much of the ecoregion remains sparsely settled and resulting human population pressures are minimal. Large areas of habitat are relatively intact. Future population growth and associated activities are a potential threat.

Specific threats: In Zambia the expansion of agricultural areas in Central, Eastern, Lusaka and Southern provinces threatens ecological zones. Apart from having a high irrigation potential, 50 per cent of this area has been set aside for National Parks, and game management and forest reserves. Loss of biodiversity as a result of dwindling miombo woodlands, pollution from agro-chemicals, and changes in aquatic vegetation are some of the consequences of increased agricultural activity in the area (WWF-Zambia pers. comm.).

Zambezian Flooded Savannahs
The Okavango Delta and associated flooded grasslands and savanna habitats that constitute this ecoregion are among the most important biological sites in Africa, covering parts of Angola, Malawi, Mozambique, and Zambia. Besides a rich diversity of birds, this ecoregion supports significant populations of large mammals, such as the African elephant.

General threats: Human populations in these wetland areas are generally low, due largely to the high density of disease-carrying organisms (especially malaria mosquitoes, tsetse flies, and aquatic snails that transmit bilharzia). Some of the threats include the spread of cattle ranching,

and contamination from heavy metals, insecticides and agricultural runoff. Water diversions for irrigation and hydroelectric dams have already affected some floodplain systems, and are threatening others.

Southern Rift Montane Woodlands

Lying across parts of Malawi, Mozambique, Tanzania, and Zambia, this ecoregion is comprised of a number of disjunct mountains and ranges – some peaks rise to 3,000m – that support a mosaic of habitats naturally fragmented into areas of grassland and forest. These habitats, combined with the high degree of isolation, support a rich array of endemic species of plants and animals, including some that are restricted to single mountains. The endangered Mulanje cedar (*Willddringtonia whytei*) is among the most well-known plant species found in this ecoregion.

General threats: Much of the ecoregion has been converted to tea plantations and other agricultural uses. For the most part, what remains of these forests has been protected since the 1920s. However, present day forest and woodland conversion to agriculture is still a concern. Other threats include firewood collection, wild fires, and invasion by alien species.

East African Mangroves

Compared to South-East Asia, African mangroves support relatively low species diversity. However, the mangroves of East Africa (principally Mozambique) support the greatest floral and faunal diversity of the continent's mangroves, as well as providing habitat critical for maintaining nearby coral reefs and populations of fish and birds. In addition, many migratory bird populations rely on the mangroves and surrounding wetlands as stopover and wintering habitat.

General threats: Mangroves are being converted to rice farms, salt pans, aquaculture, and urbanization. They also receive untreated waste discharges, as well as oil and industrial pollution, silt, and pesticides. Damming of rivers is also threatening mangroves by increasing salinity during the dry season.

Rift Valley Lakes

The Great Rift Valley, created by the moving of tectonic plates beneath the surface of Africa, has many lakes that harbour extraordinary assemblages of endemic species. Some, such as Lakes Malawi (>800m deep) and Tanganyika (>1,400m deep), have formed in the rifts, while the vast Lake Victoria is located in a shallow depression. Several small soda lakes in the eastern part of the valley represent a globally rare habitat type, and support upwards of 800 cichlid fish, which represent a classic example of evolutionary adaptation akin to the Galapagos. The lakes also support high numbers of endemic molluscs and crustaceans. Lake Tana hosts one of only two known flocks of cyprinid fish species in the world.. The Rift Valley Lakes ecoregion falls across parts of Malawi, Mozambique, and Zambia.

General threats: Over-fishing has led to declines in species abundance. Runoff from urban areas, pollution from industrial activities, and deforestation on steep banks also threaten the health of the lakes. Harvesting of species for the aquarium trade is a potential threat to fish populations, although the impact is as yet unknown.

5.3 Zambia

Zambia is a land-locked country covering an area of 752,610km^2. Total cultivable land is estimated to be over 16 million ha, or 21.7 per cent of the total area. About 1 million ha is cultivated, which is 6.3 per cent of the cultivable area and 1.4 per cent of the total area.

The population is about 10.4 million (2000), with an annual growth of 3.2 per cent. Average population density is 14.2/km^2. The rural population is estimated at 62 per cent. The mining sector's contribution to GDP has declined from 36 per cent in 1970 to 8 per cent in 1990, while manufacturing has almost doubled from 24 per cent to 43 per cent. The agricultural sector has enormous potential for expansion, given appropriate economic incentives, ensuring security of land tenure, and modifying taxation. About 60 per cent of the population is currently dependent upon agriculture, which provides employment to 67 per cent of the labour force.

5.3.1 Climate and water resources

Mean annual rainfall is 1,011mm and is lowest in the south at 750mm/year, increasing uniformly to 1,400mm/year in the north. Most of the cropping land in the central zone receives 900mm to 1,200mm annually. Rainfall has a single annual peak, influenced by the inter-tropical convergence zone, and is concentrated in the period November to April. The climate is cool and dry from May to August, and becomes hotter with the onset of the rains.

Zambia has five major river systems:

- the Upper Zambezi, which rises in Angola and flows to Mozambique after forming the border with Zimbabwe
- the Kafue and the Luangwa River systems, which together drain most of the central part of the country and empty into the Zambezi
- a small drainage area of the Tanganyika River in the north
- the Luapula River, which flows into Zaire.

Average annual water resources are estimated at around 116km^3, of which about 80km^3 originate within Zambia. Groundwater resources are estimated to be about 47km^3/year. There are extensive limestone aquifers covering an area of 25,000km^2, extending north-west from the capital, Lusaka.

Table 5.4 Water demand forecast for Zambia

IWMI Characteristics	Units	1995	2025	Annual growth (%)
Population	million	8.2	14.9	2.0
Total cereal consumption	m mt	1.6	3.3	2.5
Cereal production	m mt	1.2	2.9	3.0
Irrigated cereal area	m ha	0.02	0.04	2.0
Rain-fed cereal area	m ha	0.75	1.37	2.0
Total cereal area	m ha	0.78	1.41	2.0
Net irrigated area	m ha	0.1	0.2	2.0
Gross irrigated area	m ha	0.1	0.2	2.0
Primary irrigation supply	km^3	0.3	0.5	63
Total water withdrawals	km^3	0.8	1.56	2.2
Total primary water supply	km^3	0.5	0.9	Total growth
Total PWS as % of PUWR	%	1.0	1.7	73%
Scarcity level	Economic			

Source: Molden 2000
m mt = million metric tons
m ha = million hectares

The total dam capacity is approximately 200km^3, of which major dams (including Kariba) account for 188km^3. The country's energy requirements are mainly provided by hydropower

(Kariba and Kafue), from a total installed capacity of 1,643.5MW and annual generation of 10,500GWh.

5.3.2 Irrigation development

Irrigation potential, based on water and soil resources, has been estimated to be 1.4 million ha. Of this 520,000ha, including existing *dambo* and irrigated areas, could be developed economically in the future.

The total area of managed water is about 146,400ha. At present, some 46,400ha are equipped for full or partial irrigation control. A total of 61,900ha of crops are grown annually by these schemes, of which only 46,400ha are irrigated. Two crop rotations are grown each year on 15,500ha: in winter, wheat (12,077ha) and barley (2,200ha); and in summer, rain-fed soybean (12,500ha) and cotton (3,000ha). All irrigation is from surface water, either from weirs, pumped from rivers, or from dams, except for some 2,500ha which is reported to be irrigated from groundwater. Surface irrigation (furrow and basin) is practised on 28,400ha, there are 17,200ha under sprinkler and centre pivot systems, and 800ha are fed by drip systems. Some 259ha of land under surface irrigation need rehabilitation. There are no standard criteria for defining irrigation farming in Zambia, but three main types are used in the irrigation sub-sector:

- **Commercial estates** (18,000ha): These include both large- and small-scale company estates and commercial farms growing a range of high-value crops, including coffee, fruit, and vegetables, as well as wheat and barley.
- **Parastatal and semi-parastatal** (12,400ha): Large-scale farming development with varying degrees of government control, such as the Nakambala Sugar Estate, which is owned by Zambia Sugar Corporation and managed under contract by a commercial company, Illovo Sugar of South Africa. As a variation of the conventional parastatal concept, the government develops and operates estates in partnership with commercial investors such as the Commonwealth Development Corporation, International Finance Corporation, commercial banks and other privately owned companies.
- **Smallholder** (16,000ha): Of this area, 3,669ha have been established by the government as formal schemes in areas of traditional land tenure, on which farmers are allocated 0.5–1.0ha plots and where the government has continued to accept responsibility for operation and management. However, performance has been disappointing and 13 of the 32 schemes have been shown to be non-operational.

A further 100,000ha or so are under so-called traditional irrigation in wetland areas which have been used for growing rice, fruit and vegetable for several generations without government intervention.

Trends in water resources management

Apart from traditional wetland farming, no significant irrigation development in Zambia occurred until independence in 1964, when a pilot scheme of 120ha was established at Nakambala.

Following droughts in 1982 and 1985, together with the decline in world copper prices, the government placed more emphasis on agriculture. There was an upsurge in irrigation development, mainly in the commercial and semi-parastatal categories, and by the late 1980s about 35,000ha were under irrigation. By 1991 this had grown to 46,400ha.

Table 5.5 Irrigation data for Zambia

Irrigation potential	1992	520,000ha
Irrigation		
1 Area equipped for irrigation	1992	46,400ha
- surface irrigation	1992	28,400ha
- sprinkler irrigation	1992	17,200ha
- micro-irrigation	1992	800ha
% of area irrigated from groundwater	1992	5.4%
% of area irrigated from surface water	1992	94.6%
% of equipped area actually irrigated	1992	99.0%
2 Spate irrigation		
3 Equipped wetland and inland valley bottoms		
4 Other cultivated wetland and inland valley bottoms	1992	100,000ha
5 Flood recession cropping areas		
Total water managed area (1+2+3+4+5)	1992	146,400ha
- as % of cultivated area	1992	14.2%
- increase over the last 10 years	1980–1992	8.0%
- power irrigated area as % of water managed area		
Full or partial control schemes		
Large schemes		
Medium schemes		
Small schemes		
Total number of households in irrigation		
Irrigated crops		
Total irrigated grain production	2000	85,835T
As % of total grain production	2000	8.0%
Harvested crops under irrigation	2000	54,000ha
- wheat	2000	11,000ha
- sugarcane	2000	15,000ha
- rice	2000	10,000ha
- vegetables	2000	9,000ha
- cotton	2000	4,000ha
- fruits	2000	5,000ha

Source: FAO 1995, FAOSTAT

A lack of appropriate policies and strategies, and insufficient resources committed by government have been the main constraints facing irrigated agriculture in Zambia. Yet one of the five main objectives in the 1994 Agricultural Sector Investment Programme is to "ensure national food security through dependable annual production of adequate supplies of basic food stuffs" (Policy Framework Paper 1993). Irrigated agriculture, for which land and water resources potential are substantial, offers a viable option for increasing crop production and reducing dependency upon rainfall – and therefore a real means of achieving national objectives.

Specific objectives for the irrigation sub-sector in the investment programme are to:

- promote economically sustainable irrigation systems among small- and large-scale farmers
- expand the area under irrigated agriculture and contribute to increased crop production
- create rural employment and income generation, and
- increase incomes at both national and household levels.

To achieve these goals, the following strategies are being adopted:

- Development of a National Irrigation Water Master Plan to ascertain the full potential for irrigated agriculture in Zambia. (This would be complementary to the National Water Resources Master Plan currently being prepared with Japanese bilateral aid.)

- Strengthening the institutional capacity of the Irrigation Engineering Section to provide an effective irrigation service and training to farmers.
- Encouragement and support for the National Electricity Grid, where economically feasible, to supply potential irrigation areas.
- Support for the development of economically sustainable irrigation infrastructure, including multi-purpose dams.
- Renewal and streamlining of procedures for granting water rights.
- Encouragement of socially and economically viable smallholder irrigation schemes.
- Provision of technical and extension services (such as training in new techniques) to small-scale farmers in rural areas.

Approximately 90 per cent of Zambia is traditional land held under 'customary tenure', with 10 per cent under leasehold tenure. The Ministry of Lands (MoL) holds to the policy that for farming households to improve their living conditions and help build the nation's wealth, farmers should retain title to the rural land they work. The MoL is encouraging the taking out of title deeds (leases) on customary land. This will assist in particular the promotion of smallholder irrigation schemes.

This new process of distribution of leases has been carried out mainly in consultation with traditional authorities, but the Commissioner of Lands retains ultimate authority. By the end of 1991, some 60,000 title deeds to customary land had been issued; the target was to increase the number to one million by 1995/96.

5.3.3 Agriculture

Zambia's principal crops are maize (the staple cereal), sugarcane, cassava, cotton, tomatoes, onions, sunflower seeds, yams, groundnuts, and tobacco. For export, the most important are sugar, cotton, and tobacco. A wide variety of other food crops, including vegetables, pulses and grains, are grown. The strongest production increases in recent years have been in maize, cotton, sunflower seeds, groundnuts, and coffee, a relative newcomer.

Outside drought years, major production increases have been recorded for wheat, which has grown by 15 per cent a year since 1980, coffee, soybeans, and cotton. Wheat production reached a record level of 90,000 tonnes in 1999. The other major grains are millet and sorghum, both of which are smallholder crops. Sugarcane is grown on modern estates (in addition to large-scale smallholder production) for processing into sugar for local consumption and export; in 1995, Zambia was given a quota for sugar exports to the EU.

Tobacco production in 2000 was 3,200 tonnes. Cotton production, by smallholders, was estimated in 2000 at 62,000 tonnes; the lint is sold mostly to local textile factories, with some going for export in good years.

Tea is grown on the state-owned Kawambwa Tea Company estate, while the Zambia Coffee Company produced an estimated 3,000 tonnes of coffee in 2000 on two estates. Horticulture has been expanding, and is seen as a promising export industry, producing vegetables and flowers for shipment to Europe.

<u>Maize</u>

Maize grows on a wide range of soils in every province of Zambia – over 50 per cent of agricultural land is under maize cultivation.

Wheat

Compared to other major crops such as maize, cereal, sunflower and tobacco, wheat production is a relatively new activity in Zambia. In 2000, output was about 75,000 tonnes harvested from some 12,000 hectares. Under irrigation, wheat production has high potential in most areas of Zambia, with a growing season that runs to August or into September. If production was to expand beyond domestic requirements, there is also considerable potential for export to several neighbouring countries.

Figure 5.2 Zambia crop calendar

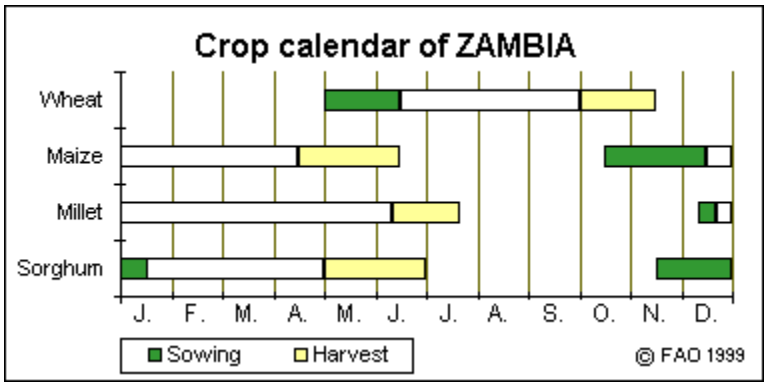
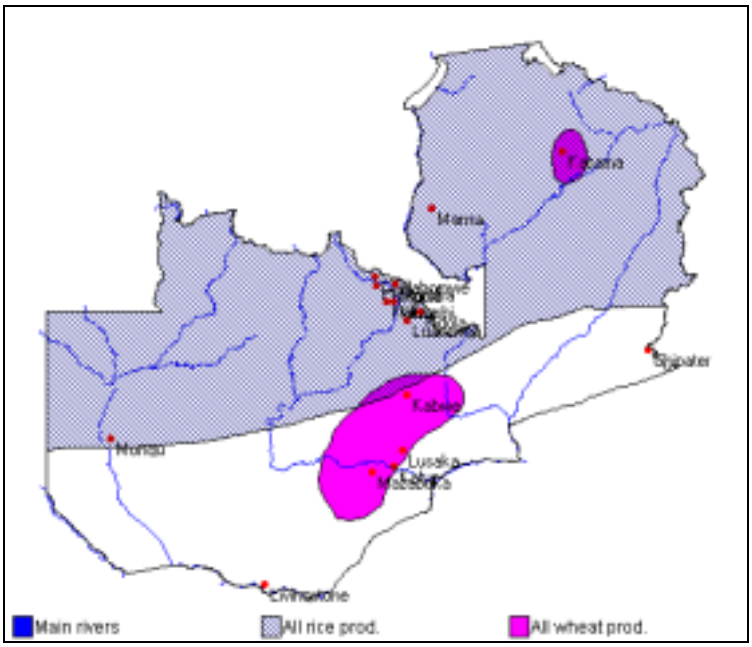


Figure 5.3 Rice and wheat cultivation areas in Zambia



Source: FAO GIEWS

Rice

Large-scale irrigated rice is a relatively new crop to Zambian agriculture. The area under production has been fluctuating, with an annual average of about 10,000ha and an output of about

11,000 tonnes. Good growing conditions exist throughout most of Zambia. Most of the production is located in special rice development areas, which are often far from urban markets. Yields are low: about 900kg per hectare compared to a potential of 4 tonnes. Also, there are areas closer to urban centres which could be developed for rice production. Huge potential for rice export exists within the region, if the quality and quantity produced are improved. The regional deficit in rice requirements is met with imports from other parts of the world.

Table 5.6 Water requirements for major irrigated crops in Zambia

Crop	**Location**	**(Trans)planting date**	**Total cultivation requirements** (mm)	**Irrigation requirements** (mm)
Rice	Kasama	1/12	814	235
	Mongu	1/12	870	312
Sugar	Lusaka	1/12	1,789	1,365
Wheat	Kasama	1/5	465	455
	Kabwe	1/5	440	439
Vegetables	Lusaka	1/5	382	382
Cotton	Mongu	5/11	740	236
Fruits (Mango)	Lusaka	1/12	1,718	1,203

Source: FAO CROPWAT

Table 5.7 Irrigated crop area in Zambia

Irrigated area (1,000ha)		**Crop area as % of the total area equipped for irrigation, by month**											
		J	F	M	A	M	J	J	A	S	O	N	D
Wheat	11					24	24	24	24	24			
Rice	10	22	22	22	22								22
Sugarcane	15	33	33	33	33	33	33	33	33	33	33	33	33
Vegetables	9					20	20	20	20	20			
Fruits	5	11	11	11	11	11	11	11	11	11	11	11	11
Cotton	4					9	9	9	9	9	9	9	
All irrigated crops	54	65	65	65	65	96	96	96	96	96	52	52	65
Equipped for irrigation	46												
Cropping intensity	117												

Source: FAO AQUASTAT

Table 5.8 Agricultural water withdrawal in Zambia

Total Renewable Water Resources (TRWR)	105km^3
Irrigation water requirements	0.26km^3
Water use efficiency percentages	30%
Water withdrawal for agriculture	0.85km^3
Water withdrawal as % of TRWR	1%

Source: FAO AQUASTAT

Table 5.9 Water requirement per crop in Zambia

Crop	**Location**	**Season**	**Area** (ha)	**CWR** (mm/ha)	**Efficiency** (%)	**Total crop** (million m^3)
Wheat	n/a	dry	11,000	450	30	165.0
Rice	n/a	wet	10,000	275	30	91.7
Sugarcane	Lusaka	Wet/dry	15,000	1,365	30	682.5
Vegetables	n/a	dry	9,000	382	30	114.6
Cotton	n/a	Wet	4,000	236	30	31.5

Fruits	n/a	Wet/dry	5,000	1,203	30	200.5
						Total 1,285.7

5.4 Zimbabwe

Zimbabwe is a land-locked country in the Southern African Region covering an area of 390,760km^2. Total population was estimated at about 12.5 million in 2000, of which 65 per cent lived in rural areas.

Agriculture contributes between 30 and 40 per cent to total exports and 14 per cent of GDP, with most crops being produced under rain-fed conditions.

5.4.1 Climate and water resources

Average annual rainfall is 652mm, but ranges from 1,000mm in the Eastern Highlands to around 350 to 450mm/year in the Lowveld in the South. About 90 per cent of precipitation occurs during the period mid-November to early April. The winter season is from April to August, and the hottest and driest period is from September to mid-November.

Zimbabwe is bordered to the north by the Zambezi and to the south by the Limpopo, both rivers flowing into Mozambique. Together with the Save in the east, they collect most of the streams emanating from the Highveld, a plateau which runs diagonally across the country. Most of Zimbabwe's rivers dry up a few months after the rainy season and, by the end of each dry season, major rivers such as the Limpopo and Save become "rivers of sand" with only few scattered pools. It should be noted, however, that the rivers carry large volumes of interflow: during drought years, sand-point abstraction (a technique for extracting water from the sand layers in river beds) is the most reliable form of water supply.

Internally produced water resources amount to about 14km^3/year. The potential yield (probably including external resources) is estimated at about 13km^3/year, of which 29 per cent (3.8km^3/year) is currently used. The estimated groundwater potential is between 1 and 2km^3 annually.

Table 5.10 Water demand forecast for Zimbabwe

IWMI Characteristics	**Units**	**1995**	**2025**	**Annual growth (%)**
Population	million	10.9	14.3	0.9
Total cereal consumption	m mt	2.2	3.5	1.5
Cereal production	m mt	2.3	3.7	1.6
Irrigated cereal area	m ha	0.06	0.09	1.6
Rain-fed cereal area	m ha	1.88	2.16	0.5
Total cereal area	m ha	1.94	2.26	0.5
Net irrigated area	m ha	0.1	0.2	1.5
Gross irrigated area	m ha	0.2	0.3	1.6
Primary irrigation supply	km^3	0.9	1.2	1.2
Total water withdrawals	km^3	1.42	2.24	1.5
Total primary water supply	km^3	1.0	1.5	Total growth
Total PWS as % of PUWR	%	1.6	2.5	52%
Scarcity level	Economic			

Source: Molden 2000
m mt = million metric tonnes
m ha = million hectares

5.4.2 Irrigation development

Land suitable for irrigation in Zimbabwe is estimated to be more than 550,000ha, but water availability reduces this potential to 331,000ha. It is estimated that this development could be achieved in 20 to 30 years.

Irrigated areas have increased substantially in the last 25 years, more than tripling from 60,000ha in 1968 to 191,000ha in 1990, including double-cropped areas. In 1993, irrigated areas (called 'formal irrigation') had been achieved for about 116,600ha, while cultivated wetlands and gardens (called 'informal irrigation') represented about 20,000ha. It is characteristic of Zimbabwean agriculture that there is almost no intermediate position between large- and small-scale farmers. Most of the areas developed for irrigation are large-scale commercial, private and parastatal schemes (covering 107,156ha), while small-scale schemes cover only 9,421ha.

As far as full or partial control irrigation management is concerned, four categories can be distinguished:

- *Large-scale commercial:* operations on land owned by private individuals or groups (93,656ha)
- *ARDA schemes:* (Agricultural and Rural Development Authority): operations by a parastatal organization, mainly on large farms situated on communal (public) lands (13,500ha)
- *Settler farming:* operations by small-scale commercial farmers who are attached to ARDA and sugar estates; they generally do not have title deeds to their plots (3,421ha)
- *Smallholder* farming*:* operations by communal or resettlement farmers who generally irrigate small plots; they do not have title deeds to their plots (6,000ha).

In 1988, 93 per cent of large-scale private irrigated schemes operated areas larger than 50ha, and 62 per cent were larger than 250ha, while the average area of irrigated settler farming was 2.6 ha.

In 1992, about 87,000ha of the equipped area was under sprinkler irrigation (traditionally used on commercial farms), with surface irrigation on most of the remaining area, barring 8,000ha of micro-irrigation. In small gardens, water can also be provided by hand from nearby water pools or hand-dug wells.

Table 5.11 Irrigation data for Zimbabwe

Irrigation potential	1993	331,000ha
Irrigation		
1 Area equipped for irrigation	1993	116,577ha
- surface irrigation	1993	21,144ha
- sprinkler irrigation	1993	87,433ha
- micro-irrigation	1991	8,000ha
% of area irrigated from groundwater		
% of area irrigated from surface water		
% of equipped area actually irrigated		
2 Spate irrigation		
3 Equipped wetland and inland valley bottoms		
4 Other cultivated wetland and inland valley bottoms	1993	20,000ha
5 Flood recession cropping areas		
Total water managed area (1+2+3+4+5)		136,577ha
- as % of cultivated area		
- increase over the last 10 years		
Full or partial control schemes		
Large schemes	1993	93,656ha
Medium schemes		
Small schemes	1993	9,421ha
Irrigated crops		
Total irrigated grain production		
As % of total grain production		
Harvested crops under irrigation		189,780ha
- wheat	2000	56,000ha
- cotton	2000	50,000ha
- sugarcane	2000	40,000ha
- soybean	2000	20,000ha
- maize	2000	9,000ha
- citrus	2000	5,000ha
- barley	2000	5,000ha

Source: FAO 1995, AQUASTAT

Most water for irrigation is pumped from regulated-flow rivers or stored in farm reservoirs. Water is treated as a free commodity. Since 1986, a 'National Blend Price' is charged to commercial farming groups for water from dams, based on the amount of capital investment and operation and maintenance costs.

In 1990, it was estimated that about 40 per cent of the value of the country's nine principal crops came from irrigated cultivation. The major irrigated crops are wheat, cotton, sugarcane, soybean, tobacco and maize. The winter:summer irrigated area ratio is 1:1.6.

Major environmental issues related to irrigation are soil erosion (with severe impacts on communal lands), siltation (of dams, intake structures, pumps, and canals), and water pollution (due to agrochemicals).

Trends in water resources management

In Zimbabwe, the limiting factor in irrigation development is water availability. Provision of water depends almost entirely on expensive storage works. One way in which to increase irrigated area at marginal cost of in-field development, without drawing on public funds, could be to lower the reliability levels of regulated water from 90 to 80 per cent.

Historically, irrigation development has largely been a function of private investment. With the significant exception of the construction of large dams, the private commercial sector is capable

of expanding its irrigated area without specific government support. Present practice within the small-scale commercial farming sector is for the core estate to bear the cost of providing management assistance and services to farmers as part of its overheads.

Communal irrigation is an exercise in community development in which irrigation is the major, but not the only element. Major factors limiting the rate of development are the extent of irrigation experience and the willingness within the community to lend support for the greater good of all. Community development and involvement in the creation of new projects and in training leaders and irrigators is necessarily a slow process.

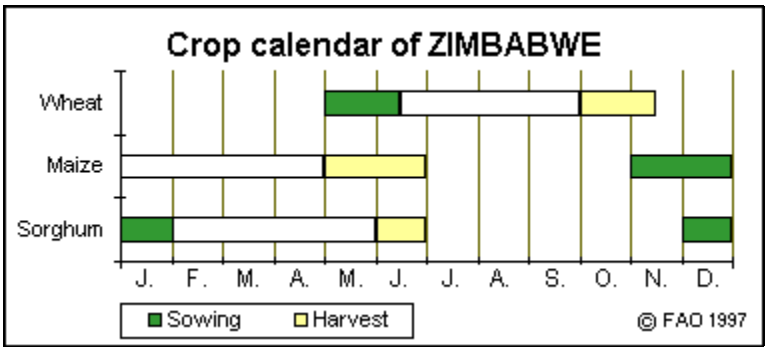
5.4.3 Agriculture

In general, the topography, soils and climate of Zimbabwe are unfavourable for intensive agricultural production. More that 75 per cent of the country is subject to conditions that make rain-fed crop production a risky venture.

Agricultural production patterns in Zimbabwe are dominated by rainfall. Most crops are planted in November/December at the beginning of the rains and harvested between January and April. Winter wheat, barley, and various horticultural products are grown in the dry season under irrigation. Irrigation schemes originally subsidized to achieve wheat self-sufficiency are important in the large-scale sector for the supplementary irrigation of tobacco, maize, cotton, soybeans, groundnuts, and coffee.

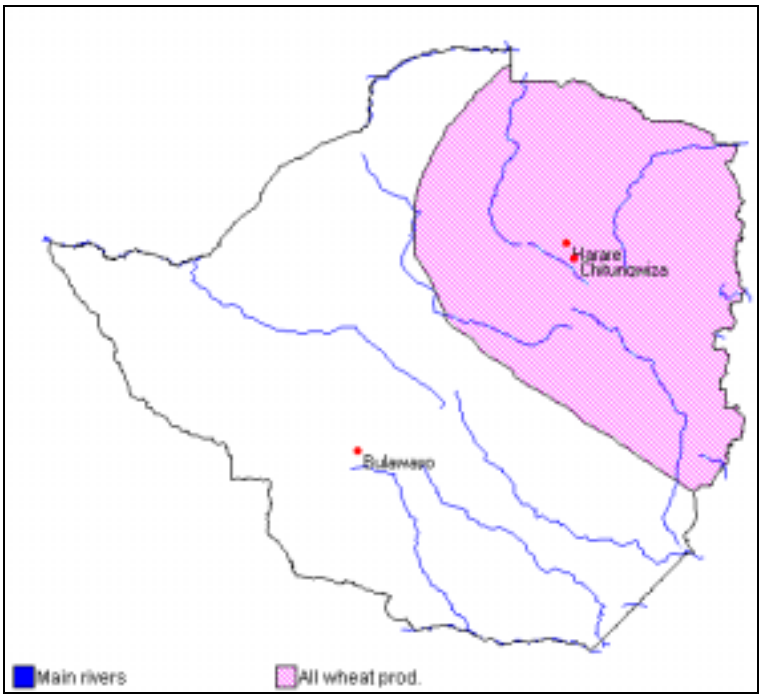
Maize and soybean have low irrigation requirements and are probably only cultivated under irrigation to overcome periods of drought as a result of irregular rainfall distribution. When cultivated under normal rain-fed conditions, no yield reduction as a result of water stress is anticipated.

Figure 5.4 Zimbabwe crop calendar



Source FAO GIEWS

Figure 5.5 Wheat cultivation areas in Zimbabwe



Source: FAO GIEWS

Table 5.12 Water requirements for major irrigated crops in Zimbabwe

Crop	**Location**	**(Trans)planting date**	**Total cultivation requirements** (mm)	**Irrigation requirements** (mm)
Wheat	Harare	1/5	414	412
Barley	Harare	1/5	386	384
Sugarcane	Harare	1/11	1,680	1,110
Citrus	Harare	15/11	1,130	613
Soybean	Harare	15/11	693	65
Maize	Harare	15/11	517	53
Cotton	Harare	1/11	743	210

Source: FAO CROPWAT

Table 5.13 Irrigated crop area in Zimbabwe

Irrigated area (1,000 ha)		**Crop area as % of the total area equipped for irrigation, by month**											
Wheat	56						48	48	48	48	48		
Maize	9						8	8	8	8	8		
Barley	5						4	4	4	4	4		
Sugarcane	40	34	34	34	34	34	34	34	34	34	34	34	34
Vegetables	1						1	1	1	1	1		
Citrus	5	4	4	4	4	4	4	4	4	4	4	4	4
Soybean	20	17	17	17								17	17
Cotton	50	43	43	43	43	43						43	43
All irrigated crops	186	98	98	98	81	81	99	99	99	99	99	98	98
Equipped for irrigation	117												
Cropping intensity	159												

Source: FAO AQUASTAT

Table 5.14 Agricultural water withdrawal in Zimbabwe

Total Renewable Water Resources (TRWR)	20km^3
Irrigation water requirements	0.67km^3
Water use efficiency percentages	30%
Water withdrawal for agriculture	2.24km^3
Water withdrawal as % of TRWR	11%

Source: FAO AQUASTAT

Table 5.15 Water requirement per crop in Zimbabwe

Crop	**Location**	**Season**	**Area** (ha)	**CWR** (mm/ha)	**Efficiency** (%)	**Total crop** (million m^3)
Wheat	Harare	dry	56,000	412	30	769.0
Barley	Harare	dry	5,000	384	30	64.0
Sugarcane	Harare	wet/dry	40,000	1,110	30	1,480.0
Citrus	Harare	wet/dry	5,000	613	30	102.2
Soybean	Harare	wet	20,000	65	30	43.3
Maize	Harare	wet	9,000	53	30	15.9
						Total 2,474.4

5.5 Mozambique

Mozambique is located on the east coast of southern Africa and covers an area of 801,590km^2 including 13,000km^2 of inland water. The total cultivable area is estimated at 36 million ha (45% of the total area). In 1994, the cultivated area was 3.6 million ha, 4.5 per cent of the total area and 10 per cent of the cultivable area. According to the 8th Article of the Mozambican constitution, all land is state-owned.

The total population in 2000 was estimated at 18.3 million.

5.5.1 Climate and water resources

Average precipitation is 969mm per year, but varies between 327mm in Pafuri (in the south-west) and 2,611mm in Gurue, in the mountainous part of the northern provinces. The rainy (warm) season is between October and April.

Mozambique is located at the end of several major international southern African rivers, the Zambezi and Limpopo being among the most important. The total water resources are estimated at 216km^3 per year, of which 100km^3 are generated internally.

In 1987, the total capacity of 12 large dams was 44.64km^3. Water allocation from these reservoirs is shared as follows: 3.90km^3 (9%) for irrigation, 0.01km^3 for water supply, and 40.73km^3 (91%) for hydropower. The Cabora Bassa dam, on the Zambezi, is the largest hydroelectric plant in southern Africa, with an installed capacity of 2,060 MW and a storage capacity of 39.2km^3 (i.e. 88 per cent of total dam storage capacity). In 1971, 583 small dams (of which 90% were for irrigation or livestock watering) were registered, with a total volume of 60 million m^3. It is believed that most of them were destroyed during the war of independence.

Table 5.16 Water demand forecast for Mozambique

IWMI Characteristics	Units	1995	2025	Annual growth (%)
Population	million	17.4	29.9	1.8
Total cereal consumption	m mt	1.6	3.1	2.3
Cereal production	m mt	1.1	2.6	3.0
Irrigated cereal area	m ha	0.1	0.14	1.2
Rain-fed cereal area	m ha	1.54	2.07	1.0
Total cereal area	m ha	1.64	2.21	1.0
Net irrigated area	m ha	0.1	0.1	1.0
Gross irrigated area	m ha	0.1	0.2	1.2
Primary irrigation supply	km^3	0.5	0.6	39
Total water withdrawals	km^3	0.66	1.03	1.5
Total primary water supply	km^3	0.5	0.8	Total growth
Total PWS as % of PUWR	%	0.3	0.5	51
Scarcity level	Economic			

Source: Molden 2000
m mt = million metric tonnes
m ha = million hectares

5.5.2 Irrigation development

There is no long tradition of irrigation management by farmers in Mozambique. Thirty years ago, the total area of managed water was about 8,000ha. After independence, irrigation was developed on state-owned farms for the cultivation of sugarcane and rice. Families irrigate land mainly for food crops, such as rice.
The irrigation potential is estimated to be 3,300,000ha, 61 per cent of which lies in the Zambezi River Basin, which represents 9 per cent of the cultivable area.

The land area equipped for irrigation was estimated in 1993 at 106,700ha (3.2% of the irrigation potential), divided into small schemes (less than 30ha), medium-scale (30–200ha) and large schemes. The total land area actually irrigated is estimated at 45,000ha (42% of the equipped area). The main irrigated crops are rice, sugarcane, maize, and citrus. Areas planted with sugarcane are reported to have decreased substantially in recent years. In most irrigation schemes surface water is used, mostly from rivers, and, to a much smaller extent, lakes. Basin irrigation for rice, and furrow irrigation for maize and vegetables, is practised. Sprinkler irrigation is widespread, especially in the sugarcane and cotton areas. All kinds of irrigation systems can be found in Mozambique, from large multi-user (30,000ha) to small individual (1ha) schemes, and from large industrial schemes to subsistence, family-owned irrigation plots. In the large schemes, where commercial and family irrigation co-exist, water management is almost non-existent.

Hydraulic structures do not function, large and unwieldy administrative bodies have been set up to run the schemes, and effective water control is practically impossible. In Chokwe, one of the major irrigation schemes covering 27,000ha, complete rehabilitation of the main and secondary canals will be necessary before any efficient water management can take place.

Table 5.17 Irrigation data for Mozambique

Irrigation potential		1994	3,300,000ha
Irrigation			
1 Area equipped for irrigation		1993	106,710ha
- surface irrigation			
- sprinkler irrigation			
- micro-irrigation			
% of area irrigated from groundwater			
% of area irrigated from surface water			
% of equipped area actually irrigated		1993	42%
2 Spate irrigation			
3 Equipped wetland and inland valley bottoms			
4 Other cultivated wetland and inland valley bottoms			
5 Flood recession cropping areas			
Total water managed area (1+2+3+4+5)		1993	106,710ha
- as % of cultivated area			3.0%
- increase over the last 10 years			
- power irrigated area as % of water managed area			
Full or partial control schemes			
Large schemes	>200 ha	1993	70,040ha
Medium schemes		1993	28,200ha
Small schemes	< 30 ha	1993	10,000ha
Total number of households in irrigation			
Irrigated crops			
Total irrigated grain production		2000	152,388T
As % of total grain production			10.1%
Harvested crops under irrigation		2000	67,000ha
- rice		2000	22,000ha
- sugarcane		2000	20,000ha
- wheat		2000	1,200ha
- maize		2000	18,000ha
- vegetables		2000	7,000ha

Source: FAO 1995, FAOSTAT

Trends in water resources management

Given its geographical situation and the importance of water management in the rivers of the south, Mozambique is interested in improving cooperation at international level for river basin management. A National Irrigation Development Master Plan Study was concluded in 1993 and submitted to government for approval. It covers five of the most important river basins of southern and central Mozambique: Umbelezi, Incomati, Limpopo, Buzi, and Pungoe. In total, rehabilitation and extension of existing schemes would cover an area of 105,000ha. As the areas equipped for irrigation are under-utilized, the priority is to rehabilitate existing schemes, where possible, taking into account the new institutional and economic environment before developing new projects.

5.5.3 Agriculture

The major cash crops are cotton, cashew nuts, sugarcane, maize, cassava, sorghum, peanuts, bananas, citrus fruits, and rice. Coconut and sisal are also important crops. Livestock farming following the war, however, is very underdeveloped, with Mozambique currently importing much

of its present requirements. Investment in poultry and pig production is a particular need, as is the supply of feedstock for these industries.

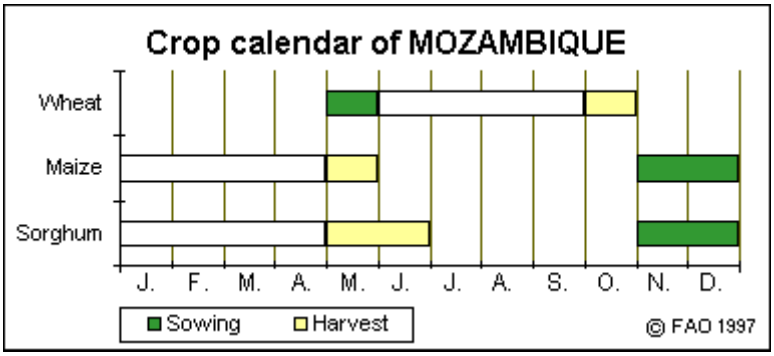
Constraints to agricultural development are both technical and institutional. The technical constraints include low and erratic rainfall, floods and drought, poor-quality soils, difficult access (due to landmines), low level of irrigation development, poor crop management, weak support services, high transportation costs, and limited storage and processing capacity

Rainfall patterns are highly variable and have a major influence on farming practices. Of the main food crops produced in the country, the most notable are maize, rice, cassava, groundnut, beans, sweet potato, and sugar cane. Production in the agricultural sector is dominated by peasant families, whose 2.5 million households occupy 95 per cent of the cultivated area. One of the main characteristics of this sector is the practice of rain-fed farming using basic agricultural techniques which produce very low yields.

The remaining 5 per cent of the total cultivated area is exploited by large firms which grow exclusively cash or traditional export crops such as sugar, citrus, copra, tea, cotton, and sisal.

Among the principal irrigation systems in the country, the most outstanding are at Chokwe (25,000ha) and the sugar plantations at Incomati, Maragra, Buzi, Mafambisse, and Luabo (totalling 34,000ha).

Figure 5.6 Mozambique crop calendar

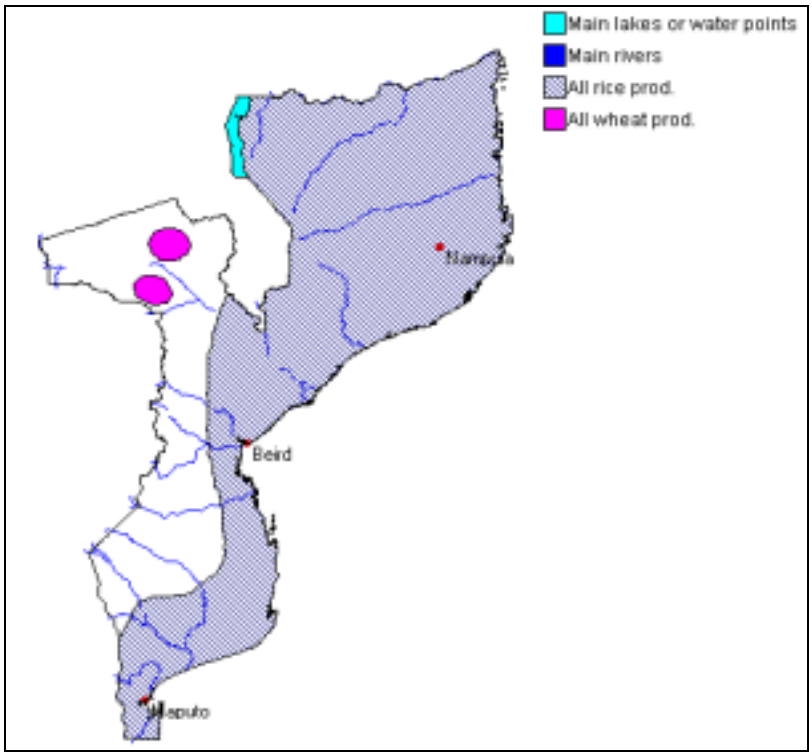


Source: FAO GIEWS

Rice

There are three major ecosystem types in which rice is grown in Mozambique. The rain-fed lowlands account for over 90 per cent of rice area, and are located mainly in Sofala, Zambezia, Nampula, and Cabo Delgado provinces. Rice varieties are mainly traditional. About 15,000ha of rain-fed lowland rice in coastal areas are affected by tides and salinity. Upland rice accounts for only 7 per cent of the national rice area and is found mainly in the northern provinces of Nampula and Cabo Delgado. Rice varieties are similar to those in the rain-fed lowlands, but are more drought-tolerant. Irrigated rice is grown mainly by commercial farmers. Yields are 3–5t/ha. The area of irrigated rice was about 20,000ha in the early 1980s but in recent years this has fallen to less than 5,000ha. In 1994/95, less than 100ha of rice were planted at Chokwe, Gaza Province, the country's largest irrigation scheme, as a result of extended drought.

Figure 5.7 Rice and wheat cultivation areas in Mozambique



Source: FAO GIEWS

Table 5.18 Water requirements for major irrigated crops in Mozambique

Crop	**Location**	**(Trans)planting date**	**Total cultivation requirements** (mm)	**Irrigation requirements** (mm)
Rice	Chinde	1/11	994	570
	Maputo	1/11	957	592
Sugar	Maputo	1/11	1467	843
	Beira	1/11	1480	681
Wheat	Chicoa	1/5	397	397
Maize	Maputo	1/11	557	173
Vegetables	Maputo	1/5	245	199

Source: FAO CROPWAT

Table 5.19 Irrigated crop area in Mozambique

Irrigated area (1,000ha)		**Crop area as % of the total area equipped for irrigation, by month**											
		J	F	M	A	M	J	J	A	S	O	N	D
Rice	22	21	21	21								21	21
Maize	18				17	17	17	17	17				
Sugarcane	20	19	19	19	19	19	19	19	19	19	19	19	19
Vegetables	7						7	7	7	7	7		
All irrigated crops	67	39	39	39	36	36	42	42	42	25	25	39	39
Equipped for irrigation	107												
Cropping intensity	63												

Source: FAO AQUASTAT

It should be noted that figures given in the text do not necessarily match those given in Tables 5.17 and 5.19. This is probably a result of the fact that irrigation intensity in Mozambique is lower than 100 per cent, with land prepared for irrigation not in use.

Table 5.20 Agricultural water withdrawal in Mozambique

Total Renewable Water Resources (TRWR)	216km^2
Irrigation water requirements	0.22km^2
Water use efficiency percentages	39%
Water withdrawal for agriculture	0.55km^2
Water withdrawal as % of TRWR	0.0%

Source: FAO AQUASTAT

Table 5.21 Water requirement per crop in Mozambique

Crop	**Location**	**Season**	**Area** (ha)	**CWR** (mm/ha)	**Efficiency** (%)	**Total crop** (million m^3)
Rice	Coast	wet	22,000	580	39	327,2
Sugar	Coast	wet/dry	20,000	760	39	389,7
Wheat	Chicoa	dry	1,200	397	39	12,2
Maize	Maputo	wet	18,000	173	39	79,8
Vegetables	Maputo	dry	7,000	199	39	35,7
						Total 844,7

5.6 Malawi

Malawi is a land-locked country with a total area of 118,480km^2, with the Rift Valley running north–south. The country is 850km long with a maximum width of 250km. Lake Malawi and Lake Chuwa cover a total of 24,200km^2. The cultivable area is estimated to be 3.6 million ha (38% of the total land area), of which 2.1 million ha are cultivated (58% of the cultivable area and 22% of the total area).

Agriculture constitutes the backbone of the economy, contributing more than 33 per cent of GDP and providing employment to about 90 per cent of the working population.

5.6.1 Climate and water resources

Mean annual rainfall of l,014mm ranges from 700mm to 2,400mm/year. The movement of the inter-tropical convergence zone provides a wet season between mid-November and about mid-

April. The climate is cool and dry from May to August, but becomes hotter until the onset of the rains in mid-November. Internal surface water resources have been estimated at 16.1km^3/year. There are seven major dams, with a total storage capacity of 39 million m^3, and 700–750 small dams in various states of (dis)repair, with a storage capacity of approximately 64 million m^3. Water resources play an important role in hydropower development. Installed capacity is 164MW and energy generation in 1993 was 785GWh.

The potential yield from groundwater is estimated at 1.4km^3/year, based on a recharge of 15mm. Reliable yields under irrigation are only achievable in the alluvial basins along the western shores of Lake Malawi, Lake Chuwa and in the Lower Shire Valley. Yields from groundwater in the basement complexes covering the rest of the country are generally only sufficient for hand-pumped rural water supplies.

IWMI has not included Malawi in their water demand calculations, but from Figure 2.6 (in Section 1) on projected water scarcity in 2025 it can be seen that Malawi will face economic water shortages during the 1995–2025 period.

5.6.2 Irrigation development

The total area of managed water is about 89,900ha, which is about 56 per cent of the potential irrigation area, estimated at 161,900ha. At present, 28,000ha is equipped for full or partial control irrigation. Almost all irrigation is from surface water, either from weirs or by pumping from rivers. There are some very small areas (15–20ha) along the shore of Lake Malawi which are irrigated by groundwater. Irrigation techniques include 15,700ha of surface irrigation (furrow and basin), 9,000ha of sugarcane under sprinkler at Sucoma, 2,300ha of tea, coffee and other crops (also under sprinkler), and some 1,000ha under micro-irrigation. Some 1,100ha of surface irrigation schemes are in need of rehabilitation. The cropped area in these schemes covers 31,500ha per year.

Table 5.22 Irrigation data for Malawi

Irrigation potential	1992	161,900ha
Irrigation		
1 Area equipped for irrigation	1992	28,000ha
- surface irrigation	1992	15,700ha
- sprinkler irrigation	1992	11,300ha
- micro-irrigation	1992	1,300ha
% of area irrigated from groundwater	1992	0.05%
% of area irrigated from surface water	1992	99.95%
% of equipped area actually irrigated	1992	96.00%
2 Spate irrigation		
3 Equipped wetland and inland valley bottoms		
4 Other cultivated wetland and inland valley bottoms	1992	61,900ha
5 Flood recession cropping areas		
Total water managed area (1+2+3+4+5)	1992	89,900ha
- as % of cultivated area	1992	4.3%
- increase over the last 10 years		
- power irrigated area as % of water managed area		
Full or partial control schemes		
Large schemes		
Medium schemes		
Small schemes		
Total number of households in irrigation		
Irrigated crops		
Total irrigated grain production		100,490T
As % of total grain production		15%
Harvested crops under irrigation		
- sugar		19,000ha
- rice		43,542ha
- wheat		2,278ha
- vegetables		21,000ha

Source: FAO 1995, FAOSTAT

There are three basic categories of farming sectors in the irrigation sub-sector

- *Private estates* (18,300ha): These include the sugar estates of Sucoma (9,000ha) and Dwangwa (6,000ha), and the Kawalazi estate, which have been developed as joint ventures between government and local and foreign investors such as the Commonwealth Development Corporation (CDC) and Lonrho. Private coffee and tea estates are also operated by large-scale commercial farmers and enterprises on freehold and leasehold land.
- *Government-run smallholder schemes* (3,200ha – 6,000 households): These were established by the government to provide irrigation opportunities to local farmers, who were allocated irrigated plots in addition to adjacent dry-land holdings. The schemes are operated by the government and the farmers pay no water charges for use of their plots.
- *Self-help smallholder schemes* (6,500ha – 32,500 households): These have been designed and constructed largely by government with the full support and participation of farmers in each stage of development, including identification and planning. Farmers contribute labour during construction and, when completed, they manage and maintain their schemes with the minimum of government support.

There are some 61,900ha of wetland areas under rice cultivation. Simple diversions and bunding are employed, and farmers often cooperate in small groups to manage water. Studies are currently going on to estimate areas, uses and potential for drainage using low-cost structures.

Total irrigation potential has been estimated at about 161,900ha, including the existing wetlands. Future irrigation development potential of 72,000ha is mainly along the lake shore in northern central and southern regions, and in the lower Shire Valley. Water resources will be drawn from Lake Malawi and the Shire River, as well as from tube-wells in the alluvial aquifers.

Trends in water resources management

Isolated instances of irrigation development occurred in the late 1940s, but it was not until 1968 that the government adopted a deliberate policy of irrigation, mainly for rice growing along lakeshore plains and in the lower Shire Valley. By 1979, 16 smallholder schemes had been established, covering an area of 3,200ha and with the settlement of 6,000 farmer households. The importance of self-help smallholder schemes has also been recognized by government, which provided varying degrees of assistance during the 1970s. Over the last 15 years, irrigation has had a low priority in agricultural production. The main constraints have been:

- focusing of the agricultural economy on rain-fed agriculture and existing irrigation schemes, where emphasis was on funding extension activities
- reluctance of donors to fund irrigation development
- placement of irrigation services under the Ministry of Agriculture, which has focused on rain-fed agriculture
- price setting of crops making irrigation unviable
- almost no irrigation technology training facilities within the country
- an Irrigation Department that has been both poorly funded and understaffed
- a lack of farmer ownership of plots on government schemes.

Following droughts in 1991/92 and in 1992/93 which caused low yields and crop failures, government realized the increasing importance of irrigation as a means of ensuring food security at both household and national levels. The newly created Ministry of Irrigation and Water Development put forward a 23-point irrigation development plan for poverty alleviation. The main features are to:

- give highest priority to development of irrigation and water resources in the country and to provide the Ministry of Irrigation and Water Development with sufficient funds and staffing to undertake studies on pumping sites, boreholes and dam development
- establish a National Committee for Irrigation and Drainage and promote research into irrigation
- recommend the installation of electricity power lines along rivers and the lake shore to encourage irrigation and agro-industrial development
- provide support to farmers, including credit facilities
- increase development of self-help farmer schemes, and hand over operation and management of existing government-run schemes following completion of rehabilitation
- promote irrigation development by the private sector, and support smallholder farms through new irrigation technology and diversified cropping systems (with discouragement of pump-based schemes except where farmers are prepared to pay for their construction and operation themselves)
- develop training programmes at field and management levels, and assist farmers in the creation of water user associations to ensure future irrigation development is socially and economically viable
- establish clear water rights regulations
- ensure the participation of women

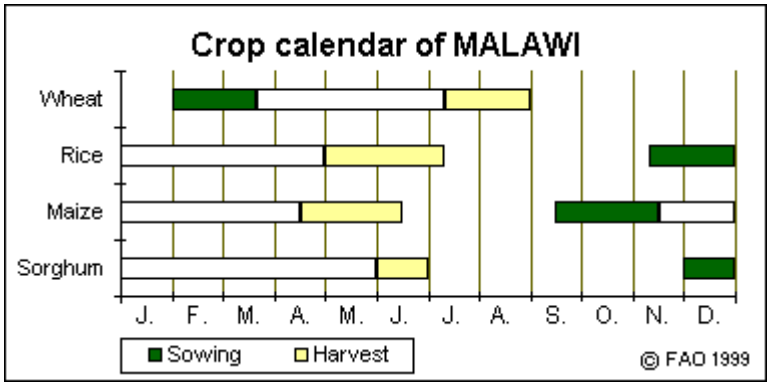
- ensure adequate health and safety standards for irrigation schemes
- ensure, in close collaboration with relevant ministries and organizations, the enforcement of legislation on water conservation and catchment protection, and
- strengthen monitoring activities to ensure projects are executed as planned.

The new ministry started an active development programme in 1995/96, including construction of 30 dams, 7,500ha of irrigation (2,500ha in each region) and 60 pumping sites for irrigation of 1,200ha.

5.6.3 Agriculture

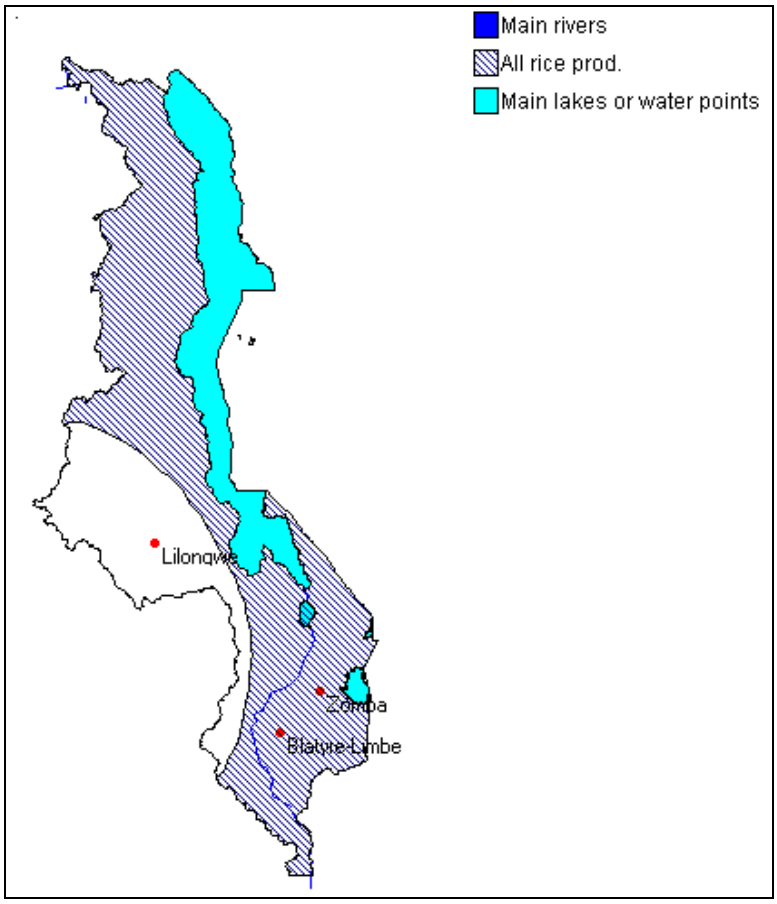
Tobacco is the dominant export earner, accounting for more than 60 per cent of agricultural exports. The other main domestic exports are sugar, tea, pulses, cotton, and coffee. The main subsistence crop is maize, which is grown by most smallholder farmers. Other subsistence crops include sorghum, pulses, millet, fruit, and root crops. Fish is also an important part of the subsistence diet. The main cash crops grown by smallholder farmers are maize, cotton, rice, groundnut, and tobacco. Estate crops include tobacco, tea, sugar, coffee, rubber, and macadamia nuts. Estate farms cover around 1.15 million ha of land, while smallholders occupy a total of 4.1 million ha.

Figure 5.8 Malawi crop calendar



Source: FAO GIEWS

Figure 5.9 Rice cultivation areas in Malawi



Source: FAO GIEWS

The meteorological stations given in FAO's CLIMWAT system seem not to represent the general climatic conditions in Malawi, with the exception of Lilongwe and Nkhata Bay. The latter has been selected for the water requirement calculations of rice and sugarcane.

Table 5.23 Water requirements for major irrigated crops in Malawi

Crop	**Location**	**(Trans)planting date**	**Total cultivation requirements** (mm)	**Irrigation requirements** (mm)
Rice	Nkhata Bay	1/12	810	267
	Nkhata Bay	1/5	774	600
Sugar	Nkhata Bay	1/12	1,536	794
Maize	Nkhata Bay	1/4	394	254
Vegetables	Lilongwe	1/6	323	323

Source: FAO CROPWAT

Table 5.24 Irrigated crop area in Malawi

Irrigated area (1,000ha)		**Crop area as % of the total area equipped for irrigation, by month**											
		J	F	M	A	M	J	J	A	S	O	N	D
Rice	13												
Rice-one		33	33	33								33	33
Rice-two					14	14	14	14	14				
Maize	2				7	7	7	7	7				
Sugarcane	18	64	64	64	64	64	64	64	64	64	64	64	64
Vegetables	3						11	11	11	11	11		
All irrigated crops	36	97	97	97	85	85	96	96	96	75	75	97	97
Equipped for irrigation	28												
Cropping intensity	129												

Source: FAO AQUASTAT

Table 5.25 Agricultural water withdrawal in Malawi

Total Renewable Water Resources (TRWR)	17km^3
Irrigation water requirements	0.20km^3
Water use efficiency percentages	25%
Water withdrawal for agriculture	0.81km^3
Water withdrawal as % of TRWR	5%

Source: FAO AQUASTAT

Table 5.26 Water requirement per crop in Malawi

Crop	**Location**	**Season**	**Area** (ha)	**CWR** (mm/ha)	**Efficiency** (%)	**Total crop** (million m^3)
Rice	Nkhata Bay	wet	9,000	810	25	291.6
Rice	Nkhata Bay	dry	4,000	774	25	123.8
Sugarcane	Nkhata Bay	wet/dry	18,000	1,536	25	1,105.9
Maize	Nkhata Bay	dry	2,000	394	25	31.5
Vegetables	Lilongwe	dry	3,000	323	25	38.8
					Total	**1,591.6**

6 CONCLUSIONS FOR THE ZAMBEZI RIVER BASIN

6.1 Irrigated agriculture

WWF's Living Waters Programme is working in one river basin in Southern Africa: the Zambezi River, including Lake Malawi. This study has assessed which countries are situated in this basin and their respective surface areas in the basin. Data were collected (from FAO AQUASTAT) on major irrigated crops, their water requirements in the wet and dry seasons, and the area under cultivation in the wet and dry seasons. Calculations were then carried out to establish the total water requirement per crop, using FAO's CROPWAT system. Total areas for irrigated crops in Southern Africa were assembled from individual country data (FAO AQUASTAT)(see Table 6.1).

Table 6.1 Irrigated crop areas in Southern Africa

Country		Rice	Wheat	Sugarcane	Vegetables	Cotton	Maize	Fruits	Barley	Soybean
Angola		16,000		9,000	15,000					
Botswana						1,000	1,000			
Malawi		13,000					2,000			
Mozambique				18,000	3,000					
Namibia			1,000			1,000	2,000	1,000		
Tanzania		34,000		13,000	38,000		16,000	7,000		
Zambia		10,000	11,000	15,000	9,000	4,000		5,000		
Zimbabwe			56,000	40,000	1,000		9,000	5,000	5,000	20,000
Total	**ha**	**73,000**	**68,000**	**95,000**	**66,000**	**6,000**	**30,000**	**18,000**	**5,000**	**20,000**
	%	**19.1**	**17.8**	**24.9**	**17.3**	**1.6**	**7.9**	**4.7**	**1.3**	**5.2**

Source: FAO AQUASTAT

Table 6.2 Irrigated crop areas in Madagascar

	Rice	Sugarcane	Vegetables
Madagascar	869,000	27,000	9,000
%	96	3	1

Table 6.3 Irrigated crop areas in South Africa

	Wheat	Sugarcane	Cotton	Maize	Fruits	Fodder	Tobacco	Root crops
South Africa	170,000	100,000	22,000	106,000	141,000	333,000	20,000	28,000
%	18.5	10.9	2.4	11.5	15.3	36.2	2.2	3.0

Source: FAO AQUASTAT

The total irrigated area for Southern Africa, including Madagascar, amounts to 2,207,000ha, of which the major share is located in Madagascar (41%) and South Africa (42%). Rice is the main crop in Madagascar (96%) and fodder in South Africa (36.2%). As these crops are not representative of the other Southern African countries, a separate analysis has been carried out for this group. The results showed that sugarcane covered the largest area (95,000ha – 24.9%),

followed by rice (73,000ha), wheat (68,000ha) and vegetables (66,000ha). The top four irrigated crops are thus similar to those in West Africa, although their sequence differs.

A similar calculation carried out for the entire region, including Madagascar and South Africa, revealed that the major irrigated crops were rice (46%), fodder (15.2%), sugarcane (4.4%), and wheat (13.9%).

Table 6.4 Water consumption by four major crops in the Zambezi River

	Sugarcane		**Rice**		**Wheat**		**Vegetables**	
	ha	million m^3	ha	million m^3	ha	million m^3	ha	million m^3
Zambia	15,000	682.5	10,000	91.7	11,000	165.0	9,000	114.6
Zimbabwe	40,000	1,480,0			56,000	769.0		
Mozambique	20,000	389.7	22,000	327.2	1,200	12.2	7,000	35.7
Malawi	18,000	1,105.9	13,000	415.4			3,000	38.8
Total	**93,000**	**3,658.1**	**45,000**	**834.3**	**68,200**	**946.2**	**19,000**	**189.1**

When considering these figures for the Zambezi River , it should be kept in mind that in Africa south of the Sahara agriculture is still mainly rain-fed (80%) and that increases in irrigated area, although apparently substantial in terms of surface area, are in fact relatively small when compared to rain-fed cultivated area (see also Table 6.5). The importance of sugarcane most likely results from the fact that it is a foreign currency earner, while the staple food crop is maize, which is generally grown under rain-fed conditions.

6.2 Future water demand

IWMI Working Paper No.32 *Water for Rural Development* was used collect information on the future water situation. The general conclusion for the Southern Africa region is that there will be economic water scarcity – i.e. primary water supply (PWS) less than 60 per cent of the potential utilizable water resources (PUWR) – with a requirement to increase PWS by more than 25 per cent over the current levels. Unfortunately IWMI has not made any projections for Malawi, for which reason it is not included in Table 6.5.

Table 6.5 Water demand forecasts for three Southern African countries

	Irrigated Cereal Area (million ha)	**PWS** (km^3)	**Rain-fed cereal area** (million ha)	**PUWR** (km^3)
Zambia				
1995	0.02	0.80	0.75	53
2025	0.04	1.56	1.37	
Increase (%)	100	73	83	
Zimbabwe				
1995	0.06	1.42	1.88	60
2025	0.09	2.24	2.16	
Increase (%)	50	52	15	
Mozambique				
1995	0.10	0.66	1.54	160
2025	0.14	1.03	2.07	
Increase (%)	40	51	34	

Source: Molden 2000

In South Africa a decrease in rain-fed cereal area is expected by 2025, a tendency that is more common in temperate developed countries. In sharp contrast is the fact that, by 2025, it is expected that more than 60 per cent of PUWR will be used, which places South Africa in the physical water scarcity category.

Madagascar has abundant freshwater supplies but will incur economic water scarcity because it will have to increase its PWS by 78 per cent to meet future irrigation demands.

Table 6.6 Water demand forecasts for South Africa and Madagascar

	Irrigated Cereal Area (million ha)	**PWS** (km^3)	**Rain-fed cereal area** (million ha)	**PUWR** (km^3)
South Africa				
1995	0.43	16.49	6.20	30
2025	0.64	21.05	5.99	
Increase (%)	49	32	**-3**	
Madagascar				
1995	0.35	2.54	0.97	117
2025	0.53	4.32	1.27	
Increase (%)	51	78	31	

Source: Molden 2000

In Southern Africa quite a number of inter- and intra-basin transfers are under study/execution. Most of them involve the Republic of South Africa, which is understandable in view of the projections for future water supply. However, of the water transfer schemes that are currently being studied, only three involve the Zambezi River (Table 6.7).

Table 6.7 Major water transfer schemes in the Zambezi River

Water transfer scheme	**River basin involved**	**Countries directly involved**	**Other basin states indirectly involved**
Turgwe – Chiredzi	Zambezi	Zimbabwe	Angola, Botswana, Mozambique, Namibia, Tanzania, Zambia, Malawi
Zambezi - Bulawayo	Zambezi	Zimbabwe	Angola, Botswana, Mozambique, Namibia, Tanzania, Zambia, Malawi
Zambezi – Gauteng	Zambezi-Orange	Zimbabwe, Botswana, South Africa	Angola, Lesotho, Mozambique, Namibia, Tanzania, Zambia, Malawi

Source: Pallett 1997