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VOLUME 7
WATER REQUIREMENTS

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This volume is one of a series of seven volumes which have been prepared as part of the SAVANNA REGIONAL WATER RESOURCES AND LAND USE PROJECT.

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INTRODUCTION

In the first three volumes of the "Savanna Regional Water Resources and Land Use" report an overview is given of the land, water and human resources available in the Savanna Region of West and Central Africa. Volume 4 of this report series identifies gaps in the existing data base that are relevant to future planning efforts in water resources development. The report also contains a series of proposals for studies to eliminate these gaps. Volumes 5 and 6 of the series give an assessment of how and to what extent the land and water resources of the Savanna Region are now used by its inhabitants.

This Volume 7 examines the future requirements for water in the Savanna Region. An assessment is made of water required for human and livestock consumption, for irrigation and industrial use in the year 2,000. In addition, the in-stream water requirements for hydro-electric power, fisheries and navigation are assessed. This report is prepared on the basis of information and documentation available at the C.I.E.H. Documentation Center in Ouagadougou. Due to restriction on available funds, only very limited time and travel for the staff involved in this work could be allowed.

The Savanna Region includes 17 countries (wholly or in part) and data presented here are therefore of widely different quality and reliability; the aggregate figures presented for the whole Savanna Region should be interpreted with care.

The overall purpose of this report and the previous reports in this series is:

1. To assist CIEH in future planning efforts in water resource development.
2. To provide other regional and national organizations in the Savanna with a framework for their planning.

3. To alert national policy and decision makers to the potential of the Region, the need for regional cooperation to insure efficient use of the resource base, and the apparent benefits of such cooperation.

4. To help direct investments by interested donor organizations and countries to those sectors where such assistance can be most effective.

It is expected that in C.I.E.H.'s future planning operations the Savanna will be subdivided into subregions (such as those with similar water supply and demand) and that proposals and guidelines will be prepared for specific water resource development projects.

This study was undertaken in the period 1978/1979. Dam sites referred to in this report are coded for easy identification on Map 1 of Volume 5. Wherever data given in this Volume do not correspond with that of Volume 5, such data should be considered as an update superseding that of Volume 5.

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CHAPTER 1

POPULATION

1.1 Introduction

Projections of water requirements for human consumption are, to a considerable extent, dependent upon the policies that countries and governments may choose to adopt. It is believed that the general policy of the World Bank in matters relating to water supply reflects the objectives of most if not all of the Savanna countries involved in this study. The Bank suggests using three principles that have been applied successfully in several countries (BIRD, 1977). These principles are quoted as follows:

1. A social principle. Access to drinking water is desirable for each citizen, which implies a minimum level of service to be furnished to each person at the lowest possible cost.

2. An economic principle. Once the minimum requirements are satisfied, drinking water charges must reflect the long term marginal costs of water supply. This will facilitate an efficient distribution of a scarce resource among different sectors by preventing waste through controlling the rate of growth of water demand and by allowing consumers to indicate the justification for new investments in this sector (when demand exceeds supply at a given price).

3. A financial principle: The sector of urban water supply must be financially viable and at the same time involve financial measures ranging from complete recovery of all costs (i.e. an appropriate rate of return on capital costs in the more prosperous towns) to recovering at least the operating cost and a partial contribution of costs of construction of the systems supplying the poorer urban areas.

1.2 Water Consumption per Capita

In general, the in-house water use in rural areas supplied by public wells averages about 15 to 20 liters/day. In residential districts of urban areas supplied by house connections, average water use is about 100 to 150 liters/capita/day (United Nations, 1976).

Estimates of current average daily water consumption and the future daily water requirements in the Sahel countries were given in a 1976 report of the French Ministry of Cooperation (France Ministere de la Cooperation, SCET Int. 1976) and are shown here in Table 1 and 2. CILSS, in its 1977 report to the UN Water Conference in Mar del Plata, uses slightly lower estimates of current consumption (Table 1) but reports the same data on future requirements (Table 2).

Table 1. Average daily water consumption (1975) in the Sahel countries (l/capita/day)

Population	France Min. de Coop. (1976)	CILSS (1977)
Rural areas	40 - 50 (1)	30
Small towns (5,000 to 100,000 inhabitants)	70 - 100	40 - 50
Large towns (over 100,000 inhabitants)	150 - 200 (2)	150 - 200

(1) Probably including livestock consumption

(2) This figure includes:

domestic consumption	120 l
watering private gardens	50 l
watering public gardens	7 l
commerce	2 l
air conditioning	11 l
crafts and very small industries	10 l
Total	200 l

Table 2. Future Daily Water Consumption (2000) in the Sahel countries (l/capita/day) (CILSS, 1977)

Population	Average Requirements	Peak Requirements
Rural areas	55	80
Small towns	110	150
Large towns	250	300

The figures in Table 2 above are used in this report as the basis for calculating the water requirements of the population of the Savanna Region in the year 2000.

The projected increase in water consumption by the year 2000 is modest as it ranges from 20 percent in the rural areas to 40 percent in the large towns. This generally modest increase seems justified in the light of country data given in Tables 3,4,5. A higher increase was assumed to allow for peak water consumption toward the end of the dry season. This peak period was taken to be 65 days in the months of April, May, June depending on the latitude.

For comparison, water consumption data of Upper Volta are given in Table 3 (Haute Volta, Direction de l'Hydraulique, 1976), of Chad in Table 4 (Tchad, Bureau de l'Eau, 1976) and of Ghana in Table 5 (Tahal, 1965)

Table 3. Current (1975) and Future (2000) Daily Water Consumption in Upper Volta (l/capita/day)

Population	Average Current Consumption	Average Future Requirements
Rural Areas	5	25
Small towns	15	40
Large towns	25	150

Table 4. Current (1975) and Future (2000) Daily Water Consumption in Chad (l/capita/day)

Population	Average Current Consumption (l/day)	Average Future Requirements (l/day)
Rural areas		80*
Urban Centers	40	160

*Probably including livestock consumption.

Table 5. Current (1970) and Future (2000) Daily Water Consumption in Ghana, Accra-Tema Metropolitan area (l/capita/day)

	Current Consumption			Future Consumption		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Accra-Tema metropolitan area	79	87	96	151	189	227

1.3 Population Projections

The Savanna Region is composed of (parts of) 17 different countries. Table 6, column 2, gives the percentage of each countries' area located in the Savanna Region as measured on 1 : 2.5 million base maps of the Savanna (Chapter 1 Volume 1 of this report series discusses in detail the areal extent and subdivisions of the Region). In column 3 of Table 6 an estimate is given of the percentage of each countries' total population in the Savanna Region. In order to make this estimate of the total population of the Savanna Region it was assumed that about 85 percent of the population of the Sahelian countries, Mauritania to Chad, is resident in the Savanna Region. Conversely, for the coastal countries of Ivory Coast, Ghana and Nigeria, where the population density is highest in the coastal forest areas, a percentage lower than the land area was assumed to define the population percentage living in the Savanna. This estimate was substantiated by detailed assessments of population maps of each country.

Table 6. Estimated Percentage of the Total Population of Each Country Resident in Savanna Region

Country	Percentage of Country Area in Savanna Region	Percentage of Country Population in Savanna Region
Benin	94.5	94.5
Cameroun	53.6	45
Central African Empire	97.7	97.7
Chad	43.6	85
Gambia	100.0	100
Ghana	71.5	45
Guinea	95.0	95
Guinea Bissau	100.0	100
Ivory Coast	54.3	45
Mali	43.7	85
Mauritania	17.3	85
Niger	27.6	85
Nigeria	84.4	70
Senegal	100.0	100
Sierra Leone	38.4	38.4
Togo	100.0	100
Upper Volta	100.0	100

The population of the Savanna Region in 1975 was then computed on the basis of country data provided in Table 7-1 of Volume I of this report series. The results of these computations are given in Table 7 below.

Along the same lines, the population of the Savanna Region in the year 2000 was estimated on the basis of country data provided in table 7-1 of Volume 1 of this report series. It is assumed that the same percentage of the population lives within the Savanna Region as in 1975 (column 2 of Table 6). The estimated population of the Savanna Region in the year 2000 is given in Table 8.

Table 7. Estimate of the Population, by Country, of the Savanna Region, Year 1975

Country	Total Population (10^6 Inhabitants)	Total Population in Savanna (10^6 Inhabitants)
Benin	3.1	2.9
Cameroun	6.4	2.9
Central African Empire	1.7	1.6
Chad	4.1	3.5
Gambia	0.5	0.5
Ghana	9.9	4.5
Guinea	4.4	4.2
Guinea Bissau	0.5	0.5
Ivory Coast	5.4	2.5
Mali	5.7	4.9
Mauritania	1.3	1.1
Niger	4.5	3.8
Nigeria	63.0	44.1
Senegal	4.4	4.4
Sierra Leone	3.0	1.2
Togo	2.2	2.2
Upper Volta	6.0	6.0
Total	126	91

Table 8. Estimate of the Population, by Country, of the Savanna Region, Year 2000

Country	Projected Total Population, 10^6 inhabitants	Projected Population in Savanna, 10^6 inhabitants
Benin	5.9	5.6
Cameroun	11.6	5.2
Central African Empire	3.4	3.3
Chad	6.9	5.5
Gambia	0.8	0.9
Ghana	21.1	9.5
Guinea	8.5	8.1
Guinea Bissau	0.8	0.8
Ivory Coast	9.6	4.3
Mali	11.2	9.6
Mauritania	2.3	2.0
Niger	9.5	8.2
Nigeria	134.9	94.4
Senegal	8.2	8.2
Sierra Leone	5.7	2.2
Togo	4.6	4.6
Upper Volta	11.0	11.0
Total	256	183

1.3.1 Urban and Rural Population

As reported in Chapter 7 of Volume 1 of this report series, the vast majority of the Savanna population lives in rural areas. An average of only 18 percent are classified as urban residents. Census definitions of "urban" and "rural" populations vary widely among countries. Here, "urban" population is used as it is defined by each nation. A breakdown of the total population figures into urban and rural is given in Table 9. The total population is that computed in Table 7, percent urban population is given in Table 7-1 of Volume 1 of this report series.

Map No. 7 of Volume 2 of this report series gives the names, location and sizes of all urban centers in the Savanna Region with a population of over 10,000. For an estimate of water consumption it is important to separate between small and large towns. The Savanna Region has 37 large towns (more than 100,000 inhabitants) most of them located in Nigeria. Table 10 lists the 20 most important of these towns and gives their actual population (Afrique et Moyen Orient, 1976). An estimated 8 million people live in the large towns. The remaining 113 smaller towns also have about 8 million inhabitants or an average of 70,000 inhabitants per town. (Ediafric, 1975; Cote d'Ivoire 1976).

Almost half of the urban population is in cities of 100,000 or more people, this relatively high percentage is a typical feature of the spatial distribution of the urban population of tropical Africa (Altschul, 1976; Caldwell, 1968). In Table 11 an overview is given of the urban population in each of the Savanna countries.

As for the rural areas, a frequency distribution of population density was derived from measurements of Map No. 7 of Volume 2 of this report series and is presented in Table 12. It shows that about half of the rural population lives on three/quarters of the land with a density of from 2 to $20/km^2$.

Table 9. Urban and Rural Savanna Population, Year 1975

	Total Savanna Population (10^6 inh)	Percent Urban Population	Total Urban Population (10^6 inh)	Total Rural Population (10^6 inh)
Benin	2.9	15.5	0.5	2.4
Cameroun	2.9	21.9	0.6	2.3
Central African Empire	1.6	31.5	0.5	0.9
Chad	3.5	13.0	0.5	3.0
Gambia	0.5	13.6	0.1	0.4
Ghana	4.5	30.7	1.4	3.1
Guinea	4.2	24.2	1.1	3.1
Guinea Bissau	0.5	21.5	0.1	0.4
Ivory Coast	2.5	24.0	0.6	1.9
Mali	4.9	12.7	0.6	4.4
Mauritania	1.1	10.5	0.1	1.0
Niger	3.8	8.7	0.3	3.5
Nigeria	44.1	17.0	7.5	36.6
Senegal	4.4	29.1	1.3	3.1
Sierra Leone	1.2	14.0	0.2	1.0
Togo	2.2	14.2	0.3	1.9
Upper Volta	6.0	7.6	0.5	5.5
Total	91		16	75

Table 10. Major Cities of more than 100,000 Population in the Savanna Region (1975)

Country	Number of cities over 100,000 population	Major cities of over 100,000 population	Actual Population
Benin	2	Cotonou	175,000
		Porto Novo	100,000
Central African Empire	1	Bangui	350,000
Chad	1	N'Djamena	190,000
Guinea	1	Conakry	300,000
Guinea Bissau	1	Bissau	120,000
Ivory Coast	1	Bouaké	173,000
Mali	1	Bamako	300,000
Niger	1	Niamey	122,000
Nigeria	5 + 17	Ibadan	1,300,000
		Kano	700,000
		Ilorin	252,000
		Kaduna	181,000
		Maiduguri	169,000
		17 - approx. 150,000 each	2,550,000
Senegal	3	Dakar	650,000
		Kaolack	100,000
		Thies	100,000
Togo	1	Lome	200,000
Upper Volta	2	Ouagadougou	150,000
		Bobo Dioulasso	110,000
Total	20 + 17		est. 8 millions

Table 11. Urban Savanna Population, Year 1975

Country	Total Urban Population (Table 10) 10^6 inh.	Urban Population Small Towns		Urban Population Large Towns	
		Number of Towns	Number of Population	Number of Towns	Number of Population
Benin	0.5	5	225,000	2	275,000
Cameroun	0.6	7	400,000	0	-
Central African Empire	0.5	6	150,000	1	350,000
Chad	0.5	10	310,000	1	190,000
Gambia	0.1	1	60,000	0	-
Ghana	1.4	5(?)	1,100,000	0	-
Guinea	1.1	16	800,000	1	300,000
Guinea Bissau	0.1	-	-	1	120,000
Ivory Coast	0.6	7	427,000	1	173,000
Mali	0.6	12	300,000	1	300,000
Mauritania	0.1	3	100,000	0	-
Niger	0.3	5	178,000	1	122,000
Nigeria	7.5	18(?)	2,348,000	22	5,152,000
Senegal	1.3	6	450,000	3	850,000
Sierra Leone	0.2	?	200,000	0	-
Togo	0.3	7	100,000	1	200,000
Upper Volta	0.5	5	240,000	2	260,000
Total	16	113	± 8 Million	37	± 8 Million

Table 12. Distribution and Density of Rural Savanna Population, Year 1975

Population Density/Km^2	Area		Estimated Rural Population	
	(Km^2)	Percent	10^6 Inhabitants	Percent
0 - 2	620,000	14	1	1
2 - 10	2,250,000	50	18	24
10 - 20	1,000,000	22	19	25
20 - 30	400,000	9	13	17
30 - 50	90,000	2	4	5
50 - 100	60,000	1	5	7
more than 100	80,000	2	15	20
Total	4,500,000	100	75	100

The total projected population in the Savanna for the year 2000 is 183 million people (Table 8), based on an average projected growth rate of the total population of 2.8 percent annually. (Table 7-1, Volume 1). There exists a high and increasing average rate of urban growth of 5 to 7 percent annually. Cities with more than 100,000 population are experiencing growth rates of over 8 percent annually (Altschul, 1976).

Adopting fairly conservative growth rates for purposes of this study of 2.8% for total population (Table 8), 6% for urban population and 7% for cities larger than 100,000, an estimate of the rural and urban population per country was obtained for the year 2000.

This estimate is presented by country, in Table 13.

1.4 Water requirements of the population in year 2000

Tables 2 and 13 provide the basis for an estimate of the daily water requirements of the Savanna population in the year 2000. Table 14 gives these daily water requirements per country for the rural and urban population, the latter subdivided in population of small and large towns. Water requirements are differentiated in average (300 days) and peak (65 days) requirements. Table 15 gives the annual requirements per country for the rural and urban population as well as the total requirements for the year 2000.

1.5 Capital Investment

1.5.1 Water Supply

There exist a number of constraints on progress in community water supply in Africa.

The most important constraints in order of priority are (United Nations, 1976) -

1. Internal financing insufficient
2. External financing insufficient
3. Lack of trained personnel
4. Insufficient production of local material

Table 13. Urban and Rural Savanna Population, Year 2000 in Million Inhabitants

Country	Total Savanna Population	Rural Population	Urban Population	Urban Small Towns less than 100,000	Urban Large Towns over 100,000
Benin	5.6	3.5	2.1	0.6	1.5
Cameroun	5.2	2.6	2.6	2.6	-
Central African Empire	3.3	1.2	2.1	0.2	1.9
Chad	5.5	3.4	2.1	1.1	1.0
Gambia	0.9	0.5	0.4	0.4	-
Ghana	9.5	3.5	6.0	6.0	-
Guinea	8.1	3.4	4.7	3.1	1.6
Guinea Bissau	0.5	0.5	0.3	-	0.3
Ivory Coast	4.3	1.7	2.6	1.7	0.9
Mali	9.6	7.0	2.6	1.0	1.6
Mauritania	2.0	1.6	0.4	0.4	-
Niger	8.2	6.9	1.3	0.7	0.6
Nigeria	94.4	62.2	32.2	4.3	27.9
Senegal	8.2	2.6	5.6	1.0	4.6
Sierra Leone	2.2	1.4	0.8	0.8	-
Togo	4.6	3.3	1.3	0.2	1.1
Upper Volta	11.0	8.9	2.1	0.7	1.4
Total	183	114	69	25	44

Table 14. Daily Water Requirements of the Population of the Savanna, Year 2000, in 1000 m^3/day

Country	Rural Areas		Urban Areas: Small Towns		Urban Areas: Large Towns	
	Average	Peak	Average	Peak	Average	Peak
Benin	192	280	66	90	375	450
Cameroun	143	208	286	390	–	
Central African Empire	66	96	22	30	475	570
Chad	187	272	121	165	250	300
Gambia	27	40	44	60	–	
Ghana	192	280	660	900	–	
Guinea	187	272	341	465	400	480
Guinea Bissau	27	40	–	–	75	90
Ivory Coast	93	136	187	255	225	270
Mali	385	560	110	150	400	480
Mauritania	88	128	44	60		
Niger	379	552	77	105	150	180
Nigeria	3,421	4,976	473	645	6,975	8,370
Senegal	143	208	110	150	1,150	1,380
Sierra Leone	77	112	88	120		
Togo	181	264	44	30	275	330
Upper Volta	489	712	77	105	350	420
Total	6,277	9,136	2,750	3,720	11,100	13,320

Table 15. Annual Water Requirements of the Population of the Savanna, Year 2000, in $10^6 m^3$/year

Country	Rural Areas		Small Towns		Large Towns		Total Year 2000
	300 Av. Days	65 Peak Days	300 Av. Days	65 Peak Days	300 Av. Days	65 Peak Days	365 Days
Benin	58	18	20	6	113	29	244
Cameroun	43	14	86	25	-	-	168
Central African Empire	20	6	7	2	143	37	215
Chad	56	18	36	11	75	20	216
Gambia	8	3	13	4	-	-	28
Ghana	58	18	198	59	-	-	333
Guinea	56	18	102	30	120	31	357
Guinea Bissau	8	3	-	-	23	6	40
Ivory Coast	28	9	56	17	68	18	196
Mali	115	36	33	10	120	31	345
Mauritania	26	8	13	4	-	-	51
Niger	114	36	23	7	45	12	237
Nigeria	1026	323	142	42	2093	544	4170
Senegal	43	14	33	10	345	90	535
Sierra Leone	23	7	27	8	-	-	65
Togo	54	17	13	2	83	21	190
Upper Volta	147	46	23	7	105	27	355
Total	1883	594	825	244	3333	866	7745

5. Inappropriate administrative structure
6. Inappropriate financial framework
7. Inadequate or outmoded legal framework.

For the Second United Nations Development Decade (1971-1980) the goal was set of supplying 80 percent of Africa's urban population and 35 percent of the rural population with safe water by 1980 (Community Water, 1976). It is here assumed that 100 percent of the population in the year 2000 will have reasonable access to safe water. Reasonable access is defined as follows: in urban areas, within 200 m of a public hydrant; in rural areas, sufficiently close that family members do not spend a disproportionate part of the day in fetching water. Safe water includes treated surface water or untreated but uncontaminated water (OMS, 1973). It is also assumed that in urban areas 65 percent of the population will be served by house connections and 35 percent by public hydrants. It is further assumed that existing plant pipelines and reservoirs will have to be renewed by the year 2000.

To develop an estimate of the cost of water supply construction in the Savanna countries, data of 1970 for unit costs provided by OMS (1973) have been utilized. These estimates have been adjusted upward at a 14.5 percent annual inflation rate, for the period 1970-75, to obtain 1975 unit costs. The unit costs shown in Table 16 are average costs and the cost in individual countries or cities vary widely. For example, the per capita cost of house connections in Mauritania was estimated at U.S. $300 in 1970.

Table 16. Per Capita Cost of Water Supply Construction in Africa (OMS, 1973)

	1970 US $	1975 US $
Urban		
House connection	53	101
Public hydrant	28	53
Rural	20	38

Based on the population data of Table 13 and the costs shown in Table 16, an estimate has been made by country of the cost of supplying water to the Savanna population by the year 2000 (Table 17).

1.5.2 Waste Water Disposal

Concomitant with the increase in water supply requirements is the requirement for waste water disposal. The cost of providing for this need in 2000 is approximately 0.3 to 0.5 times the water supply costs given in Table 17. At 1975 dollar rates, this means an additional investment of from 3,000 to 5,000 million U.S. Dollars must be anticipated.

Table 17. Level of Expenditures (1975, Million U.S. Dollars) Required to Fulfill Water Requirements of the Population in Year 2000 in Savanna Region

Country	Urban		Rural	Total
	House Connection	Public Hydrant		
Benin	138	39	133	310
Cameroun	171	48	99	318
Central African Empire	138	39	46	223
Chad	138	39	129	306
Gambia	26	7	19	52
Ghana	393	111	133	637
Guinea	309	87	129	525
Guinea Bissau	20	6	19	45
Ivory Coast	171	48	65	284
Mali	171	48	266	485
Mauritania	26	7	61	94
Niger	85	24	262	371
Nigeria	2,114	597	2,363	5,074
Senegal	368	104	99	571
Sierra Leone	53	15	53	121
Togo	85	24	125	234
Upper Volta	138	39	338	515
Total	4,544	1,282	4,339	10,165

CHAPTER 2

LIVESTOCK

2.1 Livestock Density

In general, the Savanna Region of West and Central Africa is an area of high forage production and is well utilized by various classes of livestock including cattle, sheep and goats. Livestock stocking rates vary by area and by class of stock. Cattle density within the Savanna Region is generally between 5 and 15 animal units[1] per square kilometer. Cattle stocking rates in excess of 15 animal units per square kilometer occur in the Gambia/Casamance area, Central Mali (Mopti region), Northern Nigeria, and the Adamaoua Hills area in Cameroun (Davies, 1973). Stocking rates of sheep and goats vary from 5 to 20 head per square kilometer in general within the Savanna Region, but exceed 30 head per square kilometer in Nigeria (SEDES, 1975).

Water supply affects livestock density in two ways, directly for drinking and indirectly as it controls forage production. As would be expected, livestock density is somewhat less towards the desert environment to the north as forage production is reduced and the availability of permanent water supplies is less reliable. Other natural constraints affect livestock densities as well. To the south of the Savanna, the more forest-like areas favor the occurence of various tse-tse fly species which carry the debilitating livestock disease - Trypanosomiasis.

For details on stocking rates and livestock production in the Savanna countries (except Guinea and Guinea Bissau) one may refer to a statistical summary released by SEDES in 1975 (Recueil Statistique de la production animale. Paris, Ministry of Cooperation).

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(1) An animal unit equals one mature cow or its equivalent.

2.2 Stock Water Requirements

Providing a reliable supply of good quality water for grazing livestock is the major problem facing livestock producers in the Savanna Region. Forage quantity and quality are important for successful livestock production, but above all, water availability becomes the single most limiting factor. The importance of water to the well being of grazing livestock cannot be minimized. Water is the most vital of all body elements and is needed in adequate amounts in order that such essential life processes as absorption of feed nutrients, digestion, removal of waste products, and regulation of body temperature, can be carried on. Though, water quality should not be ignored, most water problems are related to shortages not quality. Grazing animals prefer pure, clear water, but they will do well on almost any water supply. However, every effort whould be made to provide livestock with the cleanest water possible.

The distribution of watering points within the traditional grazing areas for livestock utilizing the Savanna Region is of great importance. The greater the distance animals are forced to travel to water, the less body energy remains to produce meat and milk. When the distances are great between waters, livestock will water-out less frequently and will trample and overgraze those range areas near water sites.

Livestock water requirements can vary according to the average size of local animals and the environmental conditions (including climate) under which they graze. Also, daily water intake will vary seasonally with forage quantity and quality. During the growing season when animals are utilizing lush, green feed, their water requirements are considerably reduced because of the water content in the feed. During the dry season when forage consumed is mature and dry, daily water intake by grazing animals is much increased.

Water intake rates per head as previously estimated in several African countries reflects a considerable spread, which could have been seasonally influenced. For example:

- It has been generally assumed that daily water requirements for cattle in the Sahel are 30 liters per day while sheep and goats require 5 liters per day (France, Min. de la Coop., SCET Int., 1976);
- For Upper Volta estimates have been made of current water consumption for grazing livestock as low as 20 liters per day for cattle and 3 liters per day for sheep and goats (Fernandez-Bustos, 1975; and Haute Volta, Direction de l'Hydraulique, 1976);
- For Senegal daily water requirements are estimated to be 40 liters per day for cattle and 4 liters per day for sheep and goats. (Rep. du Senegal, 1977).

For this study, consumptive water use by livestock is based upon the following daily water requirements for grazing animals:

Liters of Water Needed Per Day		
Cow	-	40
Sheep	-	4
Goat	-	4

These daily water requirement averages are internationally accepted for range livestock (Morrison, 1949 and LeViness, 1972). Thus, to obtain annual requirements, cattle numbers are multiplied by a daily use factor of 40 liters times 365 days and sheep and goat numbers times a daily use factor of 4 liters times 365 days.

2.3 Livestock Projections

Present livestock numbers in the countries of the Savanna Region approximate 36 million head of cattle and about 82 million head of sheep and goats. These numbers are broken down by country on Table 18. The numbers of the different classes of livestock that actually are found within the Savanna zone of each country have not been separately estimated.

Table 18. Livestock Population in the Countries of the Savanna Region in 1969/71 and 1977 According to FAO (1978) in Thousands of Heads.

Country	Cattle 1969/71	Cattle 1977	Sheep 1969/71	Sheep 1977	Goats 1969/71	Goats 1977
Benin	552	833	551	886	578	858
Cameroun	2,308	2,917	2,000	2,100	1,500	1,553
Centr. Afr. E.	503	620	64	77	522	577
Chad	4,563	3,716	2,350	2,448	2,350	2,448
Gambia	247	290	85	95	91	92
Ghana	885	850	1,317	1,500	1,398	1,800
Guinea	1,300	1,600	323	420	342	385
Guinea B.	243	260	64	71	174	181
Ivory Coast	408	650	833	1,050	833	1,100
Mali	5,400	4,076	5,700	4,437	5,483	4,057
Mauritania	2,367	1,400	4,427	4,700	3,423	3,100
Niger	4,168	2,900	2,632	2,560	6,102	6,200
Nigeria	11,183	11,500	8,083	8,100	23,367	23,600
Senegal	2,557	2,440	1,533	1,760	1,067	895
Sierra Leone	240	318	55	70	156	185
Togo	187	240	596	775	501	645
Upper Volta	2,556	1,900	1,657	1,300	2,485	2,377
Total	39,667	36,510	32,270	32,349	50,372	50,053

All the coastal Savanna countries - Sierra Leone, Ivory Coast, Ghana, Togo, Benin, Nigeria, and Cameroun - as well as the Central African Empire had a meat deficit in 1970 (SEDES, 1975). At the same time, before the drought, the Sahelian countries of Mauritania, Mali, Upper Volta, Niger and Chad produced meat in excess of national demand and, among the Sahelian countries, only Senegal had a meat deficit. As would be expected, export of meat was previously from the Sahel to the Coastal countries. (CILSS/FAO, 1976). Meat production by country in 1969/71 and 1977 is shown in Table 19.

Estimates for meat demand in 1990 would indicate that meat production in the Sahelian countries would have to double or triple to meet national demands in the Sahelian and Coastal countries of West and Central Africa (CILSS/FAO, Club des Amis du Sahel, 1976). In order to achieve such goals, the meat producing countries would have to increase beef production by 6.9 percent per year, and sheep and goat meat production by 5 percent per year between 1975 and 1990. Such an anticipated meat production increase is impossible without a significant increase in livestock population and/or dramatic improvement of livestock management.

In the Sahel countries, it is unlikely that total livestock can realistically exceed the numbers that existed prior to 1970 (CILSS/FAO, Club des Amis du Sahel, 1976). Thus, the only way in which this area can respond to an increase in demand for meat is with the same number of animals but through more efficient grazing management and through a dramatic change in the historical livestock marketing practices that sell a very low percentage of the total number of animals per year.

If the present largely unproductive southern area of the Savanna Region is brought into production as expected within the next 25 years, following pregressive elimination of the tse-tse fly, then the cattle population there could increase tremendously. In preparing estimates for this study it has been assumed that the total cattle population in the southern Savanna countries will increase on

Table 19. Meat Production in the Countries of the Savanna Region in 1969/71 and 1977 in Thousand of Metric Tons According to FAO (1978).

Country	Beef and Veal 1969/71	Beef and Veal 1977	Mutton and Lamb 1969/71	Mutton and Lamb 1977	Goat Meat 1969/71	Goat Meat 1977
Benin	8	10	2	3	2	3
Cameroun	35	46	9	10	6	6
Centr. Afr. E.	16	21	-	1	1	1
Chad	31	28	7	9	6	7
Gambia	3	4				1
Ghana	21	15	4	4	4	5
Guinea	10	11	1	1	1	1
Guinea B.	3	3				1
Ivory Coast	39	44	4	5	5	6
Mali	38	32	18	18	15	12
Mauritania	15	13	6	7	5	5
Niger	29	29	4	3	19	16
Nigeria	205	192	28	26	82	77
Senegal	33	36	6	7	4	3
Sierra Leone	5	6	1	1		1
Togo	3	4	1	2	1	1
Upper Volta	23	17	4	4	8	8
Total	517	511	95	101	159	154

an average of about 3.5 percent per year to double between 1977 and 2000.

Sheep and goats in this area are also taken to approximately double, in population during the same period. It should be noted that Nigeria has a current density of sheep and goats per km^2 of 38. This is already three times higher than in other Savanna countries. So in Nigeria, the rate of increase in sheep and goat population has been taken to be only 1 percent per year to 2000.

Based on the information and assumptions above, the total livestock population in the Savanna countries in the year 2000 is estimated to be 64 million head of cattle and about 112 million sheep and goats (see Table 20).

2.4 Water requirements - year 2000

The water requirements for livestock in the year 2000 are computed from the data provided in sections 2.2 and 2.3. Results are presented in Table 21. In the last column of this table a percentage of 20% of the total water requirements is added to account for losses of water at water delivery points such as wells and troughs. The total demand is estimated to exceed 1,300 million m^3/year. During the dry season most of this water will have to be obtained from either surface water storage or from groundwater. In the case of the former, all future sources should be provided with proper draw-off facilities and, at reservoirs, with troughs below the barrages. In addition to the consumptive water use considerations discussed above, it is also important that planning for specific projects which involve the use of water storage facilities (barrages) take into account water losses from evaporation.

Table 20. Estimated Livestock Population in the Countries of the West African Savanna Region in Year 2000 in Million Heads.

Country	Cattle	Sheep/Goats
Benin	2	3
Cameroun	6	7
Central African Empire	1	1
Chad	5	10
Gambia	< 1	< 1
Ghana	2	6
Guinea	3	1
Guinea Bissau	< 1	< 1
Ivory Coast	1	4
Mali	6	11
Mauritania	3	8
Niger	4	9
Nigeria	23	40
Senegal	3	3
Sierra Leone	< 1	< 1
Togo	< 1	< 3
Upper Volta	3	4
Total	64	112

Table 21. Estimated Water Requirements of Livestock in the Savanna Region, Year 2000, in $10^6 m^3$/year.

Country	Cattle	Sheep/Goats	Total	Total incl. 20% losses of water
Benin	29	4	33	40
Cameroun	88	10	98	118
Centr. Afr. E.	15	1	16	19
Chad	73	15	88	106
Gambia	4	< 1	< 5	5
Ghana	29	9	38	46
Guinea	44	1	45	54
Guinea B.	7	< 1	< 8	9
Ivory Coast	15	6	21	25
Mali	88	16	104	125
Mauritania	44	12	56	67
Niger	58	13	71	85
Nigeria	336	58	394	473
Senegal	44	4	48	58
Sierra Leone	7	< 1	< 8	9
Togo	5	4	9	11
Upper Volta	44	6	50	60
	930	162	1092	1310

CHAPTER 3

IRRIGATION

3.1 Introduction

To estimate water requirement s for irrigation in the Savanna Region it would be logical to start by defining the need for irrigation. The need for irrigated agriculture should be justified in terms of national or regional needs for food and other crops. The most desirable means of establishing water requirements for irrigation would be by the following procedure:

1. Estimate market demands for food, fiber and industrial crops for the year 2000.

2. Estimate food, fiber and industrial crop production in year 2000 under rainfed farming.

3. Determine the difference if any, between market demand (1) and rainfed output potential (2) which must be made up by imports or irrigated production.

4. Estimate irrigated yields likely in year 2000 and convert irrigated agriculture production required to area (hectares) and water requirements.

5. Adjust water requirements of (4) for improved production on existing irrigated lands assuming these will be cropped as at present.

This appraisal should be done on a country-by-country basis, or for the parts of each country that are located in the Savanna Region. Aggregate regional figures can then be obtained for the Savanna area.

The problems inherent in each step of the above outline illustrate the basic difficulties and uncertainties underlying estimates of irrigation water requirements for any given country or area. These uncertainties are only compounded when considering an area as politically and socio-economically diverse as the West and Central African Savanna Region.

On the basis of agricultural and socio-economic data available at the CIEH Documentation Center, it is not now feasible to arrive at reasonably reliable estimates of market demands for food in all of the Savanna countries. However, there is a study of the agricultural development of the Sahelian countries between 1975 and 1990 (FAO, 1976) which does estimate food requirements for those parts of the Savanna that also lie within the Sahel.

Although much of the basic data has been collected, in order to develop an estimate of potential crop production that would be feasible under rainfed farming in the Savanna Region, detailed analyses are needed focussing on each bioclimatic zone, and areas within zones. A study to deal with this issue has been proposed by CIEH in Volume 4 of this report series, (Study Proposal TP 05).

Thus, the assessment of water requirements for irrigation presented here is based on current plans and projects under way in each of the Savanna countries. It is assumed that such plans are justified on the basis of food requirements.

3.2 Water Requirements per Hectare

The quantity of irrigation water necessary, in addition to the rainfall, for year-round crop production has been calculated with data from each of the major meteorological stations of the Savanna Region. These data are shown on the Agro-climatological map (Map 3-2) of Volume 2 of this report series.

Although variations exist within a given country, average irrigation water requirements were computed on a country basis. Where necessary, data of neighbouring countries were used. Only data within the Savanna boundaries were considered. It is noted that the available data allow for more accurate estimates for major irrigation projects if only the stations in the immediate vicinity of such projects are used. Assuming an irrigation efficiency of 0.5 to allow for water losses between irrigation head works and plant roots, the actual water necessary for irrigation was arrived at by multiplying average country data by a factor of 2. The results are shown in Table 22 below.

Table 22. Unit Irrigation Water Consumption

Country	Number of Agro-climatological Stations (1)	Average water required for year-round crop production (1000 m^3/ha)	Estimated Irrigation water required (1000 m^3/ha)
Benin	8	8	16
Cameroun	4	12	24
Centr. Afr. Emp.	5	7	14
Chad	11	12	24
Gambia	2	11	22
Ghana	7	6	12
Guinea	3	8	16
Guinea Bissau	2	10	20
Ivory Coast	6	6	12
Mali	22	14	28
Mauritania	4	20	28
Niger	13	15	30
Nigeria	11	11	22
Senegal	12	14	28
Sierra Leone	-	est. 7	14
Togo	3	7	14
Upper Volta	11	11	22

(1) From Map 3-2, Vol. 2, Savanna Regional Water Resoures and Land Use.

The actual water requirements can vary enormously for several reasons:

1. Irrigation efficiencies may range from 30 to 95 percent depending on type of irrigation system used and the source of water (groundwater versus surface water).

2. The cropping pattern selected has great effect on water use. Even though double cropping is assumed here, only a few crops require 12 months of water.

3. The water requirements of rice, a heavy user of water, depend far more on the permeability of the soils than on climate. Efficiencies probably rarely exceed 20 percent.

The water requirements per hectare as given here should, therefore, be considered as indicative only.

3.3 Planned Irrigation Development

A country-by-country survey of planned irrigation development is given below. As may be see, substantially different data are often reported by different sources. The total area to be developed for irrigated farming in the year 2000 in the Savanna Region is estimated as an aggregate of the most reliable data available at CIEH for each country.

3.3.1 Benin

The Mono Dam at Nangbeto (M 1)[1] will regulate the flow of the Mono River and make possible irrigation of 49,000 ha of which 33,000 are to be situated in Benin; the remaining 16,000 ha are in Togo.

The irrigated area at Oueme is expected to total 4,000 ha, of which 1,000 ha is actually developed. For each of the six provinces an additional area of 1,000 ha is projected to be used for irrigated rice (BDPA/IRAT, 1976). The total area planned for irrigation in Benin is therefore 43,000 hectares (33,000 + 4,000 + 6,000).

3.3.2 Cameroon

SEDES (1974) reported for Cameroon an area of 4,400 ha under traditional irrigation for rice in 1967/68 in the Semry area. This is scheduled to increase to 5,200 ha by 1985/86 (casier de Garabeye). Also in 1985/86, an additional 2,000 ha are scheduled for rice cultivation in low lands. In project Semry II the integrated development of 55,000 ha is envisaged with double-crop rice on 7,000 ha (Ediafric, 1977).

The Miderim project in the area south of Dschang calls for the development of 9,600 ha for cultivation of rice and soja. A further 3,000 ha will be developed in the upper-Noun basin (Plaine de Ndop) for the production of rice.

Other projects planned in the Savanna area of Cameroon include the proposed irrigation of 7000 ha below the Tsanaga Dam (LZ) near Maroua, the Wum Area project, and irrigated farming in the Logone and Chari valleys of 1,000 ha.

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(1)Reference code for damsite as shown on Map No. 1, Existing and Proposed Dams, of Volume 5 of this report series.

Once the Lagdo Dam (BE6) is built on the Benue (Ediafric 1977) it is expected that this will allow the irrigation of 4,000 ha. Also, the Koumban Dam (L7) on the Vina River would allow for irrigation of a total of 120,000 ha in Cameroun and Chad (Lotti, 1970).

Summarizing, it appears that at least 80,000 ha will be irrigated in the Savanna area of Cameroun which may increase to an estimated 120 to 150,000 ha with completion of the Koumban Dam.

3.3.3 Central African Empire

Farra-Frond (1976) reports that irrigation is practiced only on a small scale near Bangui, Bozoum, Paoua and Alindao. The government of the Central African Empire has given a high priority to irrigated agriculture. However, the potential for irrigation is not known and needs to be assessed. Estimates indicate that from 20-25 percent of the area actually cultivated (110-140,000 ha) can be irrigated. It is here assumed that 40,000 ha will be irrigated by the year 2000.

3.3.4 Chad

It is estimated (Table 23) that the total irrigable area of the Chad Savanna is about 660,000 ha. (Tchad, Bureau de l'Eau, 1977).

Tabel 23. Potentially Irrigable Areas in the Savanna Area of Chad (Tchad, Bureau de l'Eau, 1977)

Region	Irrigated in 1976 (ha)	Irrigable area (ha)
Kanem	50	500
Lac	3,500	60,000
Assale	5,150	13,000
Ouaddai Geographique	150	1,000
Batha	3,500	21,000
Bahr Azoum	1,000	200,000
Chari/Mandoul	0	165,000
Logone/Bas Chari	0	200,000
Total	13,350	660,500

All the above areas are conjectural, however, as another source (Ediafric, 1978) suggests that the land aptitude for irrigation is limited to 250 to 300,000 ha and that 47,770 ha were under irrigation in 1976. It should be noted in this case that only 570 ha were considered to be subject to full water control and that a further 7000 ha were worked under flood recession techniques, the rest being traditional areas. The largest areas are located in the Logone flood plain. Some 4000 ha of polder have been brought under cultivation on the lake edge.

Food requirement projects are illustrative of the need to extend production (Ediafric, 1978).

Table 24. Estimated Food requirements of Chad (1000 tons)

Crop	1976	1980	1985	1990	2000
Rice (paddy)	50	59 to 66	72 to 84	88 to 104	123 to 138
Wheat	16,5 (1)	26	31	42	53
Sugar	22 (2)	27	33	42	60

(1) 10,000 tons imported

(2) all imported.

Water resources are considerable and could meet the demand of all irrigable land, subject to construction of regulation storage in the upper reaches of the main streams (Chari, Logone) and their tributaries. Groundwater is also present in Chad.

3.3.4.1 <u>The Logone and Chari Rivers</u>

It is proposed to create regulation storage on the Logone River in order to reinforce the dry season flows. The Goré dam (L6) on the Pende in Chad, a tributary of the Logone, would permit the irrigation of 95,000 ha, and the dam at Koumban (L 7) on the Vina in Cameroon would regulate sufficient water to irrigate a total of 120,000 ha in Chad and Cameroon (Lotti, 1970). The mean annual flow of the Logone downstream at Bongor amounts to 17,000 ($10^6 m^3$); the 10 year dry flow is 11,500 ($10^6 m^3$).

The potential for irrigation in the Chari River basin is even greater than that of the Logone, but it seems to be more difficult to find suitable sites for large scale regulation storage. Large volumes are lost to evaporation in the lower reaches where overbank flow occurs. The mean annual flow of the Chari River at Mailao is 26,300 ($10^6 m^3$); its 10-year dry flow falls to 13,900 ($10^6 m^3$).

The irrigation potential of the Logone and Chari Rivers amounts to more than one million hectares, assuming the 10-year dry flows and a very high unit demand of 24,000 m^3/ha. Both rivers flow into Lake Chad whose level is maintained in equilibrium by evaporation and to a much lesser extent, by infiltration.

3.3.4.2 Lake Chad Basin as a Whole

All the irrigation potential discussed above, if brought into operation, would have repercussions upon the level of Lake Chad. The Lake Chad Basin Commission estimated in 1972 (Ediafric, 1978) that 260,000 ha would be irrigated within the basin by 2020. Withdrawal from the river system to meet the water requirements of this area would lower the lake level by 76 cm. This is considered to be the acceptable limit but any greater depression would lead to splitting the lake into two parts, depriving both Niger and Nigeria of irrigation water.

Earlier estimates in 1970 placed the upper limit of irrigation potential for the basin at 243,000 ha with the following distribution amongst riparian states (Ediafric, 1978):

Cameroon	200,000 ha.
Chad	18,000 ha.
Niger	7,000 ha.
Nigeria	18,000 ha.

The sharing of surface water inputs to Lake Chad will require careful coordination and agreement between countries. No final decisions have been reached in this regard at the present time.

3.3.4.3 Groundwater

Estimates of the groundwater resources available in Chad are given in Volume 2 of this report series. Use of this large resource for irrigation is dependent on suitable specific yields. The main water bearing formations are the following:

Aquifer	Annual Volume ($10^6 m^3$)
Plioquarternary (centered on Lake Chad);	3,590
Continental terminal (south)	13,330
Basement complex (south)	660

It should be noted that the potential of the Nubian Sandstone aquifer is little known in Chad. Non-rechargable water resources of this formation are thought to be within the limits of 36,500 and 73,000 million m^3. These, however, extend beyond the Savanna belt.

3.3.4.4 Conclusion

In order to achieve self sufficiency in food production, Chad intends to have 72,000 ha of land under modern irrigation by 2000. Of this area about 29,000 ha should be subject to full water control. Paddy will occupy 43,000 ha of the above total area, providing over 85 percent of the country's need, the rest being produced by traditional methods.

The water resources required to irrigate 72,000 ha amount to 1,728 million m^3 per year. This volume represents only 7 percent of the 10-year dry flow of the Chari and Logone rivers together.

This share corresponds fairly well with the proportional distribution attributed to the riparian states in 1970 but the area is far in excess of the 18,000 ha attributed to Chad at that time. It can be seen that the question of water development in the Chad basin will require much further discussion if the food production requirements of the neighbouring states are to be met.

3.3.5 Gambia

An area of approximately 23,000 ha in the Gambia is devoted to flood recession farming (FAO, 1976). The area on which modern irrigation with full water control is practiced did not exceed 2000 ha in 1976 (Dunsmore et al. 1976) and it has been estimated that this area will have to be increased by 3800 ha for the country to attain self-sufficiency in paddy by 1980. Double cropping occupies 1500 ha (Edlafric, 1978).

The major surface-water resource of the Gambia is the Gambia River with a mean annual flow of 9500 million m^3 and a 10-year dry flow of 5200 million m^3 These volumes could in theory irrigate 430,000 and 236,000 ha, respectively, if storage capacity were made available to regulate river flow. The land area suitable for irrigation, however, does not exceed about 80,000 ha (Dunsmore et al, 1976) or 120,000 ha (FAO, 1976).

The development of the Yelitende Dam (G 1) would create regulation storage to irrigate 24,000 ha. Other dam sites have been identified and several are under consideration including Kekreti (G 3) 170,000 ha and Sambangalou (G 5) 130,000 ha in Senegal.

Large scale extension of modern irrigation will depend essentially upon construction of regulation storage, without which progress can only be marginal in view of the limited dry season flows.

Development of sites in Senegal appears, according to present estimates, to be tied to iron ore extraction in Senegal which would justify the installation of generating capacity at the dam sites. In some variants, backwater would enter Guinea, rendering decision making even more complex. If the dam having maximum storage were to be finally selected (Kekreti) water would be available to irrigate 170,000 ha to be shared with Senegal. Total water availability would amount to 1760 to 2640 million m^3 per year.

An alternative solution would be to develop the Yelitende Dam on the Gambia river. The regulation storage created by this dam would be wholly within the Gambia and the dam itself would have the advantage of excluding the penetration of salt water from the ocean. It is estimated that the regulating capacity of this dam would allow 24,000 ha to be irrigated, involving 528 million m^3 of water per year.

3.3.6 Ghana

A report by the Ghana Irrigation Department (1977) shows that out of the 27 existing or planned irrigation projects in the country, some 22 schemes are located in the Savanna region. A map at scale 1:1,000,000 showing the location of irrigable areas and dam sites is attached to that report. Table 25 (below) gives a summary of existing schemes with a total irrigable area of 11,340 ha. Short term plans (Table 26) and long term plans (Table 27) call for additional irrigation of about 425,000 ha throughout the Ghana Savanna region bringing the total irrigation to about 436,000 ha.

Annan (1973) estimated that by the year 2030 the irrigated area in Ghana's Upper and Northern regions alone would have to be 800,000 ha to help feed the population of the country. Such a program seems ambitious. Whether the area can provide the water required for this irrigation development and satisfy the needs for human and livestock consumption and industrial demands is an issue that can best be resolved through an approach considering the entire Volta basin in conjunction with Upper Volta.

Tabel 25. Existing Irrigation Projects in the Ghana Savanna Region (Ghana Irrigation Dept., 1977)

Name of Project	Region of Ghana	Area Irrigated in 1976 (ha)	Total Irrigable Area (ha)
Tono	Upper	-	2,540
Vea	Upper	500	1,400
Akumadan	Brong Ahafo	275	1,400
Afram	Eastern	-	200
Asutsuare	Eastern	1,360	4,000
Afife	Volta	100	1,000
Adidome	Volta	-	200
Dawhenya	Gr. Accra	100	400
Ashiaman	Gr. Accra	160	200
Total		2,495	11,340

Table 26. Irrigation Projects in the Ghana Savanna Region Estimated to be Completed Before 1981 (Ghana Irrigation Dept., 1977)

Name of Project	Region of Ghana	Potentially Irrigable Area (ha)
Tamne	Upper	1,440
Bontanga	Northern	500
Passam	Northern	1,200
Lamassa	Northern	400
Kpong Akuse	Eastern	6,600
Areyime	Volta	400
Kpandu Torkor	Volta	400
Total		10,940

Table 27. Long Term Irrigation Projects in the Ghana Savanna Region (Ghana Irrigation Dept. 1977)

Name of Project	Region of Ghana	Potentially Irrigable Area (ha)
Pwalugu	Upper/Northern	138,000
Lake Shore (1)	Northern/Volta	39,000
Bui	Northern/Brong Ahafo	32,000
Avu Keta	Volta	30,000
Accra Plains (2)	Eastern	165,000
Angaw	Gr. Accra	10,000
Total		414,000

(1) excluding the Afram, Kpandu Torkor, and Lamassa schemes (total 1,000)

(2) excluding the Asutsuare, Areyime, and Kpong Akuse schemes (total 11,000 ha.)

3.3.7/3.3.8 Guinea/Guinea Bissau

The data available at CIEH do not allow for a detailed assessment of the irrigation potential of the savanna areas of each of these two countries.

3.3.9 Ivory Coast

In 1980, 37,000 ha are planned to be irrigated for the production of 276,000 tons of paddy rice. An estimated 30,000 ha of this total is located in the savanna area of the Ivory Coast (Northern & Central Regions). A further 10,000 are scheduled to be irrigated by drip-irrigation in the Bandama Valley for the production of sugar cane (Ediafric, 1975).

Detailed information on the irrigation potential of Ivory Coast is not available at CIEH.

3.3.10 Mali

Irrigation is practiced more extensively in Mali than in other countries of the Savanna Region. By 1976 some 117,000 ha of land were under modern irrigation. Of this area 50,000 ha had full water control (5,000 ha double cropped). A further 155,000 ha are cultivated by traditional irrigation methods (Ediafric, 1978).

The present irrigation schemes are distributed over four main regions located along the reaches of the Niger River upstream of the inland delta and within the inland delta itself in its westerly or inactive part. These main areas are the following:

Riz Sikasso	4,243 ha
Riz Segou	40,375 ha
Riz Mopti	14,890 ha
Office du Niger	55,600 ha
Total	115,108 ha

Irrigation in the Office du Niger or delta area is made possible in part by the operation of the following structures:

- The Sansanding Dam (N 34) near Markala having a total length of 2,836 m with an 816 m gated structure completed in 1947.
- A feeder canal upstream on the left bank, 8 km in length for a discharge of 110 m^3/sec.
- Two main canals
  1. Macina canal, 14 km long
  2. Sahel canal, 25 km long
- A navigation canal 8 km long with a lock on the right bank.

A number of improvements in the delta area are planned for the immediate future. They include: repair work on the dam; dredging of the lead-in; recalibration of the feeder canal to increase its capacity to 200 m^3/sec.; extension of the irrigated area by 22,000 ha.; construction of the Costes canal (19 km), which would allow 68,000 ha of gravity irrigation in the upper Kala area with supression of the now existing pump irrigation of sugar cane areas (Dougabougou and Siribala); recalibration of the Sahel canal to increase its capacity from 55 to 120 m^3/sec. raising the irrigable area from 18,333 ha to 40,000 ha and recalibration of the Macina canal to raise its capacity from 55 to 80 m^3/sec. and increase the potential from 18,333 ha to 26,667 ha Much of this civil engineering work has already obtained financing (Ediafric, 1978).

In 1976 there was a deficit in national production of cereals of approximately 5 percent, on a total harvest of 1.5 million tons. As the population increases from the present near 6 million to 10 million in 2000 it is proposed that the increasing demand for cereals be met by maintaining production of millet, sorghum and maize at the present level, but raising the output of paddy rice from 200,000 tons to nearly 2 million tons in 2000. (Ediafric, 1978). It is hoped that this increase can be attained by a massive increase of double cropping on a gradually modernized irrigation sector. In this way food production would become much less dependent upon the variability of the Sahelian climate.

3.3.10.1 Prospects for 2000

The water resources of the Niger and Senegal basins in Mali are very considerable:

	Annual Runoff (10^6 m^3)
- Niger (including Bani)	
median flow	66,500
10-year dry flow	43,500
- Senegal (at Bakel)	
median flow	23,800
10-year dry flow	13,600

If the annual objective of 2 million tons of paddy rice is to be attained with an average yield of 2,3 tons/ha, it will be necessary to irrigate 870,000 ha. Assuming water requirements for paddy of 28,000 m^3/ha with double cropping, it can be seen that the total water requirements amount to 24,360 million m^3 per year. This annual water demand is well within the capacity of the available surface water resources of the country (43 percent of the 10-year dry flow) even if yields obtained are lower or if the water requirements are under estimated.

It should be noted however that regulation storage will have to be provided to irrigate these large areas. Such storage is under construction today at Selingue (N41) on the Sankarani (Niger Basin) with a storage capacity of 2170 million m^3 and an irrigation capacity of 50,000 ha. Another dam has now been financed at Manantali (S9) on the Bafing (Senegal Basin) with a storage capacity of 10,000 million m^3 and an irrigation potential of 450,000 ha (48,000 ha in Mali the rest in Mauritania and Senegal). Other sites have been identified, including in Guinea and Ivory Coast in the upper Niger basin, but their development is not scheduled in the immediate future.

Extension of irrigation areas in the upper Niger Basin will gradually modify the regime of the Niger River below the inland delta in Mali, Niger and to a lesser extent in Nigeria. These gradual modifications are to be studied on a basin management mathematical model at present being assembled (SOGREAH 1978). There is reason to believe that considerable extensions of the irrigated areas in Mali will not greatly affect the annual flow downstream of the delta, as a reduction of flood flows will reduce the enourmous evaporation loss which occurs at present within the delta (about 30,000 million m^3 per year for the median flow but only 21,000 million m^3 for the 10-year dry flow).

Limited renewable groundwater resources are available in Mali (BRGM 1976). These are, for the Savanna area of the country:

	$10^6 m^3$/year
- Basement complex	1,800
- Continental Terminal	
of the Gondo Plaine	450
of the Inland delta	328
- Infra cambrian Sandstones	9,150

In most cases, groundwater development would be limited to the irrigation of small holdings from individual wells or boreholes.

3.3.10.2 Conclusion

By the year 2000 both the Selingue and Manantali Dams will have been regulating irrigation water for 15 to 20 years and a second generation of regulation dams will be nearing completion, subject of course to funds being made available. The land under irrigation with full control of the water will have increased from the present 50,000 ha, to 140,000 ha in 1982, to 260,000 ha in 1990 and to 270,000 ha in 2000. New areas under irrigation with partial water control are expected to have developed from 57,000 ha in 1982, to 97,000 ha in 1990, and to 217,000 ha in 2000 (Ediafric, 1978). Assuming that 21,000 ha are reserved for sugar cane and 14,000 ha for wheat, the total area under paddy would be 452,000 ha. If the average yields are 2.3 tons/ha on land with full water control, and 1.8 tons/ha on land with partial water control, it can be estimated that the annual production of paddy will total just over one million tons. It is important to note that this production falls short by half of what was required based on projections and plans noted above.

3.3.11 Mauritania

Rain-fed and flood recession agriculture occupies 188,000 ha in Mauritania (FAO 1977, Ediafric 1978). By 1976 less than 1,200 ha of land had been placed under modern irrigation for rice growing. 855 ha of this total are in the M'Pourlé plaine (Delta) and 277 ha receive pumped water from the Senegal River. Additional flood recession rice farming is done on 20,000 ha near 250 small dams, of which 180 have been built by villagers. Rice yields on the latter areas are 0.5 ton/ha compared to 5 tons ha obtained in the modern schemes above (Ediafric 1978). In order to meet food requirements cereals have to be imported at an ever increasing rate. For the 1973-74 agricultural year imports amounted to 88,000 tons, whereas the national production totalled 80,000 tons. If Mauritania is to become self sufficient in cereals within 10 years, the national output must increase at the rate of 4.2 percent each year, according to the World Bank. This goal does not seem to be within reach of rain-fed agriculture and it will be necessary to orient agricultural production towards modern irrigation methods in order to increase yields and ensure a degree of security in dry years. It should also be noted that the regulation of the Senegal River flows will lead to the disappearance of flood recession agriculture, at present the major contribution to food production. This must be taken into account when evaluating the benefits of regulating dams and developing programs to increase production.

3.3.11.1 Prospects for 2000

Large scale extension of irrigation in Mauritania will depend essentially upon the development of regulation storage on the Senegal River together with a salt excluding structure in the lower reaches. The mean annual volume of water passing into the ocean is 21,570 million m^3 whereas the ten-year dry flow is 14,500 million m^3. Regulation storage available after construction of the now financed Manantali Dam on the Bafing River in Mali (capacity 10,000 million m^3) will permit the irrigation of 280,000 ha. The addition of a salt excluding dam at Diama, (S1) in the delta, would raise the capacity to 428,000 ha to be shared as follows: Mauritania 141,000 ha, Mali 45,000 ha, and Senegal 242,000 ha.

The initial rate of development in Mauritania is planned to be on the order of 1,600 ha per year (Ediafric, 1978).

There are a number of projects anticipated for irrigation of smaller areas within the Senegal Basin. For example construction of dams on both the Black and White Gorgols (right-bank tributaries of the Senegal River), together with a levee along 15 km of the Senegal River bank, would enable irrigation of 10 to 12,000 ha. 3000 ha of this area has been selected for sugar cane. The volumes of water stored by the two structures would total 500 million m^3 of which about half would be available for irrigation, the remainder being lost to evaporation.

Another objective is to divert water from the Senegal River into the long depression behind the coastal dunes northwards as far as Nouakchott. Some 10,000 ha could be brought under irrigation as well as providing a source of water to the city of Nouakchott. At Lac R'Kiz the production of cereals (wheat) and forage crops could be undertaken on 5 or 6,000 ha, if regulating structures were built to control the rate of flooding from the Senegal. Development of 4,200 ha of irrigated agriculture in the Boghi Plain will be undertaken after flood protection embankments and a drainage system have been completed.

The groundwater irrigation potential in the Savannah belt of Mauritania is apparently limited to the vicinity of the Senegal River and to the continental terminal aquifer. In both cases the only significant recharge occurs directly from the stream bed (BRGM, 1976).

3.3.11.2 Conclusion

The recent decision to go ahead with construction of the Manantali Dam, together with the probable development of the Diama Dam in the Senegal delta, will enable Mauritania to go ahead with the development of its share of the Senegal River water resources.

The target set for 2000 is some 140,000 ha of modern irrigation with a total annual water requirement of just 4,000 million m^3, representing

30 percent of the Senegal River's 10-year dry annual flow. This volume may at first sight appear to be very close to the limiting total water resource (in view of the needs of Mali and Senegal) but it should be kept in mind that the unit water requirements used throughout the present discussion are total headworks requirements based on twelve month irrigation cycles and that, in practice, the actual water used will be significantly less.

3.3.12 Niger

In years of normal rainfall the food deficit of Niger is of the order of 200,000 tons, less in wet years, but much more in dry years. Cereals production amounted to 1,317,000 tons in 1977 but only 871,000 tons in 1975.

The government of Niger is concentrating on a massive expansion of irrigated crop production, without a decrease of the effort made to improve the productivity of rainfed agriculture. About 5,800 ha of land is under modern irrigation in 1978, of which a little less than 4,000 ha lies on the Niger River banks. The balance is in the department of Tahoua, receiving water from nine small dams. It is estimated that there is full control of water on 4,600 ha (2,600 ha with double cropping) and partial control on 1,200 ha (Ediafric, 1978). Without resorting to regulation of Niger River flows, the total area that could be irrigated amounts to only 11,000 ha. Traditional irrigation is practiced on 3,000 ha.

3.3.12.1 Prospects for 2000

Two major water resources are available and almost unutilized in Niger: the Niger River and groundwater, A considerable volume is also present in the minor streams.

A feasibility study (Sofrelec, 1978) shows that 140,000 ha could be brought under irrigation along the river Niger within about 15 years subject to construction of a regulating dam at Kandadji (N25)

The limiting factor (apart from finance) is suitable soils and not water resources, since the annual flow at the dam site (just downstream of the Mali border) amounts to 32,000 million m^3 (median) and 26,000 million m^3(10-year dry). The total head works requirement for 140,000 ha of irrigation, livestock, industrial, and Niamey urban water amounts to 2500 million m^3 per year which is only 8 percent of the median flow. Evaporation on the regulation storage, however, accounts for a further depletion of 10 percent of the total resource, leaving more than 80 percent of the potential for further development.

The Kandadji Dam has yet to be financed and negotiations have to be finalized with Mali in connection with the entry of the backwater from the dam, the extent of which varies according to the selected closure level, itself governed by hydro-power optimization considerations.

Large scale irrigation development in Mali could significantly reduce the Niger River flow at the entry to Niger, but it can be seen that even after the Kandadji scheme becomes operational, 80 percent of the median flow is still available. Development of this resource, in Niger, would entail:

a) Additional regulation storage (in Mali)
b) Massive transfer out of the Niger valley to suitable soils elsewhere in the country
c) Sacrifice of navigation potential made available by Kandadji Dam.
d) Some agreement with Mali on sharing Niger River waters (and also with Nigeria).

The flow of Niger River right bank tributaries is accounted for in the Kandadji scheme.

Other gauged streams in Niger have an annual median flow of about 1000 million m^3 but suffer from the disadvantages of:

a) Non-permanency

b) Watersheds wholly or partly in Nigeria, hence out of control (Goulbi de Maradi)

c) Border stream (Komadougou)

Their potential is therefore subject to modification and the available volume of water, after regulation, is probably (for Niger) less than 500 million m^3 per median year (less than 15,000 ha after subtracting regulation loss).

It can be estimated that the ungauged, unregulated, short distance surface flows amount to about 5,000 million m^3 (Henry, 1978). In theory, over 100,000 ha of land could be irrigated by impounding this resource but this would require over 500 small dams, probably more. Small scale development would, however, contribute to the livelihood of many areas out of reach of major development.

Groundwater is present in most of the Savanna belt of Niger. The major aquifers (continental terminal, basement complex and continental intercalaire-Nubian sandstones) are very attractive alternatives to surface water development for irrigation. According to BRGM (1976) more than 1000 million m^3 might be available annually from the continental terminal aquifer.

An initial area has been selected in the Goulbi de Maradi by the World Bank for irrigation with groundwater which should pave the way for large scale development of this resource in other parts of the country. Suitable soils are present in the Dallol Maouri and Dallol Bosso dry valleys for development of 50,000 to 75,000 ha with water from the Nubian sandstone aquifer, which at present is artesian. Studies are urgently required to define the life of such a project based on non-renewable water resources.

The Indian example shows that micro-irrigation based on individual boreholes and wells in the basement complex can make a significant contribution to food production if large numbers of farmers are involved, 100,000 families in Niger could cultivate perhaps 25,000 ha of gardens under such conditions.

3.3.12.2 Conclusion

Should finance be obtained to build the Kandadji scheme it is clear that all available resources in the field of agriculture development will be harnessed in this direction.

Kandadji will, with its potential of 140,000 ha of irrigated land situated on the Niger River banks however, maintain food self sufficiency until just beyond 2000. Planners should, therefore, spare no effort to define the possibilities of agricultural growth beyond this scheme and there seems to be no reason why small-scale development of the very powerful and ever present groundwater resources should not be undertaken right away in order to gain valuable experience in this promising field.

The need for regional surface water resources management is obvious and indeed a mathematical model of the middle reaches of the Niger River (inland delta to Nigeria border) has recently been financed. (SOGREAH 1978). This management model is a very powerful planning tool and when expanded upstream to Mali and Guinea, it will be possible to locate structures and irrigation schemes with much greater security than at present.

3.3.13 Nigeria

It is estimated that a total of 73 million ha of land can benefit from either full or supplemental irrigation in Nigeria. Projected irrigation schemes to date, for all Nigeria, are planned to cover an area of 356,000 ha by 1985. Yet this total is considered to be at least 250,000 ha too low. (Nigeria, Min. of Agr. 1974).

Of this total, irrigation in the savanna area of Nigeria is expected to cover about 300,000 ha in the same period. The total Nigerian Savanna area with potential for irrigation, based on the reservoir sites documented in Volume 5 of this report series amounts to about 420,000 ha. However very few target dates for

for dam construction are available on which to develop a realistic projection of implementation.

3.3.14 Senegal

In years of normal rainfall, cereals imports represent about one third of the country's needs (consumption 850 to 920,000 tons; imports 260 to 330,000 tons each year). Imported cereals are mainly rice and wheat, (Ediafric, 1978). In view of this very large food deficit it is clear that every effort must be made to free production from uncertainties due to climatic variation and increase productivity. Large-scale irrigation extension is dependent upon the creation of regulation storage on the Senegal, Gambia and Casamance rivers. In the absence of such storage reservoirs it has been possible to develop only small areas of modern irrigated agriculture.

By mid 1977 SAED (Société d'aménagement et d'exploitation des terres du delta du fleuve Sénégal) had brought 9600 ha under irrigation in the Senegal valley and delta area. Under the direction of SODEFITEX (Société de développement des fibres textiles) there were 8,000 ha of modern irrigation systems in operation in eastern Senegal and continental Casamance by the end of 1976. SOMIVAC (Société de mise en Valeur Agricole de la Casamance) supervises rice production on 7,000 ha in the Casamance (Ediafric, 1978).

The total area under modern irrigation with double cropping in Senegal appears to be on the order of 7,000 ha, whereas 12,000 ha are single cropped. Partial water control is achieved on 76,500 ha and traditional irrigation, as practiced by African farmers with minimal water control, covers 65,000 ha (Ediafric, 1978).

3.3.14.1 Prospects for 2000

Regulation storage available after construction of the now financed Manantali Dam on the Bafing River in Mali (capacity, 10,000 million m^3) will enable 280,000 ha of land to be irrigated with Senegal River water. The addition of a salt excluding dam at Diama in the Senegal delta would raise the capacity to 428.000 ha (Ediafric, 1978). As mentioned earlier, these areas would be shared between the three countries involved as follows: Senegal, 242,000 ha; Mali, 45,000 ha; and Mauritania, 141,000 ha.

The construction of the following dams (equipped with navigation locks) is planned for irrigation development in the Casamance.

- Bignona (C2) 12,000 ha
- Baila (C1) 34,000 ha
- Kamobeul 32,000 ha

It is estimated that a total of 100,000 ha could be irrigated in the Casamance area and the planned rate of growth is 3,000 ha per year.

The water resources of the Gambia River are sufficient to irrigate over 200,000 ha. This resource could be shared between Senegal and the Gambia, soil quality limiting the irrigation potential to 80 to 120,000 ha in the Gambia.

Only main stream water resources have been examined in the above sections. Clearly, development of minor streams and short-distance runoff with small storage dams would offer the possibility of extending irrigation to other areas.

Groundwater availability has been estimated throughout Senegal (BRGM 1976). The main aquifers could supply significant volumes of water for irrigation, subject to suitable well yields.

Formation	Annual Volume ($10^6 m^3$)
Senegal river alluvium	50
Dune sand - Dakar to St. Louis	210
Continental terminal	7,460
Basement complex	820
Eocene marly limestones	720

3.3.14.2 Conclusion

It can be assumed that both the Manantali and Diama Dams will have been completed by 2000. The regulation storage afforded by these dams raises the irrigation potential of the Senegal River basin to 428,000 ha of which area 242,000 ha is available to Senegal. The water requirements of the total area amount to:

Country	Irrigated Area	Annual Volume ($10^6 m^3$)
Senegal	242,000 ha	6,776
Mali	45,000 ha	1,260
Mauritania	141,000 ha	3,948
	Total:	11,984

This volume represents 89 percent of the 10-year dry annual flow of the Senegal River at Matam. This volume represents a maximum value as it is based on 12 months of irrigation per year with an annual water requirement of 28,000 m^3/year per hectare.

3.3.15 Sierra Leone

For the whole of Sierra Leone, the area of rice cultivation did not increase between 1960 and 1973 and was about 340,000 ha. Out of this total 16% (54,000 ha) is irrigated by flood waters or simple irrigation/drainage systems.

The major development thrust is toward improving the rice production under irrigation (two crops per year) (BDPA/IRAT, 1976). Data for a detailed assessment of Sierra Leone's irrigation potential in the year 2000 are not available at CIEH.

3.3.16 Togo

Development of the Nangbeto Dam (M1) on the Mono River is planned to regulate flows for hydropower production. At the same time, water to irrigate 49,000 ha will be provided. Of this total 16,000 ha are to be developed in Togo, the remainder in Benin on the left bank of the river.

Almost 1,100 ha of land were estimated to be irrigable at Fosse aux Lions and Paiokou (BDPA, 1965). This is in addition to the existing irrigated areas of Tantiégou and Gravillòn. Another 1,870 ha were planned for irrigation in the Oti Valley (BDPA, 1968).

3.3.17 Upper Volta

In 1973, a very dry year, the food deficit in Upper Volta was 85,600 tons. It is estimated that by 2,000 demand will increase by 685,000 tons (Ediafric, 1978).

Increasing areas of rain-fed crops, along with application of better methods and improved varieties, could result in production to meet this demand in years of normal precipitation. However severe shortages would still occur in years of drought. In order to protect the population from such disasters the government has decided to explore every way of utilizing the relatively limited surface water resources for irrigated crops, thus guaranteeing that a certain fraction of the total agricultural product is little influenced by climatic variability.

The total area of land under irrigation in Upper Volta today amounts to 7,900 ha including 4,300 ha on which there is full water control. Double cropping occupies 3,200 ha. One of two main irrigation schemes is Banfora, where 2,600 ha are devoted to sugar cane. This area is being expanded to 4,000 ha. On the Kou, 1,200 ha is under rice cultivation, of which 900 ha is being double cropped. The remaining areas comprise small schemes in valley bottoms (bas-fonds), often in connection with small storage dams, where mostly flood recession irrigation prevails. Of the numerous (more than 300) small dams many are not being used to full potential.

3.3.17.1 Prospects for 2000

An overview of existing and planned irrigation projects is given by Fernandez-Bustos (1975). The author estimates the potentially irrigable areas on the basis of available water and soil as shown in Table 28. This potential is confirmed by Direction de l'Hydraulique, Haute Volta (1976):

Table 28. Potentially Irrigable Areas in Upper Volta (Haute Volta, Direction de l'Hydraulique, 1976)

Location	Irrigable Area (ha)
Volta Noire	35,000
Volta Rouge	10,000
Volta Blanche	37,000
Banfora	14,000
Southwest Plains	22,500
Small Dams	12,500
Bas-fonds	21,000
Total	152,000

Other estimates (France, Min. de la Cooperation, 1975) and Ediafric (1976) are lower, as shown in Table 29.

Table 29. Potentially Irrigable Areas in Upper Volta (France, Min. de la Cooperation, 1975)

River basin	Maximum irrigable area (ha)	Minimum irrigable area (ha)
Volta Noire	30,000	20,000
Volta Rouge	5,000 (?)	0
Volta Blanche	30,000	25,000

The gross area of soils that might be suitable for irrigation in the upper Black Volta valley (from the Kou tributary downstream to the region of the Sourou emissary) amounts to about 200,000 ha. Water resources here are the limiting factor, with a 1000 million m^3 median annual flow, falling to 500 million m^3 for the 10-year dry flow. Construction of one or more regulation dams would enable a little over 30,000 ha of land to be irrigated (Henry, 1975). Further downstream, at Noumbiel (V11) the water resources increase to about 6,000 million m^3 in a median year. A feasibility study (Sofrelec, 1978) of the hydro-power potential has been completed for this site, but the irrigation potential of this development is only marginal due to unsuitable soils.

A detailed feasibility study of irrigation potential in the White Volta basin (SOGREAH 1978) shows that some 30,000 ha could be irrigated with the water resources of this non-permanent stream provided that a storage dam be built in Bagré (V7), not far upstream from the Ghana border. The median flow of the White Volta in the vicinity of Bagre is 1000 million m^3, whereas the 10-year dry flow is only 425 million m^3. Some hydro-power would be produced at the dam, but much of it would be needed to pump water to the irrigation areas, since they are mainly situated above the pond elevation.

It is further estimated (Ediafric, 1978) that 15,000 ha of land could be brought under irrigation for paddy rice in the Komoe, Red Volta, Bougouriba and Poni river valleys. The potential for traditional irrigation is estimated to be 30,000 ha (Ediafric, 1978).

Three water bearing geological formations are reported (BRGM 1976). These are :

1. The continental terminal present over 11,380 km^2, with an estimated annual recharge of 430 million m^3.

2. The basement complex, present over 225,360 km^2, with an estimated annual recharge of 3,770 million m^3.

3. Primary and precambrian sandstones present over 32,290 km^2, with an estimated 1,960 million m^3 of annual recharge.

The estimated annually rechargeable volume of ground water thus would appear to total over 6,000 million m^3. This volume is of the same order as the total surface runoff and in many cases could no doubt be developed for very small scale irrigation. In time, such small schemes could produce a significant quantity of food and raise the standard of living in many parts of the country not having access to larger scale irrigation development.

3.3.17.2 Conclusion

The irrigable areas indicated above represent a total of 91,000 ha. The water requirements of this total area would be on the order of 2,000 million m^3. Surface water availability in Upper Volta is probably two or three times greater than this volume if ungauged, short distance flow is accounted for (274,200 Km^2 with 20 to 30 mm average annual runoff). Harnessing these water resources would, however, entail the construction of many more regulating dams and making full use of this water in each case.

3.4 Savanna Water Requirements - Year 2000

The total irrigation water requirements of the Savanna Region were determined by multiplying the projected irrigated areas given in section 3.3 for each country, by the unit water consumption of each country given in section 3.2 (Table 22). Results are presented in Table 30.

With an estimated area of over 2 million ha under irrigation in the year 2000, the water requirements are estimated to be between 40 and 50,000 million m^3 per year.

Table 30. Estimated Water Requirements for Irrigation in the Savanna Region, Year 2000

Country	Area irrigated (1000 ha)	Water requirements 10^6 m^3/year
Benin	43	688
Cameroun	80	1,920
Centr. Afr. E.	20	280
Chad	72	1,728
Gambia	24	528
Ghana	436	5,232
Guinea	?	?
Guinea Bissau	?	?
Ivory Coast	40	480
Mali	270[(1)]	7,560
Mauritania	140	3,920
Niger	140	3,920
Nigeria	420	9,240
Senegal	242	6,776
Sierra Leone	?	?
Togo	20	280
Upper Volta	91	2,002
TOTAL	2,038 +	44,554

(1) plus 217,000 ha with partial water control.

CHAPTER 4

INDUSTRY

4.1 Introduction

Industry, including mining, in the Sahel-Sudan region is estimated to account for less than six percent of the total gross national products. It has been estimated that about two million tons of goods were produced annually in the early 1970's (MIT, 1974).

Existing manufacturing industry has met its water requirements by locating in urban areas where municipal supplies (usually from surface water) are available, or in the lower reaches of large rivers, on the shores of lakes or where there are substantial supplies from underground aquifers. Without a detailed study of each individual industrial installation, it is not possible to make a reliable estimate of the total annual volume of water utilized. The unit consumption for all industries varies widely from less than 20 m^3 to more than 100 m^3 of water per ton of product. If the larger unit were used to estimate total industrial consumption, the total volume of water currently used per year, would be about 200 million m^3, equal to a continuous rate of only about 6 m^3 per second.

Obviously the present and future location of industries is limited to the vicinity of natural water sources, but the total availability of water does not appear to be a restraint on future industrial and mining development as a whole. Furthermore, the average growth of manufacturing industry, as shown by the MIT Study (1974) appears to be only about one percent per year, so that immediate growth of water demand for this purpose is expected to be small.

4.2 Water requirements - year 2000

A large variety of factors affect future industrial water demands. Furthermore many of these factors depend on future policy decisions related to industry and mining development that are often made outside the Savanna Region.

For purposes of this report, therefore, only a general estimate of industrial water requirements is given based on the assumption that these requirements will constitute 25 percent of the urban water requirements by the year 2000. Obviously, these data have only an indicative value. Table 31 shows estimated industrial requirements, on the basis of calculated water requirements of the populations of small towns and large towns which are given in Table 15.

Table 31. Estimated Water Requirements for Industry in the Savanna Region, year 2,000.

Country	Water requirements ($10^6 m^3$/year)
Benin	42
Cameroun	28
Central African Empire	47
Chad	36
Gambia	4
Ghana	64
Guinea	71
Guinea Bissau	7
Ivory Coast	40
Mali	48
Mauritania	4
Niger	22
Nigeria	705
Senegal	120
Sierra Leone	9
Togo	30
Upper Volta	41
TOTAL	1,318

CHAPTER 5

HYDROELECTRIC POWER

5.1 Introduction

A comprehensive study of future hydro-power development in the Savanna would require a detailed investigation by engineers assisted by economists familiar with energy production. The development of hydroelectric power is determined by the demand for electrical energy in general. Estimation of future electrical energy consumption on the basis of past growth does not appear to be meaningful in the Savanna countries where electrical energy represents less than two percent of the total energy consumed now.

Currently, the structure of the electrical energy market is determined by the presence or absence of electrical energy consuming industries in each country. This explains the large differences in the per capita consumption which can be found in Table 32. In Cameroon, for example the Alucam aluminum industry in 1971 consumed 82 percent of the total electrical energy produced. In Ghana, the Valco aluminum smelter absorbed 74 percent of the energy produced at the Akosombo Dam in 1968. Mining activities to a large extent determine the development of hydro-power potential. Forecasting of future energy demand therefore can only be realistic if the development of mineral depsoits can be anticipated. This development will, of course, depend not only upon the extent and value of the minerals but also on the cost of the electrical energy and the situation of the world market for the particular commodity.

A further characteristic of the electrical energy market is the very high concentration of consumers within a few urban centres. In Cameroon for example, where in 1971 Alucam absorbed 82 percent of the energy, the towns of Douala, Yaoundé and Edéa accounted for 90 percent of the remainder. In Nigeria, the city of Lagos in 1974 absorbed 51 percent of the total electrical energy produced and 87 percent of the non-industrial electrical energy. In the

Table 32. Per capita GNP and Electrical Energy Consumption Growth from 1971 to 1976 in Savanna Countries.

Country	GNP (US $) 1971	GNP (US $) 1976	GNP factor[1]	Electrical energy (KWH) 1971	Electrical energy (KWH) 1976	Electrical energy factor
Benin	94	133	1.41	12	17	1.42
Cameroon	170	309	1.81	190[2]	213[2]	1.12
Central AFrican Empire	117	231	1.97	31	27	0.87
Chad	77	123	1.60	11.7	12.4	1.06
Gambia	133	183	1.37	34	75	2.21
Ghana	286	584	2.04	380[3]	393[3]	1.03
Guinea	71	154	2.16	117	117	1.00
Ivory Coast	345	609	1.76	144	159	1.20
Mali	54	101	1.87	6.6	13.7	2.08
Mauritania	167	340	2.03	16.5	27.3	1.65
Niger	84	156	1.86	9.2	14,9	1.62
Nigeria	147	380	2.58	20	49	2.45
Senegal	183	386	2.10	72	80	1.11
Togo	134	261	1.94	48	44	0.91
Upper Volta	57	115	2.01	5.9	9.1	1.54
Average	141	271	1.92	73	83	1.14

Notes:

(1) The factor linking the 1971 GNP to that of 1976 is only an indicator to compare GNP evolution from country to country, no account being taken of the variation in value of the monetary unit during the time interval.

(2) If Alucam's consumption is discounted, the per capita consumption in Cameroon falls to 34.2 KWH in 1971 and 38.3 KWH in 1976 bringing Cameroon into line with other countries of the area.

(3) If the energy consumed by the Valco smelter alone is discounted Ghana's per capita consumption for 1971 and 1976 falls to 99 and 102 KWH, respectively. These values are higher than those of other countries in the area but are further reduced to 84 and 87 KWH, respectively, when allowance is made for export of electrical energy to neighbouring Togo and Benin.

Ivory Coast, Abidjan in 1974 was consuming 95 percent of the total electrical energy produced in the country.

Lastly, it should be pointed out that per capita consumption statistics are misleading, even where industrial and non-industrial consumption figures can be separated, since very few people, even in the principal cities, have access to the electric network at all. It is a fact that in the West African Savanna, even persons with full-time jobs and regular incomes that place them in an above average and relatively privileged and secure economic situation, cannot afford the cash outlay to connect their residences to the municipal distribution system.

Future electrical energy demand estimates must, therefore, not only be based on realistic and accurate forescasts of mining and industrial development (a single enterprise can instantaneously double the demand in most of the countries of the zone) but also on the future purchasing power of the city dweller, not to mention that of the peasant or villager, if one considers rural electrification.

One of the main justifications for developing hydroelectric plants is the rising cost of fuel which renders hydro-power steadily more attractive . In this connection, it should also be pointed out that many countries in the Savanna are land-locked. Their petroleum imports, therefore, depend upon the port facilities of neighbouring countries, and very long road or rail transport hauls to fuel oil burning or diesel plants in urban centers. This factor not only increases the cost of thermal generation to prohibitive levels but also renders supplies insecure in the event of unfavourable political situations. The present estimated cost of fuel oil burning and diesel power in the land-locked Sahelian countries is 11 - 15 CFA/KWH and 24 - 26 CFA/KWH, respectively, compared to hydro-power at 7 - 13 CFA/KWH.

It should be borne in mind that the production of energy from hydro-power sources generally involves the regulation of stream flow in order to raise the guaranteed power output. This means that the dry season flows of the rivers concerned are markedly increased, making possible the irrigation of large areas. Many hydroelectric schemes are likely to be justified on these grounds.

Under these conditions it seems necessary to reconsider conclusions made prior to the petroleum crisis, concerning the economic feasibility of developing hydro-power at already identified sites (see Volume 5). It is believed that a number of such studies would now be judged in a much more favourable light if not only up-to-date comparisons are made with petroleum fired plants, but also if longer transmission lines are taken into consideration, together with the benefits to agricultural production.

The relatively small amount of hydro-power that has so far been developed in the Savanna Region is mostly in the Lower Niger and Volta basins, where an installed capacity of about 2,000 MW produces about 7,000 GWH/year. Now under construction and/or financed are additional plants with a capacity of 3,200 MW to produce about 21,000 GWH/year for the whole Savanna Region. Most of the new developments are to be in Ghana, Guinea, and Nigeria. The scope for further large scale generation is limited to a known potential of about 12,000 MW or 65,000 GWH/yr.

The river basins that have the highest identified potential for hydro-power are the numerous small basins on the southwest coast, the Volta basin, the Upper, Middle and Lower Niger valley, and the Upper Benue basin.

In the following section, the potential for hydro-power development in the Savanna is considered on a country-by-country basis. Past development has been reported by the Organization of African Unity (1968) in the International Atlas of West Africa, Plate 41.

5.2 Planned Hydroelectric Power Development

A country-by-country survey of planned and potential hydroelectric power development is given below.

5.2.1 Benin

The electrical energy consumption was 54 GWH in 1976 (Notes d'information, BCEAO, 1978). Benin and Togo are linked by the Communauté Electrique du Bénin (C.E.B.), power being supplied from the Akosombo Dam in Ghana, under the terms of a 15-year contract to supply 50 MW on a line 335 Km long from the dam to Cotonou via Lome. In the north, the Mekrou and the Sota, two tributaries of the Niger, offer three small hydro-power sites - Sota (N 12), Dyogouda (N 19), and Koudou (N 20). With a low population density in northern Benin, any power developed would probably be shared with Niger. No potential hydro-power sites appear to have been identified on the Oueme River, the main river in Benin.

There is good reason to believe that the Nangbeto scheme (M 1) on the Mono River will be taken up, with considerable benefit to Benin not only in terms of hydro-power, but also involving large areas of irrigation (See also Togo).

5.2.2 Cameroon

The electrical energy consumption of Cameroon was 900 GWH in 1976 primarily used by Alucam and the towns of Douala, Yaounde and Edea, all outside the Savanna Region. Within the Savanna Region the most important potential hydro-power site is Nachtigal (SA 1) on the Sanaga river, which is currently under study. The capacity is 203 MW. On the Benue River at a point 50 km from Garoua, the Lagdo Dam (BE 6) is under construction with an installed capacity of 72 MW to produce 350 GWH/year (Ediafric, 1977) Further south in Cameroon there is a potential for four moderate sized projects (L 7- L11) on the Vina River, a left bank tributary of the Logone River.

Hydro-power sites in the Savanna Region of Cameroon have a potential of over 300 MW (more than 1500 GWH/year). Even if one or more of the sites under study is abandoned, it seem probable that new sites will be identified that are suitable for economic development.

The mountain area has a high rainfall (over 1500 mm) and its high elevation is likely to provide 45 - 55,000 GWH, so it would appear that it is a region which could become a large exporter of energy to other areas of the country less favourably endowed with this natural resource.

It follows that the demand for electrical energy that is likely to exist in the year 2000, including possible bauxite exploitation near Ngaoundere, or other mining development, can most probably be met by hydro-electric generating plants.

5.2.3 Central African Empire

Present consumption of electrical energy amounts to about 50 GWH/year. A 20 MW hydro-power plant built on the M'bi at Boali-falls supplies energy to Bangui. Regulation storage is, however, insufficient and the capital also has to rely on a 10 MW diesel installation.

No other hydro-power plants exist in the country, but sites so far identified could be developed to produce some 2750 GWH per year. from an installed capacity of 440 MW. All sites lie near the border or south of the Savanna area and include high potential sites (200-300 GWH) on the Oubangui, Lobaye and Sangha. The Oubangui Dam would provide navigation benefits.

Apart from Bangui, eight other urban centres are supplied with electrical energy from diesel generators totalling about 4 MW. Unless iron-ore mining is embarked upon at Bogoin-Danera (where it has been estimated there are 3.5 million tons of pure ore containing 62.4 percent of iron) there is little prospect for developing the high hydro-power potential. Other mining activities include some uranium at Bakouma, limestone for a cement factory at Bangui-Fatima (prospected 120,000 tons/year) and copper at N'Gade.

5.2.4 Chad

Electrical energy consumption in Chad totals 50 GWH/year (1976) all of which is produced by thermal plants.

The potential for developing a hydro-electric capacity of 27.5 MW at Gauthiot Falls (BE 7) near the Cameroon border, has long since been identified. This site, together with Gore (L 6) on the Pende could produce 300 GWH/year, which is six times the present national consumption of electrical energy. This energy would of course have to be transported to the N'Djamena area over a distance of about 350 km. This handicap, together with the lack of industry to absorb the excess energy, explains why development of these sites is held back.

Elsewhere in Chad there seems to be little opportunity to produce hydro-electric energy in spite of the existence of the large Chari and Logone Rivers, because of flat river slopes and low dry season flow.

5.2.5 The Gambia

The reach of the Gambia river that lies within Gambia has very little slope and offers little possiblity for hydro-power generation other than that afforded by a low head run-of-the river plant. Lahmeyer (1978) suggests a potential installed capacity of 20 MW at the Yelitende (G1) dam site, development of which would be multipurpose, involving salt exclusion and irrigation.

Construction of the Yelitende Dam should be studied in conjunction with regulating dams on the upper Gambia River in Senegal, where considerable hydro-electric power potential is available (See also Senegal). The development of regulation storage in Senegal would of course render the Yelitende site much more attractive, as the guaranteed output would be increased considerably. The potential costs of the upstream sites are very high and development in the near future will only be undertaken in the event that mining or other industrial activities are embarked upon. In the long run, however, food deficits may justify creation of regulation storage for irrigation.

5.2.6 Ghana

Electrical Energy production in Ghana in 1976 totalled 4000 GWH. Most of this energy is generated by the Akosombo Dam (V2) on the Volta River, ultimate installed capacity of this dam amounting to 912 MW. The bulk of the energy is used to reduce imported alumina to aluminum, although the country has considerable bauxite deposits of its own. The economics of importing alumina (including from the U.S.) will remain favourable as long as the energy produced by Akosombo Dam is held at near cost price, which is one of the lowest rates in the world.

Further hydro-power (184 MW) is being developed on the Volta River at Kpong (V 1) downstream of Akosombo. Another site is actively being studied at Bui (V 10) not far south of the Upper Volta border (150 MW). This site is in competition with Noumbiel (V 11) which would be jointly developed by Ghana and Upper Volta (70 MW).

Even after subtracting the very large energy consumption of the Valco smelter, Ghana's electrical energy consumption per capita remains higher than that of many countries in the zone. This reflects the considerable effort that was made to creat small industries after independence.

Electrical energy is also exported from Akosombo to the neighbouring countries of Togo and Benin.

5.2.7 Guinea

Consumption of electrical energy in Guina in 1976 amounted to 500 GWH. The hydroelectric generating potential is evaluated at 63,2 TWH/year with a guaranteed output of 13.6 TWH/year. The Konkouré River accounts for 40 percent of this potential (KON 1 and 2, etc.) the remainder being distributed among the other coastal rivers and the Senegal and Niger Head waters.

This very large energy potential is commensurate with the enormously rich bauxite and iron ore deposits of Guinea which place the country at the head of the world's resources of these minerals (13,750 million tons of bauxite, 15,600 million tons of iron ore). Under these circumstances it can be seen that the hydro-electric potential will be harnessed when the economic situation is deemed to be suitable. Guinea is also rich in gold, diamonds, uranium, copper, chrome, manganese, berilium, platinum, graphite, etc. indicating further electrical energy demand.

5.2.8 Guinea Bissau

Guinea Bissau is a low lying country with minimal topographic relief. Electrical energy production and potential are thus extremely limited.

Specific data in hydro-power in Guinea Bissau are not available at CIEH and so cannot be discussed here.

5.2.9 Ivory Coast

During the past ten years the rate of growth of electrical energy demand has attained 17 percent per year and by 1976 production was 13 times greater than in 1960. Electrical energy consumption in Ivory Coast in 1976 totalled 1,110 GWH. Of this total amount, hydro-electric plants generated 343 GWH in the following proportions:

Ayamé - 1	72.5	GWH
Ayamé - 2	120.4	GWH
Kossou	150.5	GWH

Kossou (B1) with an installed capacity of 17 MW is located on the Bandama River at the southern limit of the Savanna belt . Ayamé, on the Biar River (outside the Savanna area) supplies energy to the town of Abidjan.

Hydro-power plants are now under construction south of the Savanna limit at Taabo on the Bandama (210 MW) to be completed in 1979 and at Buyo on the Sassandre River which is to go into production in 1980. Each of these two dams is expected to produce 1 TWH/year, trebling the present production of the Ivory Coast.

It is interesting to note that of the 166,312 subscribers to the electric distribution network, the largest consumer in 1976 (27 GWH) was the Gonfreville Textiles Company situated at Bouake, within the Savanna area (Cote d'Ivotre, 1976).

Considerable additional hydro-power potential exists in the north of the country, on the Niger tributaries as well as on the Komoe River. Future mining activities could include iron ore near Man (340 million tons of pellets equivalent), some gold in the same area, and 150 million tons of nickel at Touba, Foungouesso and Sipilou.

5.2.10 Mali

Present consumption of electrical energy is about 80 GWH per year (1976) with an installed capacity of 22.7 MW. Approximately one third of this is provided by the following hydro-electric generating plants which supply energy to the towns of Bamako, Ségou, and Kayes:

Site	River Basin	Installed Capacity/yr
Sotuba (N40)	Niger	5.6 MW
Sansanding (N34)	Niger	1.5 MW
Felou (S4)	Senegal	0.5 MW

It should be noted that the installed capacity at these sites is well below their potential. Felou for example has a potential of 50 MW (400 GWH). At all three locations both present demand and regulation storage capability are insufficient to justify further equipment.

However, Mali's hydroelectric output will be increased in the near future. The Selingué dam (N41) now nearing completion on the Sankarani River, with an initial installed capacity of 45 MW and potential output of 200 GWH per year, will more than treble the generating capacity of the country while at the same time provide regulation storage for 60,000 ha. of double-crop irrigation. A further benefit of this regulating capacity is that it will make possible the stepping up of output from the Sotuba generating plant by an extra 30 GWH/year, the installed capacity increasing from the present 5.6 MW to 12 MW.

Even before completion of the Selingué dam it has been decided to start work on Manantali Dam (S9) on the Bafing River, tributary of the Senegal River. This major dam is primarily designed to provide regulation storage for the irrigation of 470,000 ha in Mali, Mauritania and Senegal while producing 800 GWH of electrical energy per year and ensuring that the Senegal River has sufficient depth of water for navigation as far upstream as Kayes.

The hydro-electric potential of 800 GWH/year (guaranteed output 100 MW) is to be entirely absorbed by the local iron ore industry whose development is dependent upon construction of the dam. If the production of iron pellets by Mali and Senegal is stepped up to 15 million tons per year it will be necessary to further develop the hydro power potential of this part of the Senegal river basin whose capacity is of the order of 500 MW (4 TWH/year).

5.2.11 Mauritania

The electrical energy produced in 1976 in Mauritania amounted to 40 GWH, all of which was generated by thermal plants.

In the Senegal River basin, the Gorgol and its tributaries offer no obvious potential for hydro-power development. The only opportunity for development would be the installation of very low head run-of-the-river plants on the Senegal river. No sites for such installation appear to have been identified to date and it should be noted that the river lies at a great distance from the major mining areas of the north and from Nouakchott, the capital.

5.2.12 Niger

The electricity consumption of Niger was only 68 GWH in 1976. The major electrical energy consuming center of Niamey has been connected to the national grid of Nigeria since 1976. Coal, now being mined in the vicinity of the large uranium mines in the Air, is likely to provide all the energy required for this vital economic activity in the northern part of the country.

No hydropower has been developed in Niger but three sites have been identified for the production of hydroelectric power - two on the Niger River itself and the third on the Mekrou, a right bank tributary whose waters are shared with Benin (see 5.2.1).

The major site is Kandadji (N 25) on the Niger, not far downstream from the Mali border, where the median flow of 1000 m^3/sec and the topography would allow enough storage regulation to generate 1,500 GWH annually. A recent feasibility study (Sofrelec, 1978) shows that this dam would also permit irrigation of 140,000 ha in the Niger Valley. Total final installed capacity of the order of 300 MW will be dependent upon the final choice of pond elevation. This choice can only be made in agreement with the Mali authorities as the backwater extends into Mali, and the installation of the dam will flood agricultural land and reduce the power potential of the Labezenga site (N 26) upstream.

The second site on the Niger River is at W (N 22), north of the Benin border. This site offers a slightly higher streamflow than that of Kandadji but almost no regulation volume. A run of the river plant here would only become really attractive in the event of Kandadji being completed and providing the regulation capacity. The possible installed capacity would be 84 MW for 526 GWH/year.

The third potential site, on the Mekrou River at Dyogouda (N 19), is shared with Benin. The installed capacity could reach 26 MW with an output of 15 GWH/year.

The Kandadji, W, and Dyogouda dam sites are situated 150, 125 and 150 Km, respectively, from the capital Niamey. It has been stated (Dossier: L'energie dans les Etats ACP, 1978) that the 1500 GWH produced by Kandadji alone would meet the electricity demand of Niger until 2010.

It is probable that if Kandadji dam is to be built, the main justification for doing so will be the need to irrigate on a large scale to ensure food self-sufficiency in the future. Hydro-power development will be an added benefit, helping to spread the high construction costs (60,000 million CFA 1978) of the dam, an item representing perhaps 25 percent of the total irrigation development cost.

5.2.13 Nigeria

Nigeria is self sufficient in energy production and exports electricity as far as Niamey in Niger. A major hydroelectric power plant is in operation at Kainji Dam, on the Niger River, with a potential capacity of 960 MW (N 11). This dam, with its large storage capacity of 15.000 million m^3, is operated to meet peak load requirements of the national grid which is supplied by fossil fuel generating plants.

In order to respond to increasing industrial and export demands, and expand electrification of small towns, further power plants are under construction. These include a major thermal plant at Sapele (720 MW in 1980) as well as gas-turbine generators (600 MW) and the following hydroelectric schemes which are expected to go into service between 1981 and 1984 :

Site	River Basin	Installed Capacity/yr
Lokoja (N 1)	Niger River	1950 MW
Shiroro (N 2)	Kaduna River	600 MW
Jebba (N 10)	Niger River	560 MW

The installed capacity at each of these sites will be increased to the stated values as the demand rises, the present peak demand being greater than the network capacity, leading to load shedding. This situation is largely due to failure to increase capacity in step with the Nigerian oil boom. However, a series of dry years has also severely reduced the output of Kainji Dam where the peak power has fallen recently to 520 MW.

In the more distant future low head hydroelectric plants can be foreseen on the Benue River, at the Makurdi site (BE 3), 600 MW and elsewhere and possibly also on the Niger River itself.

Plants on the Niger River such as Kainji and Jebba (under construction) will be subjected to modifications in operating conditions as irrigation in Mali and Niger modify the streamflow regime. In this respect it can be seen that Nigeria would benefit from an extension downstream of the watershed management mathematical model now under development for the middle reaches of the river.

5.2.14 Senegal

The electricity consumption of Senegal was 480 GWH in 1976. The principal power needs are met by a large (118 MW) thermal plant at Dakar, with interconnections to smaller towns in the western part of the country.

No hydropower has been developed in Senegal. The Senegal River is an important water resource but it has a flat slope for about 500 km from the sea and is not usable for hydro-power in this reach. The hydro-power potential of the upper Senegal River lies outside Senegal in Mali and also in Guinea.

Joint development of the Senegal River basin with Mali, Mauretania and and Guinea involves initially the construction of the Manantali Dam (S9) which will be able to provide 842 GWH/year. This potential will be increased to 1600 GWH/year with the construction of Gounina (S5) and further equipment of Felou (S4). The regional needs are estimated to be covered by these dams until 2000, with 350 GWH/year for iron ore and bauxite, and 600 GWH/year for the agro-industries expected to develop under the impetus of the irrigation of 450,000 ha in the three countries.

The Faleme River at Gourbassi (S14) offers the possibility of an international project on the Mali-Senegal boundary with a capacity of 113 MW. No hydro-power potential is offered by the Casamance River on account of lack of relief.

Development of hydro-power production on Senegal territory itself must necessarily take place, if at all, on the upper Gambia River. There dam sites have been identified at Kekreti (G 3) and Kedougou (G 4) and studied at Sambangalou (G 5), representing a total installed capacity of 200 MW and an annual output of about 1000 GWH. All these sites are over 500 km from the industrial centers of Dakar and Saint Louis but would be developed if it were decided to exploit local iron ore deposits. Regulation storage at these sites would be of benefit to Gambia which could then considerable extend its irrigated agriculture.

Construction of the Manantali Dam has now been decided upon, mainly with a view to providing irrigation water. The schemes in the upper Gambia Basin are not yet under way and would appear to be dependent upon mining activities going ahead rather than on plans to develop irrigation.

5.2.15 Sierra Leone

In 1973 the total installed electricity generating capacity amounted to 83.5 MW, of which only 3 percent was hydro-power. Of this total capacity, 46 percent was owned by four mining companies, 3 percent by private entities and 51 percent by the Electricity Corporation of Sierra Leone (Kaplan, 1976).

The hydro-power potential in Sierra Leone is very high, a total capacity of 1150 MW has so far been identified, with 20 sites offering more than 10 MW each. The major site, Bambura, will presumably be developed when the decision is taken to transform bauxite to aluminum rather than to alumina, the former requiring much more energy. The reduction of alumina to aluminum is at present performed in Switzerland (Alusuisse).

5.2.16 Togo

The electricity consumption of Togo was 101 GWH in 1976, most of it obtained from hydro-power produced at Akosombo in Ghana (see 5.2.6). In Togo there appears to be only one small hydro station at Kpime (SI 1), which develops about 1.6 MW and supplies a highly variable and small power output to Lome (0.8 to 4.2 GWH/year).

The proposed Nangbeto scheme (M 1) on the Mono river, to be built by the Communauté Electrique du Bénin, has a hydro-power potential which has variably been estimated at 130 GW/year and 500 GWH/ year. Power produced at Nangboto will be shared with Benin and agreements have already been made between the two countries, allowing for a quick start of construction once financing is obtained. In addition it should be possible to build one or perhaps two additional large schemes on the Mono river upstream of the present site which could supply the Atacora region by rural grid.

There is a small potential on the Kara river (V3) a tributary of the Volta in the extreme north capable of supplying 36 GWH (7 M.W).

The possibility of installing several low-head plants on the lower Mono, downstream of the Nangbeto regulating dam, has also been suggested (Sofrelec, 1963). This could increase the capacity of the scheme when the demand arises either in Togo or in Benin. The Nangbeto scheme would greatly benefit agriculture, making possible the irrigation of over 40,000 ha. in Benin and Togo by raising the dry season flow which at present is close to zero.

5.2.17 Upper Volta

The electricity consumption of Upper Volta was 51 GWH in 1976. No hydro-power has been developed so far. In the absence of any foreseeable major mining activity requiring cheap electrical energy, the country could use small amounts of hydro-power to replace energy production from imported fuels, but the demand for energy is small. The tributaries of the Volta River, which drains about half of Upper Volta, have low flows, and provide little opportunity for storage and head. Potential sites are at Noumbiel (V 11) and Samandeni (V 13) on the Black Volta (70 MW) with much lesser possibilities at Bagré (V 7) on the White Volta (7 MW), Badadougou (K1) on the Komoe and Pama on the Pendjari. Of these sites, only Bagré and Samandeni offer irrigation possibilities since Noumbiel is located far to the south of any irrigable soils in Upper Volta.

Development of Bagré includes 30,000 ha of irrigation but most of the energy produced at the dam would be used to pump water to the irrigation areas which are mainly located above the dam.

The major site of Noumbiel cannot be developed independently of Ghana as it lies on the border between the two countries and it suffers from being located at about 400 km from Ouagadougou and 300 km from Bobo-Dioulasso, the major energy consuming centers. It should be recognized also that alternative competitive sites exist in Ghana in particular at Bui (V 10).

The famous manganese deposit of Tambao (12 million tons,55 percent Manganese) is located in the north, very far from Upper Volta's potential hydropower, However, this area could benefit from development of Kandadji Dam in Niger or Tassaye in Mali, both on the Niger River.

5.3 Summary

A summary of existing hydropower development, of expected production when current dams are completed by 1983, and an estimate of total hydro-power now identified is given in Table 33. Data refer to the Savanna Region of each of the countries listed only. For comparison, the total electrical energy consumption for the whole country is given in the last column based on data provided by Notes d'Information, BCEAO (1978) and by Francou (1978).

Table 33. Hydropower in Savanna Region by Country

Country	Existing Hydropower 1978		Expected Hydropower Production 1983		Total Potential Hydropower		Electr. Energy Consumption 1976
	MW	GWH/yr	MW	GWH/yr	MW	GWH/yr	GWH/yr
Benin	-	-	?	?	100	800	54
Cameroun	15?	90?	87	440	335+	1,975+	900
Centr.A.E.	20	50	20	50	440	2,750	50
Chad	-	-	-	-	80	300	50
Gambia	-	-	-	-	20	20	27
Ghana	912 (1)	4,000	1,250	8,000	1,250	8,000	4,000
Guinea	24	28	1,000	8,000	1,000+	13,600	500
Guinea Bissau	-	-	?	?	50?	200?	?
Ivory Coast	180	530	180	530	1,730	6,630	1,110
Mali	<10	30	200	1,100	850	5,400	80
Mauritania	-	-	-	-	20	100	40
Niger	-	-	-	-	410	2,100	68
Nigeria	600	2,400	2,500	10,000	5,000	20,000	3,200
Senegal	-	-	-	-	250	1,000	480
Sierra-Leone	2.5	15?	5	15		1,150	84
Togo	1.5	1-4	?	?	90+	600+	101
Upper Volta	-	-	-	-	65	380	51
Approximate Totals	1,800	7,000	5,000	28,000	12,000	65,000	11,000

(1) Akosombo peak power, practical capacity 735 MW.

CHAPTER 6

FISHERIES AND NAVIGATION

6.1 Fisheries

As reported in Volume 5 of this report series (section 2.6) fisheries in inland waters make a significant contribution to food production in the Savanna Region. Current fish catch in the area is estimated at about 450,000 ton/year. For comparison, the beef and veal production in the Savanna amounts to slightly more than 500,000 ton/year. In the Sahel countries, fish and meat are consumed in equal quantities (Ediafric, 1976) and it has been reported (FAO) that in the Niger Basin as a whole, more protein is derived from fish than from stock.

In Table 34 estimates are given for some Savanna countries of the inland water areas (in flood season) and the number of people taking part in full time fisheries activities.

Table 34. Inland Waters and People Engaged in Fisheries in the Savanna Region

Country	Inland water area (1000 ha)	Fishermen
Benin	100	
Chad	3,500	70,000
Gambia	150	
Ghana	850(1)	20,000(1)
Mali	3,600	40,000
Mauritania	100	
Niger	400	4,000
Nigeria	790	
Senegal	400	
Upper Volta	120	3,000

(1) Lake Volta only

Under pressure of an increasing population, considerable expansion of fish production is expected by many countries in their efforts to attain food self-sufficiency. This will demand the introduction or improvement of fisheries management - both for captive and cultivated stocks.

In developing water resources for irrigation or power production there is generally a resulting decrease of over-bank flow and flood plain inundation; both these factors can be expected to markedly decrease fish production, a reduction which will not necessarily be accompanied by an equivalent increase of fish production in the storage reservoirs. Attention must also be given to pollutants which inevitably find their way to the rivers when large scale irrigation is practiced or where industrial and mining development occurs. It is, therefore, of vital importance that careful studies be made of the environmental impact of water resources development projects, with particular emphasis upon the likely consequences upon fisheries, before their implementation is decided upon. Also, funds will have to be allocated to create employment opportunities for the large fishing communities that may be affected by major water development projects wherever these can be expected to significantly reduce catches. Resettlement may be necessary where large inland water areas are created by storage reservoirs, possibly involving not only the transfer of fishing communities in the area to be submerged but also people whose subsistence will disappear in downstream reaches impoverished by the new river regime.

The possible effects of man-made and natural variations in river regime upon fisheries activities are discussed below in a series of examples from the Savanna Region. In view of the absence of statistics in many cases, the examples given must remain qualitative.

- Construction of Kainji Dam on the Niger River in Nigeria has resulted in loss of considerable areas of the flood plain as far downstream as the Benue confluence and fish catches have diminished to between 47 and 75 percent of their original values (Welcomme 1975). It is not known whether or not this loss is compensated by fish production in Kainji lake.

- The Lower Volta flood plain has disappeared completely following the construction of Akosombo Dam. An important economic activity prior to construction of the dam was clam (Egeria radiata) fishing which occupied some 2000 full-time fishers. Clam fishing has totally disappeared under the new conditions of constant flow. This industry was valued at more than U.S. 250,000 dollars per year in 1964 (Maxon, 1969). Other fishing in the flood plain has been considerably reduced also. In the newly created Lake Volta however, it is estimated that the overall fishing activity has been greatly increased. It is estimated that 20,000 people are now engaged in the fishing industry on this largest man-made reservoir compared to 2000 people previously. After an initial boom of 60,000 tons the catch decreased precipitously to 10,000 tons. However it had increased again to 42,000 tons in 1971. (Obeng, 1975).

- Construction of the port of Cotonou (Benin) had an unexpected effect upon the important fishing industry established in Lake Nokoué. The establishment of the breakwater resulted in an interruption of the west to east littoral transport of sand with the effect that the exit from Lake Nokoué to the Ocean remained permanently open instead of closing during the dry season. Scouring of the channel followed, leading to large quantities of sea water entering the lake. This sea water penetration in itself would not have apparently modified fisheries in the lake had it not favoured at the same time the entry of woodborers from the ocean. These, by rapidly destroying the wood poles (akadjis) placed in the lake to concentrate the fish population, so modified the economics of fishing that this once flourishing industry almost ceased to exit (Thomson, 1971). In order to save the Cotonou bridge from being undermined by scour, it was decided to build a dam across the channel. This dam will effectively prevent salt penetration and borer activity can be expected to cease. The presence of the dam will however prevent crayfish from migrating to the sea for reproduction and this important (100 tons annual catch) activity can be expected to disapper. The dam will also block migration patterns of fish species.

It should be noted that the Ouémé flood plain, upstream of Lake Nokoué, is often cited as a model of harmonious equilibrium between agriculture and fisheries, being "one of the most intensively managed in Africa using traditional methods. It successfully supports herds of cattle and vegetable and cash crop farming alongside an intensive dry season floodplain pool fishery and an extensive flood phase fishery" (Welcomme, 1975).

- The Sahelian drought has resulted in a decrease of area of flood plain inundation, with a corresponding dramatic decrease in fish catches. At Mopti, on the Niger River (Mali), the catch diminished by more than half between 1968 and 1973. In Chad, where an initial spectacular increase in catches due to concentration of fish in a greatly reduced lake area was observed, it is reported that the number of poeple engated in fisheries has decreased by 50 percent; a similar drop occurred in Senegal (FAO 1976).

The effect of the drought on flood plain inundation and the immediate effect upon fish population is a clear indicator of what could result from streamflow regulation by storage dams. It is urged that this important resource be fully considered in efforts to gain other benefits from the water resources available in the Savanna.

6.2 Navigation

Movement of goods in West Africa, particularly in the case of the land-locked countries, is largely in a northerly direction from the coast towards the main urban centers. There has been no impetus for any important east-west exchange. The existance of subsidized rail facilities, and a gradually improving road network, both of which are largely underused, has by and large sufficed to ensure the movement of goods from the sea ports inland. In many cases railroads offer shorter routes between seaports and inland cities than the waterways and are often less costly.

There are areas where, during parts of the year, roads are the preferred means of transport. However, in the rainy season they can become inpassable, at the same time that a nearby waterway becomes navigable. But for year round use, with the exception of Nigeria, navigation on the inland waterways is limited to specific cases where low value goods are brought by boat to railheads, without resorting to specific river improvements.

In waterways where obstacles to navigation exist in the form of rapids or insufficient depths, investment in structures or dredging is usually uneconomic unless justified by the need to transport large quantities of mineral ores. Multipurpose dams (power, irrigation), especially if provided with locks, can facilitate river navigation in localized areas.

It should be noted that detailed studies and information on the transport sector in the Savanna are largely out of date or, especially on a regional basis, non-existent. The information presented here, on navigation and waterway transport, has been compiled from available documents and data at CIEH and is provided on a river basin by river basin basis. Further comprehensive analyses of the methods of movement of goods, and the interrelationship of the effects of new or potential investments (e.g. irrigation dams, mine development) are strongly recommended in order to fully realize the benefits of such investments.

6.2.1 Senegal River

The Senegal River is navigable from the ocean to Kayes (in Mali) a distance of 948 Km, the total length of the river being 1,800 km. Kayes may be reached from about 20 August to 20 September by vessels having a draft of 4.5 m; from 1 August to 15 October by those with a draft of 3 m; and from mid July to early November by those with a draft of 1.8 m. The river is open all the year round from the ocean to Podor (km 265) to vessels having a draft of 3 m (Beziukov, 1971).

The present limitation of navigation depths is due to sand, gravel and rock sills. When Manantali Dam (S9) is in a position to regulate the flow to 300 m^3/sec. at Bakel, conditions will be more favourable, but dredging, river training and rock removal will be required to allow year-round traffic of vessels and convoys having a worthwhile draft. These works will require maintenance and the channel will call for improved markers. The consultative committee of the OMVS (Organization for the development of the Senegal River basin) has recommended that a River Navigation Authority be created for this purpose (Ediafric, 1976).

During the sixties tonnage carried on the Senegal River remained constant at 25 to 30,000 tons per year. The fleet capacity was estimated to be twice this figure. In dry years traffic fell to 14,000 tons because the roads were passable for longer periods (Hubbard 1973).

Apart from draft restrictions in the river channel, a major handicap to the development of the Senegal River waterway is that goods have to be carried between Dakar and St. Louis by road or rail because of the bar at the river mouth.

A 1977 study of the development of the waterway by Lacker and Partner (quoted in Ediafric, 1978) estimates future volumes of traffic, assuming a steady streamflow of 300 m^3/sec. below Manantali dam :

	1983	1990	2000
River traffic (petroleum products and merchandise) (1000 tons)	319	661	1,562
Total land/water traffic (1000 tons)	1,444	2,025	3,599

Development of phosphate mining in Mali would lead to the movement of a further 800,000 tons from the Kaedi region.

One of the main objectives of the Manantali dam is the provision of water to irrigate some 400,000 ha of land. The increase in production should lead to the movement of an estimated 630,000 tons of agricultural and associated goods each year, which the presence of the waterways should facilitate.

Electrical energy generated at Manantali may find an outlet in the mining industry with production of alumina and perhaps aluminum from Mali bauxite, and the preparation of iron ore from the Falemé deposits of Senegal. Both possibilities are hypothetical, depending largely on the state of the world market for these commodities (Hubbard, 1973). The decision to go ahead with alumina production could lead to the movement of 735,000 tons each year and several million tons at the end of the century (Ediafric, 1978).

If 400,000 ha of land are to be irrigated with Senegal River water, not only must Manantali Dam be built, but at some stage it will also be necessary to go ahead with Diama Dam (S 1) in the Delta. This dam, designed to limit, salt intrusion from the sea up river towards irrigation pumping stations, will have little effect upon navigation other than the passage through a lock and a local intensification of the movement of agricultural produce, both in Senegal and in

Present estimates of the cost of developing the water-way based on traffic resulting from regulation and irrigation, with Manantali and Diama Dams in operation, amount to U.S. 100 million dollars including construction of river ports at Rosso, Richard-Toll, Dagana, Podor, Boghé, Kédi, Matam, Bakel and Ambidédi, as well as Kayes and a sea/river port at St.Louis.

This cost compares with that of the two dams: U.S. 300 million dollars for Manantali including the power house and power line and U.S. 100 million dollars for Diama and considerable road development in both cases. The irrigation development is expected to cost U.S. 8,000 dollars/ha. For a total area of 75,000 ha, planned by 1990, this represents U.S. 600 million dollars. Some 40 percent of the required capital for this very large project has so far been acquired (Ediafric, 1978).

Clearly, development of the Senegal River basin transportation network would seem to depend upon a completely integrated development program. The inputs are, however, so complex and so many factors are so difficult to assess (future demand for minerals, for example) that if progress of any kind is to be made it is necessary to take decisions to proceed with certain components without being certain that others will necessarily follow. So it has been decided to go ahead with Manantali Dam, irrespective of whether or not the energy market will exist. This in turn will affect navigation on the waterway, the regular flow of water being in its favour, but the bulk transport of ore or alumina may not materialize. The absolute necessity to increase food production in the region is, however, justification for such decisions as have been taken.

6.2.2. Gambia River

The Gambia River is navigable part of the year for 200 km upstream to Kaur by cargo vessels of 3000 tons and from Kaur to Fatoto, by tugs with barges of up to 300 tons. The river and its tributaries form the principal transportation route in the Gambia. During 1975-1976 a total of 120,000 tons were transported on the river. This represents more than 20 percent of the total tonnage entering the seaport of Banjul (Ediafric, 1978).

A UNDP preliminary report on the developmentof the Gambia Basin makes the following suggestions for improving river transportation: dredging of a 6 m channel for Banjul to Kaur so that 3000 ton vessels can be used throughout the year; and a 3.5 m channel from Kaur to Fatoto for 300 ton loads.

At a later stage, depending upon decisions taken concerning the development of the Falemé iron ore and streamflow regulation at Kekreti and elsewhere in Senegal, it is suggested that a 9 m channel be opened in the Gambia River to allow transportation of the ore from Kuntaur to Banjul on 10,000 ton vessels. This alternative to the movement of ore from Falemé direct to Port Sedar by railway is thought to entail a reduction of the total capital investment by U.S. 130 million dollars, or of U.S. 17 million dollars annually. The ore would be moved to Kuntaur by rail (Ediafric, 1978).

6.2.3. Niger River

Navigation is seasonally possible on 75 percent or 3,100 km of the channel. The river is, divided into four navigable stretches by three sets of rapids located as follows:

- Bamako to Koulikouro in Mali
- Ansongo below the inland delta in Mali
- Yelwa to Jebba in Nigeria

The Kainji hydro-power dam (N11) has been established in the middle of the latter series of rapids. Flow regulation by the dam has opened up the river to navigation downstream, whereas the pond itself is of course also navigable. Present navigability of the Niger is illustrated in Figure 1, which originally appeared in NEDECO (1959) and has been modified to account for the Kainji Dam.

Construction of multi-purpose dams at Kandadji (N 25) and at Ansongo in Mali, and the provision of locks or lifts, would overcome the problem of the Ansongo rapids and allow for shipping as far upstream as Koulikouro in Mali (which connects by railroad to Dakar). However, even supposing that full flow regulation were afforded by these dams, the river upstream of the Benue confluence would remain closed to drafts of more than 1.4 m for about three months each year since the long term mean streamflow is not sufficient to ensure minimum water depth in critical crossings (Sofrelec, 1978).

In the more distant future, as more and more water is diverted from the river for irrigation, in Mali and Niger, it will become necessary to sacrifice navigability in favour of food production. The Gaya-Malanville bridge in Niger is a further obstacle to shipping, but at present, traffic on the Republic of Niger reaches of the river is in any case limited to large motorized local boats.

In Nigeria, the river is navigable by large river boats throughout the year to Onitsha and for about ten months to Yelwa. Continuous waterways connect the Niger, the Benue and coastal lagoons as far as Cotonou in Benin. Because of competition from rail and road only a fraction of the inland waterways haulage potential is put to use.

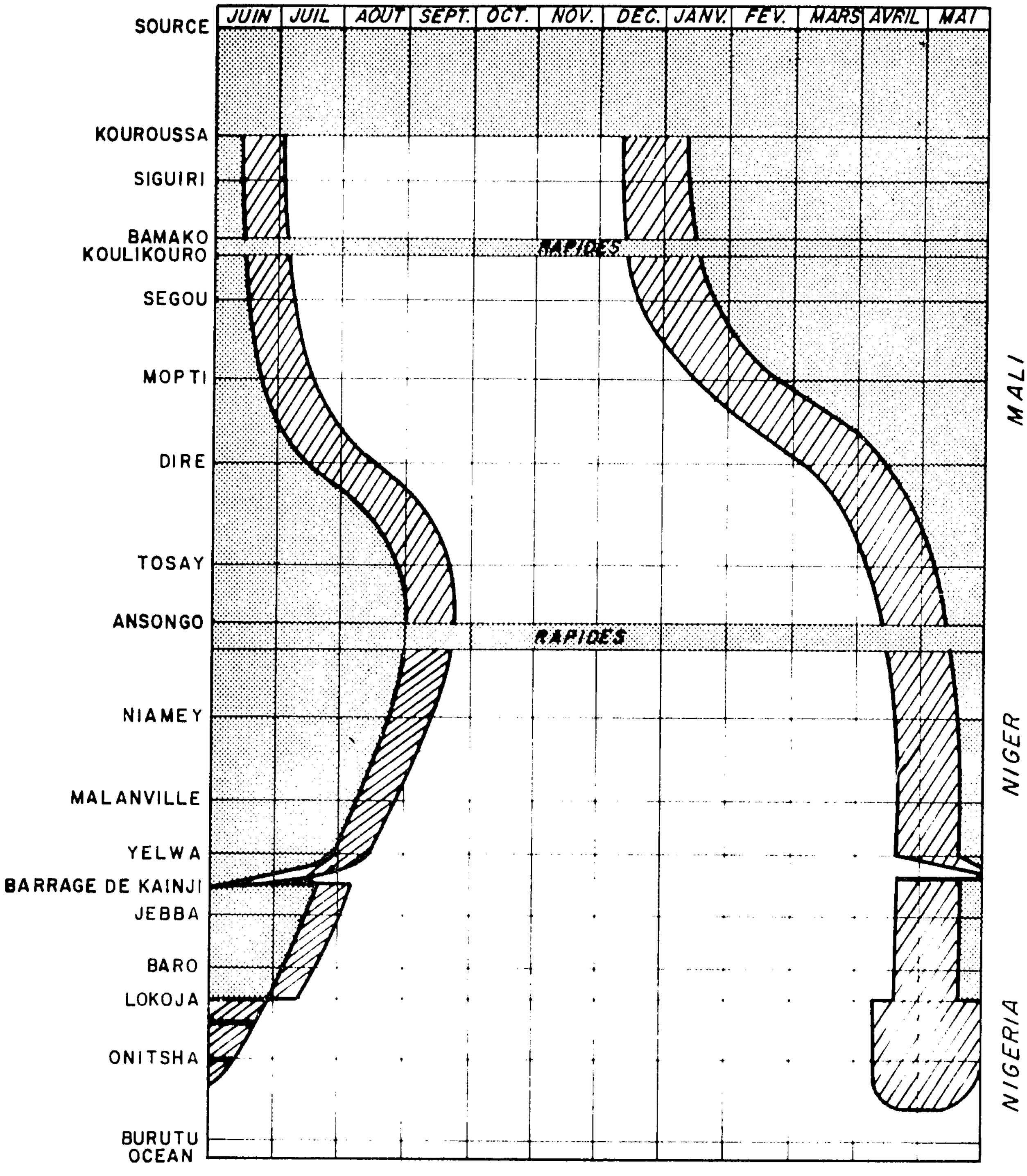
In Mali short distance transportation is mainly concentrated between Koulikouro (Dakar-Niger-railroad) and Segou where agricultural produce is assembled. This reach is 160 km length. Long distance transportation is between Koulikouro and Gao, over a distance of 1308 km. During the navigation season of 1964-65 a total of 71,500 tons were handled, corresponding to 23,8 MT km (million-ton-kilometres). These figures show, with respect to 1958-59, a considerable decrease of long hauls, since for a similar total tonnage the number of ton-kilometres fell from 31.5 to 23.8. Equipment at that time was estimated to be used to only 19 percent of capacity (Gautier 1967).

River transport in Niger is almost non existent. Prior to construction of the Gaya bridge in 1958 there was a 50 ton barge service between Malanville and Niamey. This fell into disuse when the bridge enabled through road traffic from Parakou.

Dugouts, some with outboard motors (only 4.5 percent in 1967) transport an estimated annual load of 6,000 tons, mainly towards Niamey, but also locally between Say, Kollo, Libore and Niamey. Some smoked fish is imported along the river from Mali. Fish also transits from Mali to Nigeria, structural timber, imported from Nigeria, is brought up river to Niamey. (Gautier 1967).

Only in Nigeria is river transport organized, efficient and highly lucrative. From June to October vessels mainly ply on the Benue. From November to April they move produce from the hinterland to the delta ports of Burutu and Warri.

Several private companies share the river traffic; in 1956 the total capacity amounted to 31,000 tons. In that year the annual traffic on the lower Niger and Benue of the three principal fleets amounted to 250,000 tons. Of this freight, only 90,000 tons moved up stream. For an annual total movement of 275,000 tons of goods the traffic was estimated to reach 210 MT Km in



OPEN TO NAVIGATION FOR SHIPS WITH A DRAFT ≥ 1.2m
OUVERT A LA NAVIGATION DE NAVIRES AVEC TIRANT D'EAU ≥ 1,2m

RESTRICTED NAVIGATION FOR SHIPS WITH A DRAFT OF 0.9 TO 1.2m
LIMITE A LA NAVIGATION DE NAVIRES AVEC TIRANT D'EAU DE 0,9 A 1,2m

NO NAVIGATION AVAILABLE DEPTH LESS THAN 0.9
AUCUNE NAVIGATION PROFONDEUR D'EAU MOINDRE QUE 0,9m

NAVIGABILITY OF THE NIGER (NEDECO, 1959)

NAVIGABILITE DU FLEUVE NIGER (NEDECO, 1959)

FIG - 1

1962. Competition plays an active role and the equipment is well suited to its task. Prior to construction of Kainji Dam, transportation costs were estimated to amount to 2.5 CFA per ton/km and were expected to decrease by 15 percent after river regulation by the dam. (Gauthier 1967).

6.2.4. Benue River

The Benue River is navigable from the confluence with the Niger River as far as Garua in Cameroon, a distance of about 1500 km from the port of Burutu on the ocean. Depths of water are sufficient for drafts of 2 m to this point for a period of less than three months each year, from August to October.

In Nigeria, the main river ports on the Benue River are, travelling upstream, Makurdi, Ibi, Numan and Yola. These ports are accessible during periods which vary from June to November at Makurdi to July to October at Yola. River conditions above Lau are difficult and it is rare that vessels drawing more than 2 m are seen on the Benue (Nelson, 1974).

The navigation season on the Benue is distinct from that of the Niger, vessels being transferred from one route to the other. When navigation is only possible in the delta, part of the fleet is withdrawn for overhaul. Although the navigation season on the Benue is shorter than on the Niger the traffic, measured in ton-kilometres, is of the same order of magnitude (Nedeco 1959).

Even though the port of Garua is accessible during less than three months, traffic to this point amounted to over 50,000 tons each year in the late fifties, representing almost 80 million ton-kilometres. There was an excess of downstream over upstream movement of nearly 30 percent. Downstream movements increased since then to attain about 90,000 tons at Makurdi (70 MT km) with a 40 percent excess of downstream traffic over upstream.

6.2.5 Lake Chad Basin

Waterways take an active role in Chad, mainly because roads are generally unusable during the rainy or flood seasons. The Chari is navigable between Sahr and N'Djamena from 15 August to 15 December, some 10,000 tons being transported annually. The Chari waterway between N'Djamena and Lake Chad handles a further 20,000 tons each year. Small quantities of goods are also moved along the Logone River from Moundou to N'Djamena (Ediafric, 1976).

In the future it is thought that large scale polder development for irrigated agriculture on the banks of Lake Chad, possibly not only in Chad itself but also in Cameroon, Niger and Nigeria could markedly intensify river and lake traffic. Possible regulation dam development in the headwaters of the Logone River would also no doubt favor river transportation, by increasing the length of time during which drafts are sufficient.

6.2.6 Volta Basin

The creation of a lake 320 km in length upstream of Akosombo Dam (V2) has provided opportunities for the growth of water transport in Ghana. The lake, however, does not lie along any of the existing transport routes so there was no ready-made traffic for a waterway service to tap (Her Majesty's Stationery Office, 1956). The dam itself has not disrupted existing river traffic since the river was not navigable on account of the Akosombo and other rapids in this reach.

The 1964 Kaiser report on transportation (quoted in Moxom, 1969) estimated a hypothetical lake traffic of 340,000 tons of carge in 1962, based on a percentage of actual ferry and bridge traffic. The same source forecast that by 1970, 870,000 tons of freight and 240,000 passengers, would pass through the lake's southern port, the major portion being traffic from south to north with north-south and intermediate traffic being less important.

A lake fleet of three 1,000-horsepower tugs and nine barges, three 360 ton cargo boats and three 275-passenger boats was recommended. An embryo Marine Division of the Volta River Authority, an efficient but economical fleet of modest-sized lake craft, came into being soon after the lake had started to rise in 1964. This fleet quickly expanded to over twenty vessels, ranging from the fast 420-horsepower patrol vessel to the slow tugboats used for hauling heavy freight on four 60-ton pontoons. (Moxon, 1969).

In the very early planning stages of the Volta Project it was intended to transport Ghana bauxite by rail or ropeway to the lakeside and from there to ship it to the alumina plant and smelter close to the dam. In practice it was found more feasible to locate the smelter at the ocean port of Tema, importing alumina from the United States and elsewhere and transporting electrical energy from Akosombo.

In the meantime further geological studies have shown Ghana's richest and most economical source of bauxite to be situated at Kibi. In view of the geographical situation of Kibi, no lake transport would be involved by the transfer to Tema.

Contrary to forecasts made at the time of inception of the Volta River Project, Lake Volta has not become the main route of penetration from the ocean to the land-locked countries of Mali and Upper Volta, further north. These continue to rely on rail communication with Dakar and Abidjan for the movement of most imported freight. Completion of asphalting of the Ouagadougou-Lome highway may attract some freight movement to this port, competing with any possible extension of traffic on Lake Volta.

SUMMARY

In this volume, an attempt has been made to evaluate future water requirements and use in the Savanna Region. The water requirements of the human population, livestock, industry, and irrigation have been examined separately. As might be expected, the water requirements of agriculture for irrigation are everywhere greater than all others put together, varying from 50 to 97 percent of total requirements. These variations result from climatic factors and the proportion of each individual country within the Savanna - the high rainfall belt to the South having lower requirements for irrigation than the Sahelian and semi-arid areas of the north.

Hydroelectric power, fisheries and navigation have been discussed in the last two chapters. No evaluation has been made of the water requirements of these undertakings since, in general, the water is used without reduction of the potential resource. Water that has passed through a turbine or which has served as a transportation medium has generally suffered little change in time or space. Exceptions do exist however, and must be taken into account in detailed planning:

a) Hydro-power development may frequently require stream-flow regulation by reservoirs, involving considerable evaporation losses. Energy requirements may not necessarily coincide in time with irrigation requirements downstream, leading to release of water from reservoirs when it is not required for irrigation. This problem may, in certain cases, be dealt with by the provision of compensation storage.

b) Fisheries will be notably reduced wherever there is loss of flood plains due to streamflow regulation. Since fish in the Savanna belt are as important a source of protein as beef, great care must be exercised to see that such losses are compensated for by production in the reservoirs. Wherever it is found necessary to maintain streamflow for fisheries, there may be loss of water if such volumes are not required for other purposes.

c) Water may have to be released from reservoirs to maintain sufficient depths of water in the river downstream for inland navigation. In practice this will lead to water loss unless irrigation intakes located further downstream can absorb this water without creating a conflict with navigation requirements.

As may be seen from Tables 35 and 36 irrigation requirements account for a high proportion of the total water requirements of each country. Since total headworks requirements for irrigation depend at least as much on irrigation efficiencies as on climate, it is important to keep in mind that these requirements have been based upon overall efficiencies of 0.5. In practice, overall efficiencies will range from as low as 30 percent for paddy to as high as 85 percent for low pressure pipe systems. (See Chapter 3)

It follows, therefore, that the volumes of irrigation water listed in Table 35 exceed the net water use by agriculture, leaving an appreciable margin for further water resources development - assuming that much of the return flow from drainage of water applied in excess of plant water requirements can be re-used. This is of considerable importance where future demand could be expected to approach supply. In Upper Volta, a not unlikely doubling of population, thus of water need, would require water totalling the volume of the median flow of the three main rivers put together. In Senegal and Mauritania future combined water requirements are estimated to equal future regulated flow of the Senegal River.

Table 35. Water requirements of the Savanna Region in the year 2000, in $10^6 m^3$

Country	Population	Livestock	Irrigation	Industry	Total
Benin	244	40	688	42	1,014
Cameroun	168	118	1,920	28	2,234
C.Afr.E.	215	19	280	47	561
Chad	216	106	1,728	36	2,086
Gambia	28	5	528	4	565
Ghana	333	46	5,232	64	5,675
Guinea	357	54	?	71	482
Guinea B.	40	9	?	7	56
Ivory Coast	196	25	480	40	741
Mali	345	125	7,560	48	8,078
Mauritania	51	67	3,920	4	4,042
Niger	237	85	3,920	22	4,264
Nigeria	4170	473	9,240	705	14,588
Senegal	535	58	6,776	120	7,489
Sierra Leone	65	9	?	9	83
Togo	190	11	280	30	511
Upper Volta	355	60	2,002	41	2,458
Total	7,745	1,310	44,554	1,318	54,927

Table 36. Annual Irrigation Water Requirements as a Percentage of Total Water Requirements, Year 2000

Country	Total Water Requirements 10^6m^3	Irrigation Water Requirements 10^6m^3	Percentage Irrigation Requirements
Benin	1,014	688	68
Cameroon	2,234	1,920	86
Central African Empire	561	280	50
Chad	2,086	1,728	83
Gambia	565	528	93
Ghana	5,675	5,232	92
Guinea	482	?	?
Guinea Bissau	56	?	?
Ivory Coast	741	480	65
Mali	8,078	7,560	94
Mauritania	4,042	3,920	97
Niger	4,264	3,920	92
Nigeria	14,588	9,240	63
Senegal	7,489	6,776	90
Sierra Leone	83	?	?
Togo	511	280	55
Upper Volta	2,458	2,002	81

Surface water in the main rivers is, however, not the only source of water, as gauging networks only account for a fraction of the total surface resource. Groundwater, which is a more stable and regulable source, is also present in large areas of the Savanna. In addition, there is an urgent need to make better use of rainfall "in situ", by improving soil management techniques and growing food crops with water which is now producing unused growth.

Taken as a whole, the water requirements of that part of each individual country which is situated in the Savanna Region can without doubt be met up to and beyond 2000. But the stress will become intolerable in certain parts of these areas if the population, and therefore irrigation requirements, continue to increase. This also holds for human and industrial requirements in towns located far from main rivers or abundant groundwater. The cities of Ouagadougou and, to a lesser extent, Dakar are examples where problems can be foreseen in the near or more distant future. To avoid the soaring costs of pumping water over very large distances, planning and policy emphasis should be aimed toward concentrating population in areas with sufficient resources.

Lastly it should be mentioned that our present evaluation of rainfall and of streamflow may be somewhat optimistic. There is good reason to believe that the standard period adopted by the World Meteorological Organization to define rainfall (1930-1961) is in fact representative of a fairly wet sequence, considerably wetter than the mean value for the century as a whole. It would seem to be reasonable to assume that the recent sequence of dry years is not of a very exceptional nature and that at least one more such sequence is likely to appear before the end of the century. A more realistic assessment of stream-flow might be based on figures ten percent lower than those observed during the 1931-60 "normal" period (Winstanley, 1974).

REFERENCES

A 34-page list of basic references on the land and water resources of the West African Savanna is included in Volume 1 of this report series. The references below, listed in alphabetic order are only those that are specifically referred to in this Volume.

- Afrique et Moyen-Orient 1976-1977 (1976) (Supplément annuel à Jeune Afrique) Paris.
- Altschul, Robert D. (1976) Urbanization in West Africa. In Proceedings of the West Africa Conference, April 11 - 15, 1976, Tucson, Arizona.
- Annan, C.K. (1973) National water grid; long-term multi-purpose water demand of the northern and upper region of Ghana. Ghana Water and Sewerage Corporation.
- Association pour le Développement de la Riziculture en Afrique de l'Ouest (1974) Rice in West Africa. Monrovia, WARDA.
- Bakan, Kouakou (1979) Expérience Ivoirienne en matière d'aménagement hydro-agricole. Extrait de Séminaire International d'Experts Consacré à la Politique de l'Eau pour l'Agriculture et l'Elevage en Zones Arides et Semi-Arides, CIEH/CEFIGRE, Niamey, Niger, 12 - 17 février 1979.
- Banque Mondiale (1974) Le développement du Tchad : possibilités et limites. Washington, D. C.
- Banque Mondiale (1977) Directives pour les études préliminaires sur la refronte de la tarification dans le secteur eau potable. Sénégal.
- Banque Mondiale (1975) Rural electrification. Washington, D. C.
- Banque Mondiale (1974) Sénégal : tradition, diversification et développement économique. Washington, D.C.
- Banque Mondiale (1976) Village water supply; a world bank paper. Washington, D.C.
- "Le barrage de Lagdo sur la Bénoué " (1978) Agri-Afrique, no. 61, 31 mars, p. 1281.
- BDPA (1968) Etude pour la vallée de l'Oti-plaine de Mandouri. Paris.
- BDPA (1965) Plaines de la fosse aux lions et de Paiokou. Etude comparative. Paris.
- BDPA/IRAT (1976) Renforcement des capacités rizicoles des pays membres

de l'ADRAO. Recherche d'accompagnement-multiplication de semences, formation. Rapport général. Monrovia, ADRAO.

- Beziukov, K.I. (1971) Atlas Nautique du fleuve Sénégal. Tome I - Embouchure-Port de Boghé. Paris, Editions Institut Géographique National.
- BRGM (1976) Carte de planification des ressources en eau souterraine de l'Afrique Soudano-Sahélienne. Ressources des aquifères. Orléans. (Collection CIEH-Hydrogéologie)
- Caldwell, J.C. et C. Okonjo (1968) La population de l'Afrique tropicale, New York, The Population Council.
- Chabert, J. et al (1961) Amélioration de la navigabilité du Niger entre Koulikoro et Ségou. Chatou, Laboratoire National d'Hydraulique.
- Club des Amis du Sahel. Irrigated crops; hydro-agricultural programming 1975 - 2000 (in) Republic of Niger. Provisional report.
- Club du Sahel (1978) Recueil de statistiques pour les pays du Sahel. Rapport préliminaire/Socio-economic data book for the Sahel countries. Preliminary report.
- Commission du Fleuve Niger (1976) Les principaux travaux et projets existants et en perspective pour le développement des ressources en eau dans le Bassin du Fleuve Niger. Niamey, Niger.
- "Community water supply and wastewater disposal" (1976) WHO Chronicle, vol 30, no. 8, August, p. 329-334.
- Conférence des Nations Unies sur l'Eau. Mar Del Plata, Argentine, Mars, 1977. (1977) Problèmes de mise en valeur des ressources en eau du Sahel. Ouagadougou, CILSS.
- Conférence des Nations Unies sur l'Eau, Mar Del Plata (Argentine) mars 1977. (1977) Rapport national (Sénégal). Dakar
- Côte-d'Ivoire, Ministère du Plan (1976) La Côte-d'Ivoire en chiffres. Dakar, Société Africaine d'Edition.
- Cotillon, J. (1978) "L'hydroélectricité dans le monde", La Houille Blanche, no. 1/2.
- Davies, H.R.J. (1973) Tropical Africa. An atlas for rural development. Cordiff, University of Wales Press.
- Demeville, M. Théophile (1978) "La politique générale de développement de l'élevage," Afrique Agriculture, no. 29, jan., p. 47-51.
- Des Bouvrie, C. (1975) Planning small-scale water resources development in Africa south of the Sahara. (Towards a water development strategy in rural areas.) Extrait du Séminaire FAO/DANIDA sur le Développement de Petits Aménagements Hydro-Agricoles en Afrique de l'Ouest, Ouaga; 29 sept. -6 Oct. 1975.
- "Le développement d'Abidjan à l'horizon 1990 (fin)." (1978) Bulletin de l'Afrique Noire, No. 968, 26 juillet, p. 18879 - 18887.

- "Dossier : L'énergie dans les Etats ACP" (1978) Le Courrier, no. 51, sept. - oct., p. 66 -112.
- Dunsmore, J.R. et al (1976) The agricultural development of the Gambia : an agricultural, environmental and socio-economic analysis. Surbiton, Survey, England, Land Resources Division, Ministry of Overseas Development.
- Ediafric - La Documentation Africaine. (1975) l'Afrique Noire de A à Z. 2ème éd. Paris.
- Ediafric. La Documentation Africaine (1975) L'Agriculture Africaine 2è éd. Paris.
- Ediafric. La Documentation Africaine (1977) L'Economie Camerounaise. 2è. éd. Paris.
- Ediafric. La Documentation Africaine (1976) L'Economie des pays du Sahel. L'Eau et l'irrigation. Paris.
- Ediafric. La Documentation Africaine (1975) L'Economie Sénégalaise 3è éd. Paris.
- Ediafric. La Documentation Africaine (1978) Le dossier Sahel. Tome 2 - L'irrigation et l'autosuffisance alimentaire à l'horizon 2000. Haute-Volta-Mali-Mauritanie -Niger -Sénégal -Tchad. Paris.
- "Electricité et pays en développement" (1978) Industries et Travaux d'Outremer, no. 300, nov.
- Electroconsult (1976) Etude de préfactibilité de l'aménagement du fleuve Mono. Rapport de mise en jour (RAF/ 74/086). Milan.
- FAO (1976) Etude prospective pour le développement agricole des pays de la zone Sahélienne (1975 -1990). Rome.
- FAO (1978) FAO production yearbook -1977 Vol. 31. Rome.
- FAO (1969) Fisheries survey in the western and mid-western region (Nigeria). Final report. Rome.
- Farra-Frond, F. (1976) Réunion des décideurs sur les problèmes de l'approvisionnement en eau et de l'assainissement en zones rurales, Ouagadougou du 6-11 décembre 1976. Empire Centrafricain.
- "Feeds and Feeding", Frank B. Morrism, Morrism Publishing Company, Ithaca, New York, 21st Edition, 1949.
- Fernandez-Bustos, Felix (1975) Perspective de l'irrigation en Haute-Volta. PNUD.
- France. Ministère de la Coopération et SCET International (1976) Outline of water resources development in the West African Sahel.
- Francou, Jacques (1978) " Le choix des techniques et des ouvrages. La production d'énergie électrique ; l'hydroélectricité en Afrique. " Industries et travaux d'outre-mer, vol. 26, no. 300, nov. 1978. pp. 814-817.

- Frangoulian, V. (1975) Perspective du développement de l'énergie électrique en Haute-Volta. PNUD.
- Gautier, Oliver (1967) Etude sur l'aménagement du fleuve Niger. Paris, Secrétariat d'Etat aux Affaires Etrangères.
- Ghana. Irrigation Department (1977). List of irrigation projects. Accra.
- Halidou, Amadou (1979). Note sur la politique de l'eau pour l'agriculture et l'élevage au Niger. Extrait de Séminaire International d'Experts Consacré à la Politique de l'Eau pour l'Agriculture et l'Elevage en Zones Arides et Semi-Arides, CIEH/CEFIGRE, Niamey, Niger, 12-17 février 1979.
- Harrison-Church, R.J. (1974). West Africa; a study of the environment and of man's use of it. London, Longman.
- Haute-Volta. Direction de l'Hydraulique et de l'Aménagement de l'Espace Rural. (1976). Monographie Nationale de la Haute-Volta.
- Henry, Jean-Claude (1975). Etude de l'Aménagement intégré du bassin de la Volta noire. Mission PNUD-UNOTC. Ouagadougou.
- Henry, Jean-Claude (1978). Mission d'étude en vue de la création d'un service national de l'hydrologie (Niger). UNESCO.
- Her Majesty's Stationery Office (1956). The Volta River Project. London.
- Hubbard, Fred H. (1973). Rapport de la mission de synthèse et d'évaluation du PNUD. Bassin du Fleuve Sénégal. 12 février au 30 avril 1973. Dakar.
- Kaplan, Irving et al (1976). Area handbook for Sierra Leone. Washington, D.C., U.S. Government Printing Office.
- Lahmeyer-International/ORGATEC/SEMA. (1978) L'énergie dans la stratégie de développement du Sahel. Situation-perspectives-recommandations.
- Lamarre Valois International Limitée (1970) Aménagement du Fleuve Niger en amont de Niamey. Montréal, Canada.
- Lotti (Carlo) & C. (1970) Feasibility study for the diversion of the Logone River floods. Cameroon -Chad. Rome.
- MIT. Center for Policy Alternatives (1974). A framework for evaluating long-term strategies for the development of the Sahel-Sudan region. Annex 3-Industrial and urban development. Cambridge.
- Mbepi, Henri (1976). Situation actuelle de l'approvisionnement en eau rurale au Cameroun.
- Moulaye, Abdallah (1979). L'eau: possibilités et limites en matière de développement rural. Extrait de Séminaire International d'Experts Consacré à la Politique de l'Eau pour l'Agriculture et l'Elevage en zones arides et Semi-Arides, CIEH/CEFIGRE, Niamey, Niger 12-17 février 1979.

- Moxon, James (1969) Volta; man's greatest lake. New York : Frederick A. Praeger.
- NEDECO(1959) River studies and recommendations on improvement of Niger and Benue. Amsterdam, North-Holland Publishing Company.
- Nelson, Harold D. et al (1972) Area handbook for Nigeria. Washington, D.C., U.S. Government Printing Office.
- Nelson, Harold D. et al (1974) Area handbook for the United Republic of Cameroon. Washington, D.C., U.S. Government Printing Office.
- Nelson, Harold D. et al (1974) Area handbook for Senegal, Washington, D.C., U.S. Government Printing Office.
- Ngassam, Justin (1979) Notes de synthèse sur les projets d'aménagements hydroagricoles en cours d'exécution au Cameroun. Extrait de Séminaire International d'Experts Consacré à la Politique de l'Eau pour l'Agriculture et l'Elevage en Zones Arides et Semi-Arides, CIEH/CEFIGRE, Niamey, Niger, 12-17 Février 1979.
- Nguendeung, Doumde (1976) Situation actuelle de l'approvisionnement en eau et de l'assainissement en milieu rural au Tchad.
- Nigeria, Ministry of Agriculture and Natural Resources. Joint Planning Committee (1974) Agricultural development in Nigeria, 1973-1985. Lagos.
- "Notes d'information et stastiques" (1978) Banque Centrale des Etats de l'Afrique de l'Ouest, no. 257-267, jan-déc.
- Obeng, Letitia E. (1975) Agriculture and water problems; the case of the Volta Lake. In Seminar on the Development and the Environment in Africa. University of Nairobi, Kenya, April 15 -24, 1974. p. 78-91.
- OMS (1973) Rapport de statistiques sanitaires mondiales. World health statistics report. vol. 26, no. 11. Geneva.
- Organisation of Africa Unity. Scientific, Technical and Research Commission (1968). International Atlas of West Africa. Plance 41. (Addis Abeba ?).
- Réunion Inter-Régionale des Responsables Gouvernementaux sur l'Approvisionnement en Eau et l'Assainissement en Milieu Rural. Ougadougou, 6-10 décembre 1976. (1976) Approvisionnement en eau et assainissement en milieu rural togolais.
- Réunion Inter-Régionale des Responsables Gouvernementaux sur l'Approvisionnement en Eau et l'Assainissement en Milieu Rural. Ougadougou, 6-10 décembre 1976. (1976) Rapport de la Haute-Volta. Ougadougou.
- Réunion Inter-Régionale des Responsables Gouvernementaux sur l'Approvisionnement en Eau et l'Assainissement en Milieu Rural. Ougadougou, 6-10 décembre 1976 (1976) Situation actuelle de l'approvisionnement et de l'assainissement en milieu rural au Niger.

- Réunion Inter-Régionale des Responsables Gouvernementaux sur l'Approvisionnement en Eau et l'Assainissement en Milieu Rural. Ouagadougou, 6-10 décembre 1976. (1976) Situation actuelle de l'approvisionnement en eau et de l'assainissement en République Populaire du Bénin. Rapport national.

- Réunion Préparatoire de la Conférence des Nations Unies sur l'Eau. Addis Abeba, 20-25 Septembre 1976 (1976) Le problème de l'eau en République Populaire du Bénin. Monographie nationale. Cotonou.

- Rydzewski, J.R. (1968) Irrigation development in Africa south of the Sahara: potentials and possibilities 1965- 1985. Rome, FAO.

- Séminaire Régional FAO/DANIDA sur le Développement de Petits Aménagements Hydro-Agricoles en Afrique de l'Ouest, Ouagadougou, Haute-Volta, 29 sept. -6 octobre 1975 (1976) Mise en valeur hydro-agricole... Rapport. Vol. II - Rapports techniques. Rome, FAO.

- Senegal-Consult (1970) Feasibility survey for the regulation of the Senegal River. Design of a system of water management planning in the Upper Senegal River Catchment. Geneva.

- SEDES (1974) Les perspectives de développement à long terme, tome I - Cameroun (1968 -1986) Tome 2 -Mali (1968-1986). Paris.

- SEDES (1975) Recueil statistique de la production animale. Paris, Ministère de la Coopération.

- SOFRELEC (1965) Aménagement du bassin du Mono. Rapport final. Paris.

- SOFRELEC (1978) Etude de factibilité du barrage de Kandadji (Niger). Deuxième phase. Paris.

- SOGREAH (1978) Modèle mathématique du fleuve Niger. Rapport de mission. Grenoble.

- "Stockwater", E.A. LeViness, Livestock Specialist, Arizona Agri-File: Livestock 470, Agricultural Extension Service, February 1972.

- Tahel Water Planning. Ltd. and Engineering Science, Inc. (1965) Masterplan for water supply and sewerage. Engineering report for Accra-Tema Metropolitain Area. vol.I -Summary report. Accra.

- Tchad. Bureau de l'Eau (1977) Monographie nationale de la République du Tchad.

- Thomson, R.B. (1971) Rapport d'enquête préliminaire sur la pêche au lac Nokoué. Seattle, Washington, National Marine Fisheries Service, Biological Laboratory.

- Tims, Wonter (1974) Nigeria: options for long-term development. Baltimore, The John Hopkins University Press.

- Traoré, Sitapha et Malick Sène (1976) Expérience malienne dans le domaine de l'approvisionnement en eau et de l'assainissement en milieu rural. Ouagadougou.

- United Nations. (1976) The demand for water: procedures and methodologies for projecting water demands in the context of regional and national planning. New York.
- Van der Leeden, F. (1975) Water resources of the World. Selected Statistics. Port Washington, New York, Water Information Center, Inc.
- Welcomme, R. L. (1975) The fisheries ecology of African floodplains. In Report of the Consultation on Fisheries Problems in the Sahelian Zone, Bamako, Mali, 13-20 November 1974. Rome, FAO. CIFA Occasional paper, no. 4. p. 40 - 81. fig., graph., tabl. bibl.
- Winstonley, Derek (1974) Rainfall and river discharges in the sub-sahara zone (10 ^{o} -20 ^{o} N) of Africa. In Consultation on Fisheries Problems in the Sahelian Zone, Bamako, Mali, 13-20 November 1974. (CIFA occasional paper no. 4) Rome, FAO.
- "The world water conference: a suggested action programme on irrigation management " (1977) Overseas Development Institute Review, no. 1, p. 106-110.
- Zabré, Hado, Paul (1979) Les aménagements de bas fonds en Haute-Volta. Extrait de Séminaire International de l'Eau pour l'Agriculture et l'Elevage en Zones Arides et Semi-Arides. CIEH/CEFIGRE, Niamey, Niger, 12-17 février 1979.

LIST OF ABBREVIATIONS

ACP	African - Caribbean- Pacific States
ADRAO	Association pour le Développement de la Riziculture en Afrique de l'Ouest
BDPA	Bureau pour le Développement de la Production Agricole
BRGM	Bureau de Recherches Géologiques et Minières
CEFIGRE	Centre de Formation Internationale à la Gestion des Ressources en Eau
CIEH	Comité Interafricain d'Etudes Hydrauliques
CIFA	Committee for Inland Fisheries in Africa
CILSS	Comité Permanent Interétats de Lutte contre la Sécheresse dans le Sahel
DANIDA	Danish Overseas Development Agency
FAO	Food and Agriculture Organization of the United Nations
IRAT	Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières
MIT	Massachusetts Institute of Technology
NEDECO	Netherlands Engineering Consultants
OMS	Organisation Mondiale de la Santé
PNUD	Programme des Nations Unies pour le Développement
SCET	Société Centrale pour l'Equipement du Territoire
SEDES	Société d'Etudes pour le Développement Economique et Sociale
SOGREAH	Société Grenobloise d'Etudes et d'Application Hydraulique
UNESCO	United Nations Economic, Social, and Cultural Organization
UNOTC	United Nations Office, Technical Cooperation
WARDA	West African Rice Development Association
WHO	World Health Organization