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Implications of expected climate change in the West and Central African Region: an overview

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PREFACE

In spite of uncertainties surrounding the predicted climate change, greenhouse gases appear to have accumulated in the atmosphere to such a level that the changes may have started already and their continuation may now be inevitable.

The environmental problems associated with the potential impact of expected climate change may prove to be among the major environmental problems facing the marine environment and adjacent coastal areas in the near future. Therefore, in line with UNEP Governing Council decision 14/20 on "Global Climate Change", the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP) launched and supported a number of activities designed to assess the potential impact of climate change and to assist the Governments concerned in identification and implementation of suitable response measures which may mitigate the negative consequences of the impact.

Since 1987 to date, Task Teams on Implications of Climate Change were established for eleven regions covered by the UNEP Regional Seas Programme (Mediterranean, Wider Caribbean, South Pacific, East Asian Seas, South Asian Seas , South-East Pacific, Eastern Africa, West and Central Africa, the Kuwait Action Plan Region, the Red Sea and Gulf of Aden, and the Black Sea).

The initial objective of the Task Teams was to prepare regional overviews and site-specific case studies on the possible impact of predicted climate change on the ecological systems, as well as on the socio-economic activities and structures of their respective regions. The overviews and case studies were expected to:

- examine the possible effects of the sea-level changes on the coastal ecosystems (deltas, estuaries, wetlands, coastal plains, coral reefs, mangroves, lagoons, etc.);

- examine the possible effects of temperature elevations on the terrestrial and aquatic ecosystems, including the possible effects on economically important species;

- examine the possible effects of climatic, physiographic and ecological changes on the socio-economic structures and activities; and

- determine areas or systems which appear to be most vulnerable to the above.

The regional overviews were intended to cover the marine environment and adjacent coastal areas influenced by, or influencing, the marine environment. They are to be presented to intergovernmental meetings convened in the framework of the relevant Regional Seas Action Plans, in order to draw the countries' attention to the problems associated with expected climate change and to prompt their involvement in development of policy options and response measures suitable for their region.

Following the completion of the regional overviews, and based on their findings, site-specific case studies are developed by the Task Teams and are planned to be presented and discussed at national seminars. The results of these case studies and the discussions at the national seminars should provide expert advice to national authorities in defining specific policy options and suitable response measures.

The Task Team on the Implications of Climate Change in the West and Central African Region, sponsored by UNEP - OCA/PAC, was established and met in its first meeting in Lagos, Nigeria, between 7-9 June 1989, and in its second meeting jointly with the Task Team for the Eastern African Region in Nairobi between 18-21 December 1989. Each member of the Task Team was assigned a specific subject to address in detail, and the present overview is largely based on the contributions by the individual members of the Task Team as given in the Appendix. The Task Team consisted of: T.O. Ajayi, M. Akle, E.O. Asare, L.F. Awosika, R.O. Egunjobi, I. Findlay, A.C. Ibe, K.P. Koffi, I. Niang, S. Ogbuagu, S.O. Ojo, S.G. Zabi.

This publication was prepared by A.C. Ibe and S.O. Ojo on the basis of work carried out by the West and Central African Task Team, edited by John C. Pernetta, and finalized for publication by M. Gerges (Deputy Director) and M. Kh. El-Sayed (Consultant) of OCA/PAC.

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1. INTRODUCTION

Climate change and variability have been and will continue to be characteristic of weather and climate. Over the past millions and thousands of years, extensive changes have occurred in the climates of different areas of the world. Indeed, over the past decades, a large number of relatively short-term changes and variations have occurred. In the West and Central African Region (WACAF), these variations and changes have been manifested in rainfall variations, for example, which in turn have had significant impact on hydrological and hydrometeorological characteristics in the region. Thus, rainfall variations have caused floods, droughts and desertification which in turn have had a great impact on the socio-economic situation of the region. Indeed, climate change and variabilities have created problems in human activities, and other aspects of socio-economic planning and development in the region. Human activities such as energy production, management of water resources, food production and agriculture, forestry, marine resource development, transportation and tourism, have all been subjected to the vagaries of weather and climate in the region.

In the light of these past experiences, it is anticipated that the expected global climate changes, due to the increasing greenhouse effect, will have far reaching consequences for the WACAF Region.

Recognizing this fact, in 1989 the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP) established a Task Team for West and Central Africa as part of a global initiative begun in 1987 with the formation of Task Teams to study the implications of expected climate change in regions where UNEP has active Regional Seas Programmes.

The Task Team considered and adopted the terms of reference provided by UNEP as the basis for the work of all regional Task Teams which are as follows:

Long-term objectives:

(a) to assess the potential impact of climate change on the coastal and marine environment as well as on socio-economic structures and activities; and

(b) to assist Governments in the identification and implementation of suitable policy options and response measures which may mitigate the negative consequences of the impact.

Correspondingly, the short-term objectives of the Task Teams are:

(a) to analyze the possible impact of expected climate change on the coasts and marine ecological system, as well as on the socio-economic structures and activities; and

(b) to prepare overviews and selected case studies relevant to specific regions.

This regional overview covers:

(a) the possible effects of the sea level changes on the coastal ecosystems (deltas, estuaries, wetlands, coastal plains, coral reefs, mangroves, lagoons, etc.);

(b) the possible effects of temperature elevations on the terrestrial and aquatic ecosystems, including the possible effects on economically important species;

(c) the possible effects of climatic, physiographic and ecological changes on the socio-economic structures and activities; and

(d) areas or systems which appear to be most vulnerable to the expected impact.

This overview is a summary of the highlights of written submissions by Task Team members (Appendix I).

Due to the present imprecise nature of information on some aspects of global climate change and the rapidly evolving work of Working Group I of the Intergovernmental Panel on Climate Change (IPCC) which is yielding new estimates of both the expected global warming and sea-level rise, it must be stressed that the assumptions underlying the work of the Task Team, are those accepted at the UNEP/ICSU/WMO International Conference in Villach, 9-15 October 1985, i.e. increased global mean temperature of 1.5-4.5°C and sea-level rise of 20-140 cm before

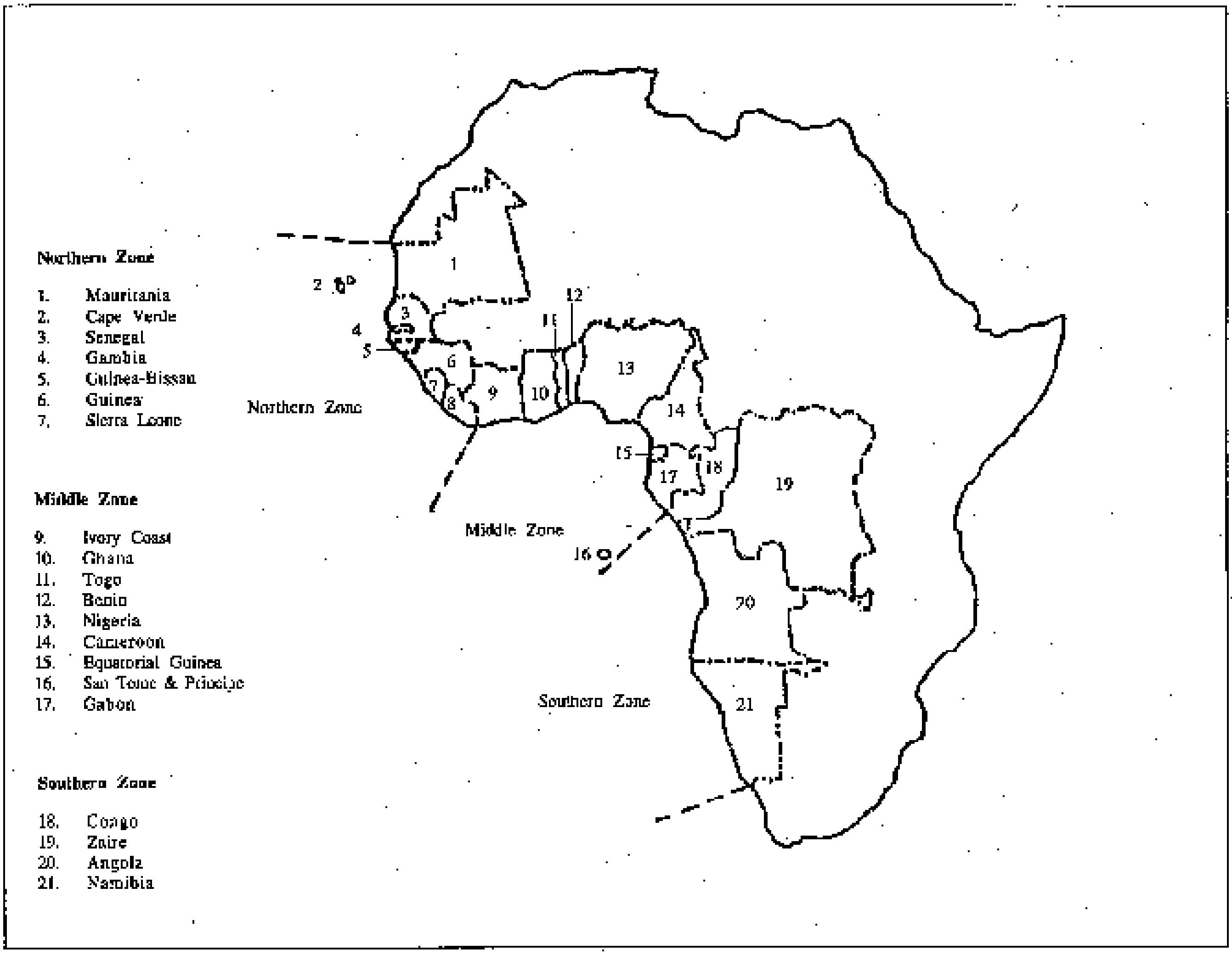


Figure 1: Countries and zones of the WACAF Region

The purpose of this overview is to draw the attention of countries in the region to the problem associated with expected climate change and to prompt their involvement in the development of technical and policy measures suitable for application in the West and Central African Region.

2. PHYSICAL CHARACTERISTICS OF THE REGION

2.1 LOCATION

The West and Central African Region comprises 21 African countries bordering the Atlantic Ocean and includes two island states, Cape Verde and Sao Tome and Principe. The region stretches for about 8,500 km between latitudes 22°N and 28°S, and encompasses from north to south, Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, Congo, Zaire, Angola and Namibia (Figure 1).

2.2 GEOLOGY AND GEOMORPHOLOGY

The evolution of the continental margins of West and Central Africa is linked with the separation of South America from Africa. The dating of this separation is inexact as it consisted of a series of overlapping events.

According to Emery *et al* (1974), the earliest of the events in the region was the development of small basins and troughs (the Senegal, Liberia and Sierra Leone basins), when North America separated from Africa about 180 date of separation is indicated by the continuity of Precambrian and Paleozoic strata and structures in Africa and South America and the disruption of Jurassic and younger structures. This separation led to the formation of the basins farther south (Mossamedes, Cuanza, Congo-Cabinda, Gabon, Cameroon, Nigeria, Dahomey and Côte d'Ivoire basins). All these coastal basins are separated from each other by cratons which are coastal extensions of the Precambrian basement complex.

Continued separation of South America from Africa produced easily recognizable continental margins and deep ocean provinces of transformational or translational faulting that are marked by numerous fracture zones. Some of these fracture zones emanate from the mid-Atlantic ridge and stretch to the continental slope and even inland.

The coasts in the West and Central African Region are mostly of low slope, sandy and surf beaten. Four broad types are recognized; drowned coasts in the northern area; sand bar or lagoon coasts along the north of the Gulf of Guinea; deltas associated with most of the major rivers, (e.g. Niger Delta) usually with mangrove swamps and marshes; and coasts with sand spits (and tombolos) formed by accumulation of longshore transported sand in bays (e.g. Angola). The land margin of West and Central Africa is bordered by lowlands that mark the margins of basins underlying major river valleys (such as the Niger-Benue) and the coastal zone (Figure 2).

The coasts descend to a generally narrow (100 km or less) continental shelf wider near the northwestern limits of the region, about 220 km northwest of Monrovia, where the shelf reaches its greatest width. The shelf break occurs in an average water depth of 100 m except to the southeast, inshore of Walvis Ridge, where it is nearly 400 m. At least seven large submarine canyons etch the seaward edge of the shelf and one, the Congo submarine Canyon, crosses the entire shelf from 25 km off-shore within an estuary (Veatch and Smith, 1939; Heezen *et al*, 1964, Shepard and Emery, 1973).

The continental shelf descends through the continental slope, which is dominated by sand (or shale) diapirs and is dissected by at least a score of submarine canyons, into the continental rises and abyssal plains. Beyond the abyssal plains are the abyssal hills, mid-atlantic ridge and other ridges of the deep ocean.

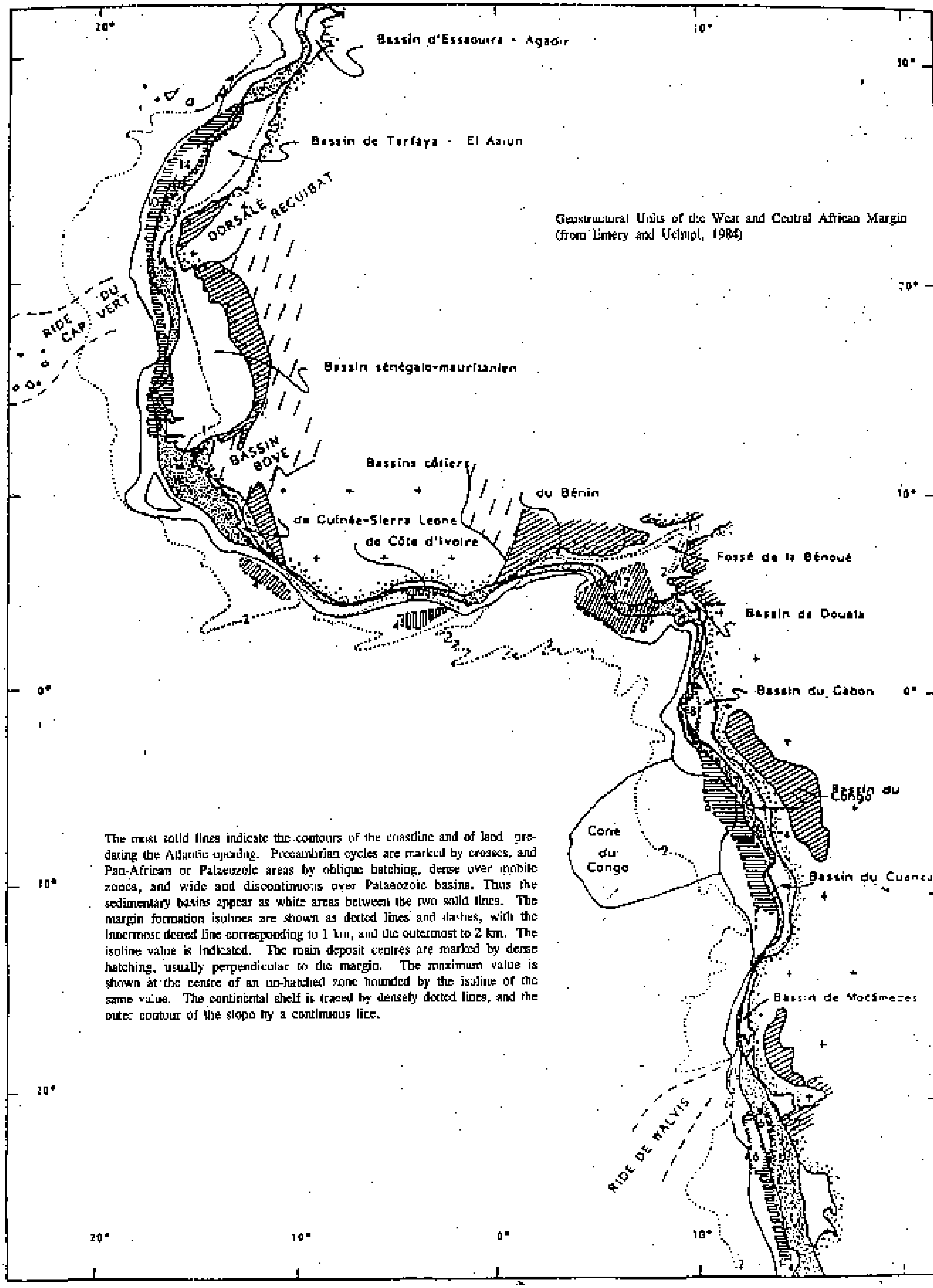
2.3 CLIMATE

The climate of the WACAF Region is related to the northward and southward patterns of movement of the Inter Tropical Convergence Zone (ITCZ) (sometimes called Inter Tropical Discontinuity, ITD) associated with the warm, humid maritime Tropical (mT) air mass with its southwesterly winds and the hot and dry continental (cT) air mass with its dry northeasterly winds. During the northern summer, the ITC and its associated air masses and winds migrate northwards reaching approximately latitudes 18°N along the coast and 22°N inland. This situation brings most parts of the WACAF Region under the influence of the mT air and its associated westerly winds. The characteristics of the atmospheric circulation and the rainfall patterns which result consist of two equinoctial rainfall maxima in the equatorial zone and one maximum to the north and one to the south of the region. Rainfall near the equator tends to be spread over 8-12 months while towards the extreme north and south, it tends to be concentrated within three to four months. Thus, precipitation over the region varies from over approximately 2,000 mm in the western equatorial regions to less than 200 mm to the extreme north and south of the WACAF Region (Figure 3). The characteristic short rainy seasons to the extreme north and south are associated with relatively high to very high rainfall variability and unreliability. In addition to the influence of the ITC and its associated winds, other meso- and micro-scale factors influence the rainfall characteristics, particularly their temporal and spatial characteristics. These factors include atmospheric disturbances and large scale fluctuations in the atmospheric and oceanic circulation patterns. The relative importance of these factors is, however, little known for the WACAF Region and research into the relative significance of the various factors which influence the weather and climate in the region is urgently needed.

In general, temperatures are high to very high throughout the year while relative humidity is high in the rainy season and low in the dry season. Cloud cover is also high in the rainy season and low in the dry season. These characteristics of the weather and climate result in three main climatic zones as follows:

The equatorial climates

These climates are found between latitudes 5°N and 3°S of the equator and are characterized by heavy



Geostructural Units of the West and Central African Margin (from Emery and Uchupi, 1984)

The most solid lines indicate the contours of the coastline and of land pre-dating the Atlantic opening. Precambrian cycles are marked by crosses, and Pan-African or Palaeozoic areas by oblique hatching, dense over mobile zones, and wide and discontinuous over Palaeozoic basins. Thus the sedimentary basins appear as white areas between the two solid lines. The margin formation isolines are shown as dotted lines and dashes, with the innermost dotted line corresponding to 1 km, and the outermost to 2 km. The isoline value is indicated. The main deposit centres are marked by dense hatching, usually perpendicular to the margin. The maximum value is shown at the centre of an un-hatched zone bounded by the isoline of the same value. The continental shelf is traced by densely dotted lines, and the outer contour of the slope by a continuous line.

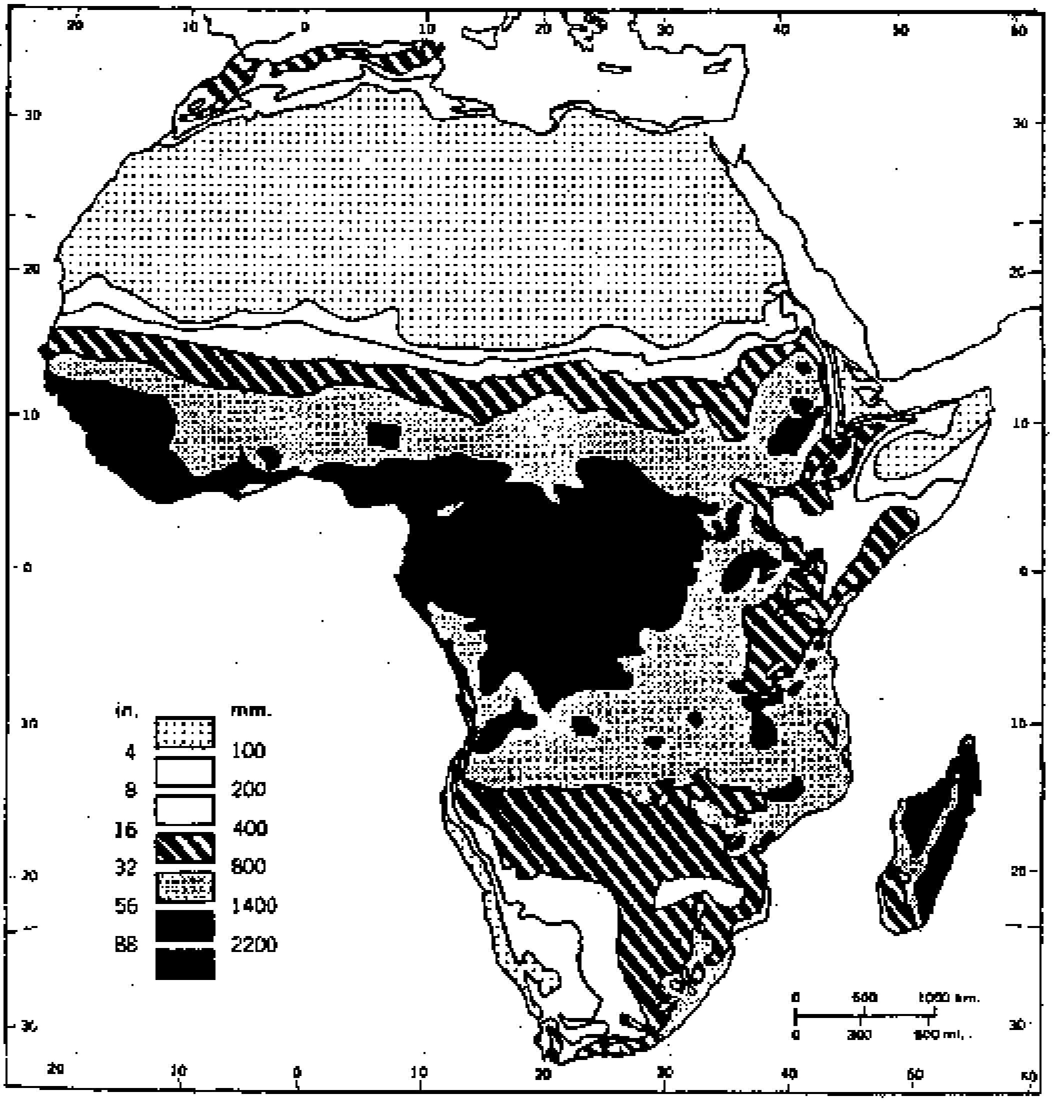


Figure 3: Mean annual rainfall over Africa

Evaporation and evapotranspiration over the equatorial regions are high. Relative humidities are generally also high, usually more than 60 per cent throughout the year. Cloud cover is also generally heavy throughout the year.

The savanna climates

These climatic zones lie to the north and south of the equatorial region generally between approximately 5°N-15°N in the northern hemisphere and approximately 3°S-12°S in the southern hemisphere. They are characterized by light to heavy annual precipitation, usually between approximately 500-1,500 mm. Rainfall patterns are characterized by single maximum, which occurs over a period of approximately 3-8 months. Mean annual temperatures are generally high, approximately 20-35°C, with mean annual ranges varying between about 10-15°C.

Evaporation and evapotranspiration are high to very high, resulting in rainfall deficits in this zone. Relative humidity is high in the wet season, usually more than 80 per cent and low in the dry season, usually less than 40 per cent. Cloud cover is also high in the wet season and low in the dry season when the *harmattan* prevails.

This zone is usually divided into three sub-zones, namely the Guinea, Sudan and Sahel savannas. Rainfall is highest in the Guinea Savanna usually more than 1,000 mm per annum, and lowest in the Sahel savanna with values

Arid and semi-arid climates

These climates lie to the north and south of the savanna climates, approximately to the north of latitude 15°N in the northern hemisphere and south of latitude 12°S in the southern hemisphere. They are characterized by little or no rainfall, usually less than 300 mm in a year. Rain falls for less than four months and rainfall in the completely arid zone is very irregular and erratic. Rainfall variability and unreliability in this zone are usually very high. Mean annual temperatures are usually high, between approximately 20-40°C while mean annual ranges may reach more than 25°C.

The climates are characterized by low cloud cover and very high evaporation potential throughout the year. Relative humidity is usually less than 60 per cent in the rainy season and less than 20 per cent in the dry season.

2.4 HYDROLOGY AND WATER RESOURCES

The hydrological processes of the WACAF Region are part of the global hydrological processes in which the occurrence, movement and storage of water determine the hydrological characteristics of the region. Basically, the land-based hydrological processes which are part of the hydrological cycle, can be thought of as a series of income - outcome units. The main source of the income component of water in the WACAF Region is rainfall which depends upon the ocean-land interactions. The Atlantic Ocean forms the main source of water for evaporation while the migration of the ITCZ, and the mT and cT air masses with the accompanying southwesterly and northeasterly winds form the major factor influencing water vapour movements. Part of the water received from rainfall returns directly to the atmosphere through evaporation and evapotranspiration, part of it is lost as runoff while part of it is held within the earth atmosphere interface as soil moisture storage.

The surface water characteristics of the WACAF Region depend on the interaction between the various components of the land-based section of the hydrological cycle. Within the large-scale hydrological processes over the region are relatively small catchment systems whose varying characteristics influence the surface water characteristics within the catchment area. In West Africa, annual runoff is greatest in areas of highest rainfall and lowest evaporation, so that the percentage of rainfall that becomes runoff tends to increase from north to south. This pattern is complicated by variations in relief and rainfall amount. Rivers such as the Konkoure and the Fare have greater mean annual discharges and higher runoff coefficients than rivers like the Niger with similar rainfall characteristics but lower altitude drainage basins. On the other hand, the low rainfall of southern Ghana, Togo, and Benin, compared with other areas of similar latitude, is reflected in marked runoff from rivers such as the Pra, Mono and the Oueme. In the absence of an effective vegetation cover, runoff coefficients of about 80 per cent for individual storms, and 30 per cent for annual rainfall are common for small high relief catchments above the 750 mm isohyet. As soon as the slope decreases, and channel degradation becomes pronounced, the water spreads over a wide area where much of it is lost through evaporation. As a result, for catchments over 100 km^2 runoff coefficients are usually below six per cent with that of Maggia being only 1.3 per cent.

The combined effects of channel degradation and high evaporation rates are clearly reflected in the mean discharge of rivers flowing northwards across the sedimentary plains. That of the Niger decreases from 1,545 m^3/sec at Koulikere to 1,146 m^3/sec at Mpoti.

The inter-annual variation in runoff is low over most of the region. The ratio between runoff exceeded in 10 per cent, and that exceeded in 90 per cent of all years is 1:3 in southern Cameroon, 1:6 to 2:0 in the Upper Niger basin, and 2:0 to 3:5 for those rivers whose catchments lie mainly within the 800 mm and 1,200 mm isohyets. In the drier areas of Benin, Côte d'Ivoire, Ghana, andTogo, however, the ratio ranges from 5:0 to 10:0. These values reflect the general balance between rainfall and runoff in this part of West Africa. The rainfall is low, from 1,000 mm to 2,000 mm, and is distributed over a long wet season, with considerable time between individual storms.

All rivers in West Africa experience a marked seasonal alternation of high and low flows. There is, however, a considerable difference between the regimes of the north where runoff is concentrated into a few floods in August and September, and those of the south where runoff is spread more evenly throughout the year. This pattern clearly reflects the seasonal distribution of rainfall to the virtual exclusion of all other factors.

The distributional characteristics of the surface water of the WACAF Region reflect the drainage system of the

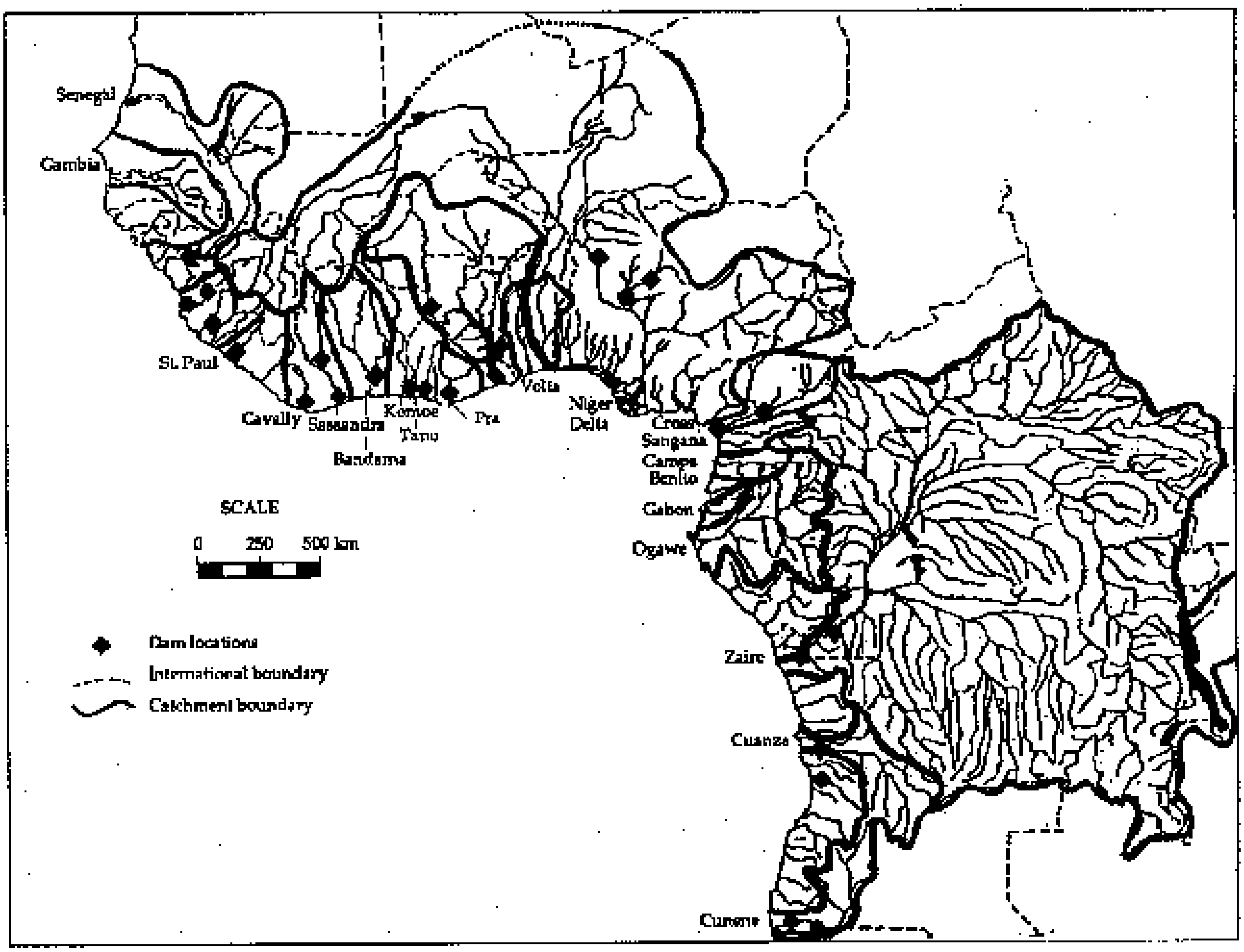


Figure 4: Major rivers and their catchment areas in the WACAF Region

2.5 VEGETATION

The vegetation zonation is greatly influenced by climatic factors especially rainfall. The vegetation zones in West Africa run roughly perpendicular to the coastline in the northern hemisphere and parallel to the coast in the southern hemisphere (Figure 5). Generally the higher the rainfall the denser the vegetation and as rainfall diminishes inland the vegetation gets less and less dense. The vegetation of the West and Central African Region may be classified into the following six biome categories:

1. Desert
2. Sahel savanna/steppe
3. Sudan savanna/dry
4. Guinea savanna/tall savanna
5. Tropical rain forest
6. Mangrove savanna

Desert

The desert is found to the north and south of the WACAF Region. It occurs in the arid regions and consists of sparsely distributed, drought resistant bushes, thorns and grasses.

Sahel savanna/steppe

This occurs to the north and south of the arid climatic zones. It consists of widely spaced, thorny, narrow-

Table 1
Hydrological characteristics of selected rivers in West Africa

1	2	3	4	5	6	7	8	9	10	11	12
River	Station	Latitude	Longitude	Catchment area km²	Predominant type of rock underlying catchment	Nature of relief	Vegetation cover	Mean annual rainfall in mm	Mean annual runoff in m³/sec	Mean annual runoff in litres/sec/km²	Coefficient of runoff in percentage
Maggia	Tsernacus	13°53'N	5°20'E	2,255	70% alluvial deposits	Slight	Open savanna	500	0.79	0.36	2.21
Black Volta	Kouri	12°43'W	3°30'W	20,000	Ancient sandstone	Slight	Open savanna big flood-plain	1,025	40	2.0	6.1
Pandjari	Porga	11°03'N	0°58'E	20,300	Mostly crystalline	Slight	Wooded savanna	965	60	3.0	9.8
Mayo Kebbi	Cossi	9°37'N	13°52'E	26,000	Cystalline	Moderate	Open savanna	925	90	3.5	11.9
Benue	Riao	9°03'N	13°41'E	31,000	Crystalline	Moderate to high	Wooded savanna	1,285	280	9.1	22.0
Palome	Kidira	14°28'N	12°28'W	28,180	Crystalline	Moderate	Open savanna	1,175	193	6.9	18.4
Niger	Kouroussa	10°39'N	9°53'W	18,000	Crystalline	Moderate to high	Wooded savanna	1,740	241	13.4	24.3
Nenkoure	Pont de Telimele	10°30'N	12°53'W	10,250	Ancient Sandstone	Very marked	Guinea savanna	2,080	355	34.6	53.0
Paro	Safai	7°39'N	12°52'E	23,500	Crystalline	High	Wooded savanna	1,545	400	17.0	34.8
N'zi	Zienca	6°01'N	4°49'W	34,000	Crystalline	Low	Wooded savanna	1,200	89	2.6	6.2
Mono	Tetetou	7°01'N	1°33'E	19,600	Crystalline	Moderate	Wooded savanna	1,230	80	4.1	10.5
Pueme	Pont de Save	8°00'N	2°25'E	24,800	Crystalline	Moderate	Wooded savanna	1,270	130	5.3	13.0
Bia	Ayame	5°36'N	3°36'W	9,320	Crystalline	Moderate	Forest	1,475	81	8.5	17.7

Source: Nai (1989)

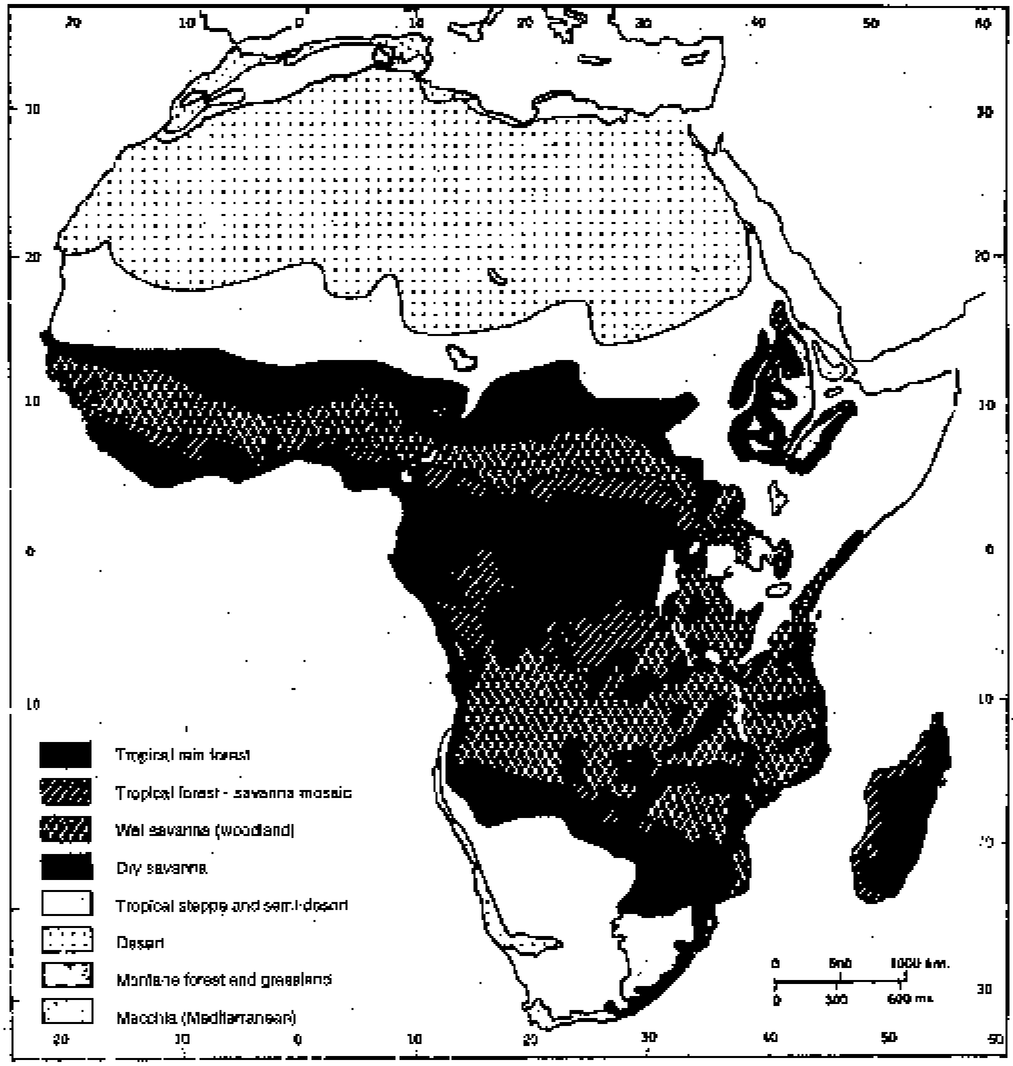


Figure 5: The vegetation regions of Africa

Sudan savanna/dry savanna

This is the most densely populated zone and has been greatly modified by grazing and cultivation. The vegetation consists of widely-spaced, short, branching trees with a herbaceous understory of short and medium grasses, many of them annuals.

Guinea savanna/tall savanna

This is usually sub-divided into northern and southern Guinea savanna and derived savanna. The northern and southern savanna vegetation consists of relatively tall trees close together but with canopies rarely touching and with a ground cover of tall and medium grasses, most of which are perennial. The derived savanna consists of a mosaic of forest and grassland and is a zone where over-cultivation, frequent burning and overgrazing result in degradation of the forest cover.

Tropical rain forest

This belt is an area of dense evergreen forest characterized by tall trees with a dense undergrowth of lianas and other climbing plants which may become so entangled as to make penetration almost impossible. The rain forest is rich in economically valuable trees such as iroko, mahogany, sapele, and walnut. Palm oil is an important economic crop in this zone.

Mangrove savanna

Mangroves are economically important not only for their wood and wildlife, but because they provide spawning and breeding grounds for coastal fish and crustaceans.

2.6 SOILS

Three soil types may be recognized in the West and Central African Region.

1. **Ferrisols (US Oxidols)**. These usually occur under heavy rainfall regimes in the equatorial area. They have poor water retention qualities, low mineral reserves and are of limited fertility. Chemical processes of weathering are powerful and rapid. When water percolates down, elements are very rapidly leached and iron and aluminum hydroxides are concentrated in the sub-soil. When exposed, they harden to give rise to ironpan layers. They are more suitable for tree crop production.

2. **Luvisoils (US Aldisols)**. These soils, which are of high to moderate fertility are found in the tree savanna and woodlands of the Guinea and Sudan savanna areas. They are used for the cultivation of cereals, root and fodder crops and grain legumes. They occupy only small areas of the humid tropics. There are three types: (i) ferric luvisols which occur under humid conditions, are highly weathered with low exchange capacity, good saturation in cations, low in organic material and fertility; (ii) chromic luvisols which occur in drier conditions, are well provided with bases but are relatively poor in organic material and phosphorus; and (iii) acrisols which occur in the same pedo-climatic zone as the ferric luvisols but are even more weathered.

3. **Arenosols (US Oxic Quartzlpsammets)**. These soils are poor in organic material, exchangeable bases and phosphorus. They are found mostly in the Sahelian zone and the Kalahari system.

2.7 OCEANOGRAPHY

Hydrography

The surface ocean circulation of West and Central Africa derives its origin from two oceanic gyral currents in the North and South Atlantic which in turn are fueled by the surface wind system of the two hemispheres.

The oceanic currents directly affecting the hydrography of the West and Central African Region are the Canary and Benguela currents, the Equatorial Counter Current, the South Equatorial Current and the Guinea Current (Figure 6).

These principal currents are fairly constant in their main directions of flow, but along most coasts, their direction at any one time is influenced by local oceanic phenomena.

The WACAF Region is not uniform either in its hydrography or in the distribution of marine resources. The most significant feature (which affects the nature, distribution and productivity of its living aquatic resources) is the presence, at least for part of the year, of a thermocline between the Tropical Surface Water and the underlying South Atlantic Central Water. The thermocline layer is characterized by low salinity and a temperature of 25°C below the Tropical Surface Water and 19°C above the South Atlantic Central Water and has an average depth of between 20-35 m over most of the region. At the northern and southern limits, the thermocline rises towards the surface to form two frontal zones, characterized by a contraction of the surface isotherms (23-27°C). Here its depth may range from 12-14 m in the Senegal - Liberia sector, the Bight of Biafra and south of the equator. It also inclines downwards offshore.

In some areas, the thermocline is relatively stable throughout the year, whilst in others it disappears as for example in the centre of the region off the coasts of Ghana and Côte d'Ivoire.

These seasonal variations in the movements of the Tropical Surface Water and the South Atlantic Central Water and in upwelling conditions affect the whole hydrographic climate of the region. Consequently two main types of hydroclimatic zones are recognized, namely, uniform or varied. The varied type is found in the Northern Transition, Central Upwelling and Southern Transition hydrographic zones where temperature, salinity, nutrients, productivity, etc. vary greatly throughout the year. In this case thermal differences are more than 12°C,

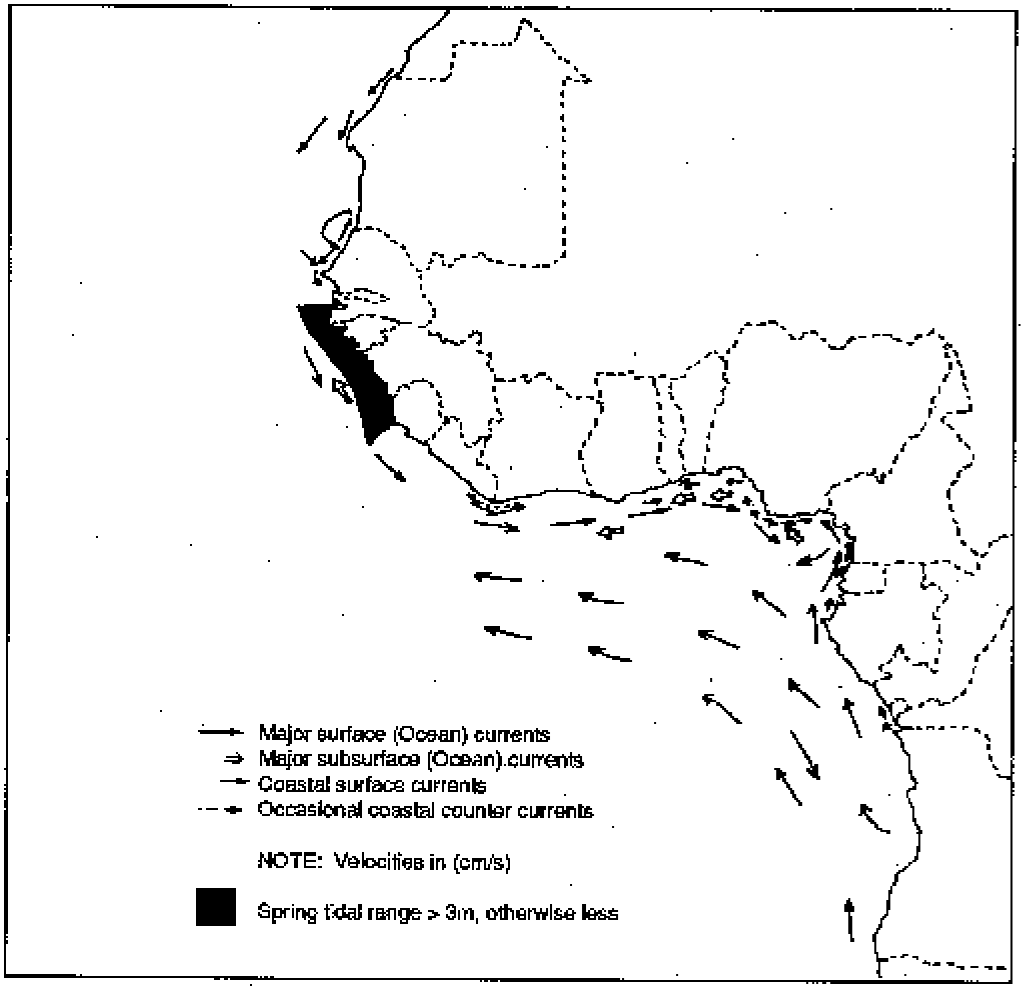


Figure 6: Currents/circulation patterns in the WACAF Region

Ocean dynamics

The tides along the coast of West and Central Africa are semi-diurnal. Tidal range varies slightly from one area to another but, except for the areas extending from Guinea-Bissau to Sierra Leone where tidal range varies between 2.1 m and 5.2 m and again in the eastern extremity of Nigeria around Calabar where the tidal range is about 3 m, the region is dominated by coasts having a mean tidal range of 1-2 m i.e. the coasts are microtidal.

The coasts are subject to high wave intensity, dominated by swells with periods of 11-16 seconds which are superimposed in the near-shore region on locally generated seas generally of a 3-8 second period. The most common amplitude of waves in the region is 1 m but according to Ibe (1985), annual significant swell reaches 3.3 m between Cape Palmas and Cape Three Points while swells attaining a height of 4.8 - 6 m occur with a 10-20 year periodicity in the area between Sherbro Island (Sierra Leone) and Cape Palmas, (Liberia). Almost invariably, the waves approach the shores obliquely, the direction at any particular time being dependent on the prevailing winds and the orientation of the coast.

Tidal and wave generated currents dominate the coastal oceans. Tidal currents are particularly important around river mouths attaining maximum velocities of between 1.6-2.8 m/sec on the ebb in the Niger delta (Allen 1965). Higher velocities may occur in the area of higher tidal range extending from Guinea-Bissau to Sierra Leone.

Breaking waves generate longshore currents, generally less than 1 m/sec which are responsible for transporting large volumes of littoral sediment and also for rip currents which are more localized in their action but move appreciable quantities of sediments away from the coast (Figure 7).

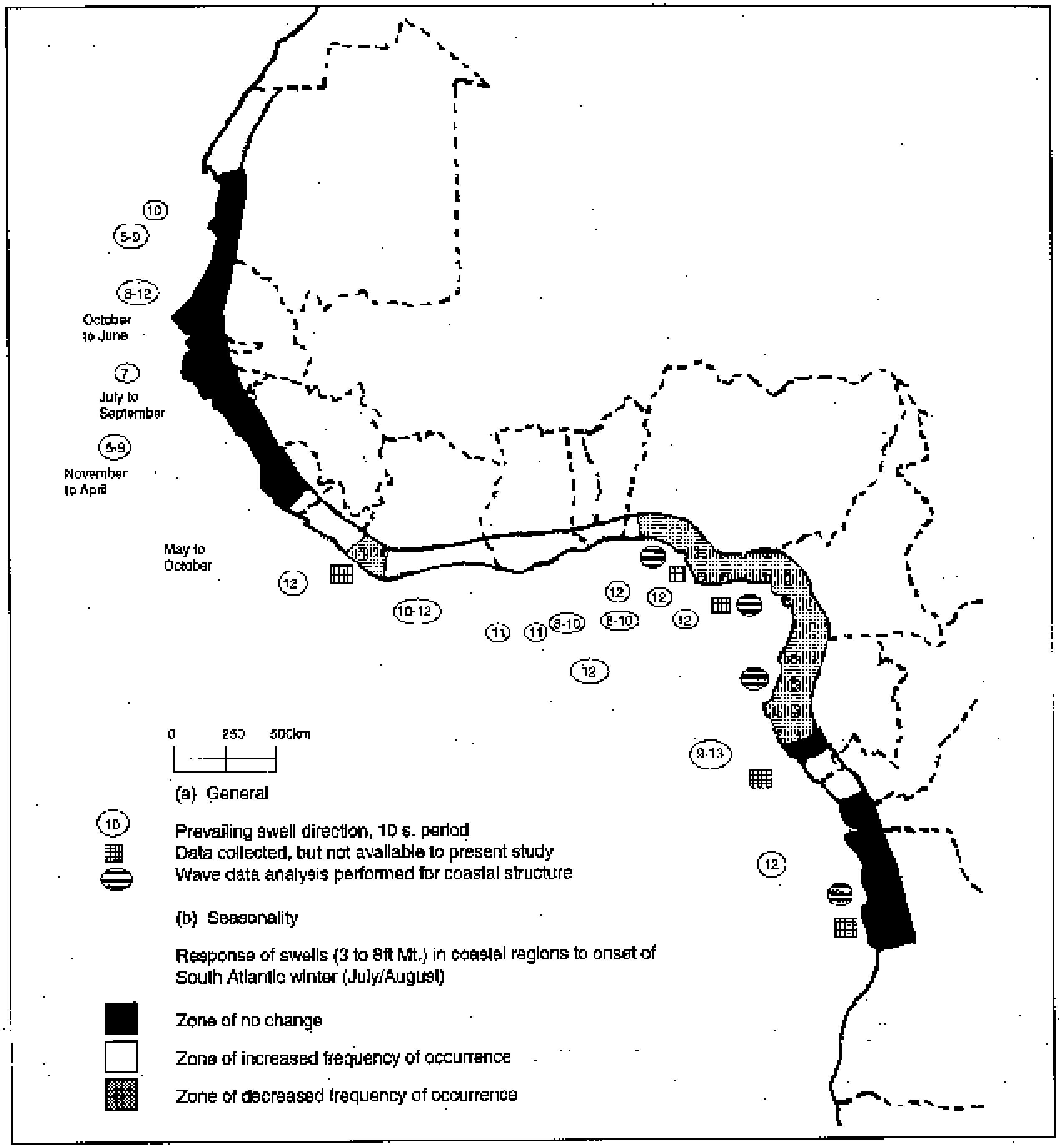


Figure 7: Wave data

3. SOCIO-ECONOMIC CHARACTERISTICS OF THE REGION

3.1 POPULATION AND HUMAN SETTLEMENTS

The countries of the WACAF region, like many other developing areas of the world, have fast-growing populations (Table 2). Estimates by the United Nations of the population of the region for 1990 are around 227 million (1988a; 1988b); annual growth rate is projected to be about 2.9 per cent. This rate is very high and means that the population will double in less than two and a half decades. Although west and central areas of the African continent are grouped together, it must be pointed out that the West African area has a higher population, about 188 million, than the Central African Sub-region, about 48 million people.

Despite these population growth differences, it is important to note that the two areas are economically

Table 2

1989 United Nations estimates of the population, size, rate of increase and density of the coastal countries in the West and Central African Region

Country	Population Size (000)	Rate of Increase	Density per km²
Mauritania	1,969	2.80	1.8
Cape Verde	368	3.13	91.1
Senegal	7,171	2.73	36.5
Gambia	835	2.71	73.4
Guinea Bissau	966	2.26	26.9
Guinea	6,705	2.54	27.3
Sierra Leone	4,046	2.60	56.4
Liberia	2,473	3.26	22.3
Côte D'Ivoire	12,097	3.91	37.5
Ghana	14,566	3.10	23.0
Togo	3,347	3.12	59.9
Benin	4,592	3.23	40.8
Nigeria	109,135	3.46	118.0
Cameroon	10,954	3.41	23.1
Equatorial Guinea	430	2.42	15.3
Sao Tome and Principe	109	2.86	109.8
Gabon	1,132	3.29	4.2
Congo	1,940	2.76	5.7
Zaire	34,853	3.21	14.9
Angola	9,747	2.81	7.8
Total	227,435	2.98	39.8

Source: United Nations (1988a). Demographic Handbook for Africa
United Nations (1988b). World Population Prospects

under 15, plus those aged above 65, to the working population aged 15-64 years is high. For this reason, leaders and policy-makers in the countries of the WACAF Region expend much effort merely providing for basic societal needs, such as the provision of social and economic infrastructure, capital for investment and reinvestment, employment opportunities for trained and unskilled manpower, and health care and protection.

As a result of early contacts with European explorers and merchants, and aided by subsequent national development efforts, the coastal areas of West and Central Africa contain the most obvious examples of efforts towards modernization in the region. Of the 21 countries, only four do not presently have their capital cities located on the coast. Up until the end of the nineteenth century, almost all these cities had populations of less than 20,000 (UNEP, 1984). Most of the capital cities were adopted in colonial times as administrative and commercial centres and were linked together by railways and roads. Today, they are nearly always synonymous with centres of commerce, industry and political power and have thus attracted very large populations. For example, Lagos (Nigeria) is reputed to have a population of over 8 million out of an estimated national population of 100 million. Other capital cities in the region e.g. Abidjan, Accra, Dakar, Freetown and Luanda are known to hold disproportionately high percentages of their national populations with a consequent high demand for goods and services.

3.2 NATURAL RESOURCES

Forestry and wildlife

The WACAF Region is the home of tropical rain forests and mangroves of great biological diversity but the density and variation of the forests is greatly influenced by climate, especially rainfall. The rain forests and mangroves form the basis of an extensive lumbering industry. The export of timber and plywood still contributes to the Gross National Product of many countries in the region and forms the basis for a thriving wood construction

The region is rich in wildlife which is an important source of protein and is hunted intensively, but several species are on the endangered list due to uncontrolled harvesting and poor management. The animal species confined to mangroves are few, most of them being found also in other brackish or saline waters, and other forests nearby. The fauna consist of, molluscs, crabs, prawns, fishes, birds such as herons, storks and ibises, reptiles and mammals including monkeys, bush pigs and manatees. Many of the reptiles, birds and mammals are semi-aquatic. The mangroves also provide important spawning and breeding grounds for a variety of fin and shellfish that are the targets of artisanal and industrial fishery in the coastal zone.

Fisheries

The fishery resources in the marine and coastal areas of the region are generally abundant, but their geographical distribution between the hydrographic zones and countries is variable. Table 3 (FAO, 1988) shows the total marine fish landings reported for the West and Central African Region according to major species. Primary and secondary productivity are highest north of Cape Verga and south of Cape Lopez, corresponding to the Northern and Southern Transition zones. The Western Tropical and Eastern Tropical zones which are characterized by permanent warm waters are poor in plankton and have low benthic productivity.

The pelagic populations of the region of economic interest are mostly clupeids and carangids. The important species are the round and flat sardines, the bonga, the cunene horse mackerel, the yellow horse mackerel and the spanish mackerel.

The demersal fish community covers a wide variety of species:

- those living between the littoral and the bottom of the thermocline (40 m) corresponding to the zones where the warm and saline TSW is present or oscillates e.g. the croakers, which live on soft bottoms, *P. elongatus, Elops* spp and *Polynemusquadrifilis* which live in low salinity areas in river/estuary zones.
- those living below the thermocline at various levels on soft and hard substrata of the continental shelf and slope which constitute the deep water community of the spands (*Dentex anagolensis, Pteroscion m'bizi, Brotula barbata),* and the snapper community.
- those living in the thermocline areas e.g. certain coastal species like *Peneaus duorarum, Brachy-deuterus auritus, Balistes capriscus* and others at the upper limit of their distribution *(Pagellus coupei)* which are found in association with a typically eurybathic community. In this area, environmental conditions, temperature and salinity, can vary greatly.

The shrimps, prawns, lobsters and oysters present in the region are now the targets of export trade because of their foreign exchange earning potential.

It is ironic that a region so abundant in fisheries resources still imports a large proportion of its fish needs. Although a great percentage of the population is coastal and engaged in fishing, traditional fishing methods are limiting in scope with fishermen confined to the artisanal sector. In addition, spoilage due to poor preservation techniques and lack of related infrastructure takes its toll on catches from this sector. Even more importantly, it has been noted that the overall level of investment in the more productive trawl fishery is low (Ajayi and Talabi, 1984).

Energy resources

The various energy sources in the WACAF Region include coal, wood, petroleum and gas and water. Solar energy and wind are other sources which remain largely untapped although the potential for wind power is rather low.

By comparison with the other continents, Africa in general and the WACAF region in particular is poorly endowed with coal. The only two areas of relative significance include Nigeria (West Africa) and Zaire (Central Africa). Petroleum is abundant in Nigeria and Gabon which are important exporters. Most other countries, including Benin, Cameroon, Côte d'Ivoire, Ghana, Senegal and Togo are, to varying degrees, oil producers.

Hydroelectric power constitutes another major source of energy in the WACAF Region. Indeed, the great African plateau with its rivers plunging down to the coast, gives Africa in general and the WACAF Region in

Table 3

1974-1986 Total marine fish landings reported for the West and Central African reg

Species Groups	1974	1975	1976	1977	1978	1979	1980	1981	1
Coastal pelagic fishes	1,948,955	2,061,957	2,163,626	2,307,709	1,775,680	1,609,788	2,014,882	1,841,810	1,74
Oceanic Pelagic fishes	270,942	246,124	230,325	295,654	273,198	242,732	293,729	320,329	34
Demersal fishes	548,310	528,982	509,958	441,679	434,367	465,042	496,709	492,746	50
Other fishes	341,971	344,379	351,828	428,804	429,978	242,604	737,230	377,415	39
Diadromous fishes	72	585	16,478	7,812	12,176	5,094	5,321	5,052	
Crustaceans	33,832	32,067	25,108	32,223	44,248	51,223	49,065	37,249	4
Molluscs	270,605	230,910	213,200	185,420	189,386	140,473	149,455	206,438	18
Other aquatic animals	100	100	100	100	100	100	101	101	
Total	3,414,787	3,445,104	3,510,823	3,699,101	3,159,134	2,757,056	3,440,491	3,280,203	3,21

Source: FAO, 1988

on the St. Paul River in Liberia and the Ayame I and Ayame II plants on Bia River in the Cote d'Ivoire Only three large-scale hydroelectric power stations have been completed as part of the multi-purpose water development projects. These are the Volta Dam at Akosombo and the Kainji and Jebba dams on the River Niger.

The most important and most widely used source of energy in the WACAF Region is fuel wood. Wood is the main source of fuel in the rural areas where more than 70 per cent of the population in the region live. Wood is also used in the urban areas, where it forms a very significant source of charcoal. In both the rural areas and the traditional residential areas of the urban centres, wood is the most important source of fuel for domestic cooking and household consumption, and some other local cottage industries including local brewing of beer, bakeries, meat processing and fish curing. Wood is also significant for the construction industry, weaving and in agricultural activities.

Solar energy constitutes a potential source of energy which remains largely untapped, as in many other parts of the tropics. Solar energy received is generally high and values received usually vary between about 100 kcal/cm^2/yr to about 200 kcal/cm^2/year and between approximately 300 and 350 cal/cm^2/day throughout the year. The highest values are usually received in the grassland and semi-arid areas where cloud cover is much less than in the forest areas. This source thus represents a big potential source for energy development in the WACAF Region, although it may be difficult to develop because of lack of technical and financial resources.

In the case of wind energy, wind speeds are generally gentle to moderate except at exposed locations or on the approach of rainstorms, when wind speeds may be as high as 30-40 knots (55-74 km/hr) or more, and this constitutes a limitation for the development of wind as a source of power for planning and development.

Non-fuel minerals

A variety of minerals ranging from sand and gravel to gold and diamonds are mined from the coastal zone of this region. According to UNEP (1984), the significance of mined resources, even when revenues from petroleum products are excluded, is appreciable in countries like Angola, Ghana, Guinea, Liberia, and Sierra Leone and their economies are mineral based. Phosphates are important in Benin, Mauritania and Togo. Placer mineral deposits have high potential in Liberia, Sierra Leone and to a lesser extent, Nigeria. Salt is mined in Benin, Ghana and Togo.

3.3 AGRICULTURE

Arable

Agriculture is the most important industry in the West and Central African Region. About 70-80 per cent of the population is engaged in agriculture and the economics of most countries in the region depend on it. The coastal areas are becoming increasingly important in this industry and have the potential to increase substantially their contribution to agricultural production. About 60-80 per cent of the food production in this zone comes from small farms.

The crops and produce from agriculture may be classified as follows:

1. **Tree and horticultural crops:** Palm oil, coconut, citrus, avocado, rubber, kolanuts, sheanut, cocoa, coffee, pawpaw, banana, plantain, mango, pineapple.

2. **Cereals:** Maize, rice, sorghum, millet.

3. **Root Crops:** Cassava, cocoyam, yam, sweet potato, ginger, tigernut.

4. **Vegetables and beans:** groundnuts, cowpea, phaseolus bean and melons.

5. **Other crops:** sugarcane, tobacco and cotton.

Agricultural production and distribution of crops are governed mainly by climatic factors particularly rainfall and temperature. These, together with the soil, determine the agricultural potential of any site.

Economic tree crops like cocoa, palm oil, rubber, kola, coffee, coconut and citrus which require high rainfall are found in the Equatorial humid zone and the maize growing belt does not extend beyond the sub-humid zone. Sorghum and millet on the other hand will grow well only in the sub-humid and semi-arid zones. Sociological and economic factors may be locally important in the small scale distribution of crops.

Livestock

The main categories of livestock in the region are large ruminants (cattle and camels), small ruminants (sheep and goats), equines (asses, mules and horses), pigs and chickens. The ruminants and equines can be fed on roughage which are of no direct use to man. The distribution of livestock is uneven and it is governed by natural factors such as the presence of tsetse fly, and historical and cultural factors as well as vegetation types.

The coastal and forest areas have low livestock populations. The northern areas (Sudan and Sahel zones) are freer of tsetse fly and are therefore able to carry non-trypanosomc-tolerant Zebu cattle and the southern area (Guinea savanna and forest zones) carry trypanosome-tolerant cattle like N'Dama and West African shorthorn which are smaller and lower yielding breeds. The population of livestock is governed by the degree of tsetse infestation. The percentage of areas infested by tsetse fly in the Sahel, Sudan, Guinea savanna and forest zones is 12, 50, 68 and 89 per cent respectively.

Fish farming (aquaculture and mariculture)

Fresh and brackish water aquaculture, and to a certain extent mariculture, are practiced to varying degrees throughout the coastal zone of the WACAF region. In more recent times, the role of fish farming in meeting the fish needs of the region has been emphasized. Captive breeding of economically important species like *Chrysicthys* sp., *Megalops* sp., *Clarias lazera* as well as oyster culture are widely practiced in Côte d'Ivoire, Ghana and Nigeria with varying levels of success. In these places, shrimp culture is also becoming popular. In Angola, the culture of mussels, *Perna perna* is widespread.

3.4 COMMUNICATIONS

Ports and harbours act as transportation access facilities for maritime activities and provide the lifeline for socio-economic development of the region. According to a recent survey (UNEP, 1985) there are 184 ports, harbours and terminals on the coast. Inland ports are hardly developed. Most of these ports, harbours and terminals are linked by intricate road, rail and air transport routes that complete the transportation network for the export - import trade that is the mainstay of most economies in the region. The development of airports has followed the same pattern as port development. As a result, virtually all international airports in the region are located on the coast, some in the proximity of seaports. Coastal roads, some of which are presently under threat from marine erosion, provide particularly easy access between the countries while air transport affords a means of rapid movement of goods and peoples in the region. Within the countries themselves there are good networks of coastal roads in Angola, Cameroon, Côte d'Ivoire, Ghana, Nigeria, Senegal, etc. Railways also link some of the coastal towns and provide communication between the coast and the food and mineral producing areas further inland.

The relatively better communications network in the coastal zone owes its pre-eminence to the early history of European contacts with the region which were mostly coast-based. The uneven nature of urban development in the region in colonial times which continued after most of the countries became independent, has further encouraged the concentration of transportation links within the coastal zone.

3.5 INDUSTRIES

When compared to America, Asia or Europe, the West and Central African Region is poorly industrialized but the pertinent issue here is not necessarily the level of industrialization so much as the fact that the industries present are located mainly in the coastal area more often in or around the capital cities. A good illustration of this is the Lagos metropolis which is reputed to have about 85 per cent of the industries in Nigeria. Elsewhere in the region, capital cities such as Abidjan, Accra, Dakar, Freetown, Luanda and Monrovia, have more than their fair share of industrial concerns. Such industries include mining, oil and gas, petroleum products, textiles, paper and pulp, timber, brewing, pharmaceuticals, plastics, leather, lumbering, food processing and various other manufacturing industries. The major reason for this disproportionate location of industries is the desire on the part of governments (which are major entrepreneurs) and other investors to take advantage of the accessibility of the coastal areas to the main arteries of transport and communication as well as the proximity of administrative facilities.

The operations of the industries also create great demands on other socio-economic amenities in the coastal zone such as water, power, housing, etc. The location of many industries on the coast puts enormous pressures

3.6 TOURISM AND RECREATION

The West and Central African Region has a great deal of anthropological artifacts, colonial monuments, natural scenery and a variety of captivating cultural attributes (including dance and drama) that constitute important tourist attractions. The region also has some stretches of sandy beaches that could be turned into magnificent recreational facilities. Only a few such spots are already in use in some of the countries. It is probably not for lack of aesthetic appreciation that many of the attractive beaches are inadequately developed for tourism. Rather the low socio-economic status of these countries has resulted in a delay in the development of beaches as tourist centres, since capital investment is limited and needed for socio-economic advancement to meet basic human needs rather than for the development of tourism. Thus, except perhaps for Gambia, tourism is not yet of great significance in revenue generation for many of the countries even though the region is endowed with natural tourist attractions that are eminently suitable for development.

Nonetheless, some of the beaches, such as Labadi beach in Accra, the Tropicana beach in Lome, and the Bar beach in Lagos, provide crude facilities for relaxation for residents of the cities and overseas visitors. In promoting tourism in the region, great care must be exercised in the siting of tourist facilities on the coast in order not to produce negative impacts. Due attention must also be paid to the increase in fresh water consumption and increased generation of solid and liquid wastes both of which will put additional pressures on coastal ecosystems.

4. CLIMATE CHANGE AND VARIATIONS IN THE WACAF REGION

4.1 PAST, PRESENT AND FUTURE

Since the late 1960s, West and Central Africa in particular, and Africa in general, have been facing a series of environmental and socio-economic consequences as a result of fluctuations and changes in climate, and most parts of the region have been subjected to a series of unusual episodic, climatic and hydroclimatic events such as droughts with their consequent crop failures, losses of livestock and widespread starvation of the local population. Prolonged droughts have caused famine and death in the affected areas and have led to mass migration of inhabitants to other parts of the region including the coastal areas. In particular in the southern border regions of the drought-stricken Sahara desert and the Sahel regions of West Africa, the drought episodes have considerably reduced food production and led to a series of socio-economic problems not only in the areas affected but also in other parts of West Africa including the coastal areas which experienced socio-economic problems as a result of the migrations of affected people. These events have demonstrated the sensitivity of human welfare and the nations' economic planning and development to climatic and hydroclimatic events. Their impacts are so great that they have attracted world-wide attention and have led to the realization that there is a growing vulnerability of society to climatic fluctuations and change and have created an awareness of the need to study the characteristics and consequences of climate change. The necessity for a sound knowledge of past, present and future natural or man-made climates and climate change and their impact in the region, and for close examination of the predictability of future climates and climate change for the purpose of warning of possible adverse consequences of future climates and climate change have been made apparent.

Some of the questions which need answering include: What are the changes in the past climates of West and Central Africa? What changes are currently taking place? What are the trends in the present climate and climate change? What are the possible future variabilities and change? What are the possible effects of the climate changes and variations? Which areas or systems of the region are most vulnerable to changes and variations in climate?

4.2 THE NATURE OF THE PROBLEM

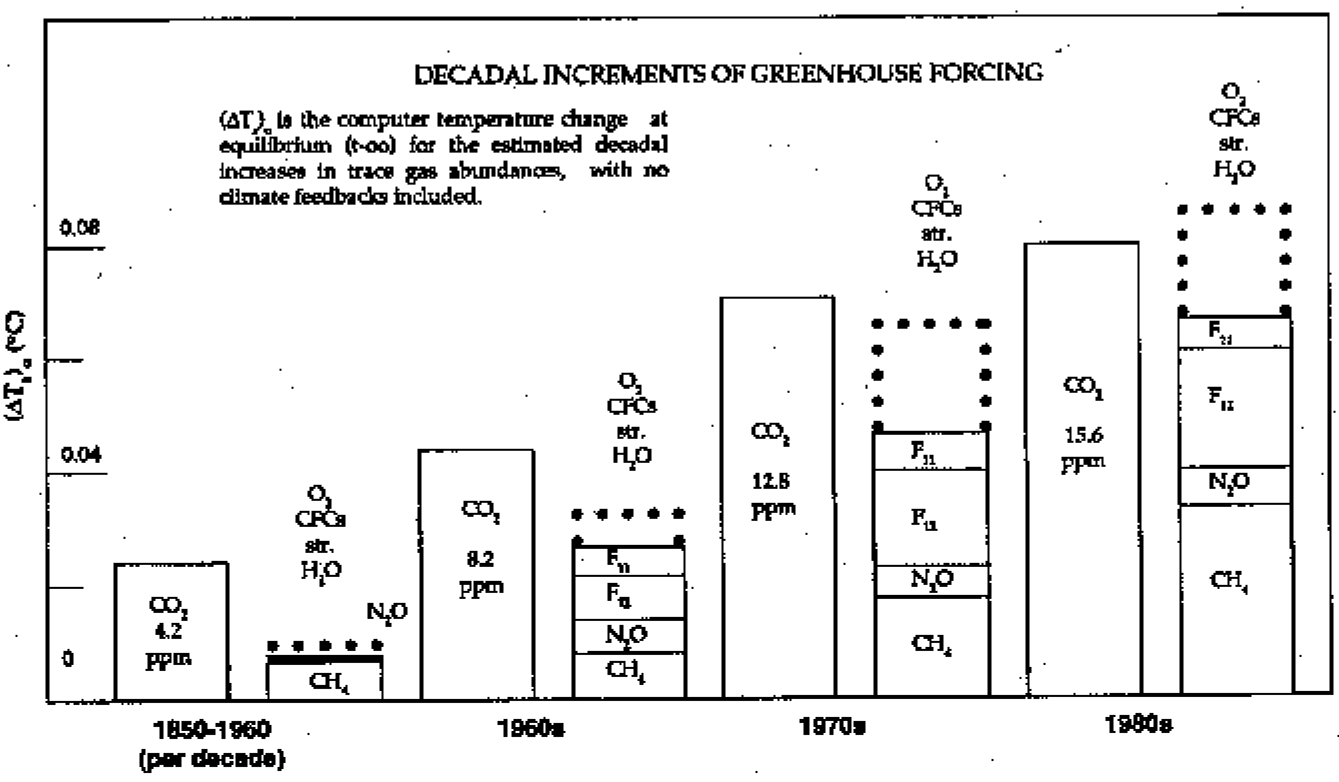
Any impact analysis or assessment of climate and climate change and variability must involve three natural time scales, namely: (a) the short-term periods which range between weekly, monthly, seasonal and annual periods; (b) the medium-term scales which cover several decades; and (c) the long-term scales of hundreds, thousands or even millions of years. Particularly in the WACAF Region, it is important to realize that the impacts created by the short- and medium-term time scale variations or change in climate play a more significant role in creating awareness on the part of the governments and people of the region for the need to examine the impacts of climate change and variations than do the long-term variations. The various climatic events particularly droughts and floods which are normally on short- and medium-term scales have caused so much damage in the region that there is a growing awareness of climate-society inter-relationships and of the socio-economic consequences of climate change and variations in the region. It therefore follows that the nature of the problem of impact analysis of climate change in the WACAF Region must consider: (a) the relatively large-scale global in climate. In addition, the nature of the problem of climate change and variations involves the spatial variability in distribution of climatic parameters.

4.3 GREENHOUSE GASES AND CLIMATE CHANGE

The general consensus is that human action is now an important factor which affects the delicate balance of forces which determine the earth's climate. Particularly in recent years, this factor has been known to have significant impacts on, and caused changes in, aspects of the global climate. The atmospheric concentrations of a number of trace gases are known to be increasing and some of these gases have important effects in trapping energy from the sun in the form of heat. Since the beginning of the century, the rate of carbon dioxide increase from burning fossil fuels has been about 4.3 per cent per year, a steady rise that slackened only during the two world wars (Kellogg and Schware, 1982, Rotty 1979; Figure 8). The effect of the increase in concentration of these gases has led to a warming of the earth-atmosphere system and hence to a change in the climate. These effects, normally known as the "greenhouse effects" arise from the fact that the gases absorb the infrared radiation coming from the earth's surface and re-radiate a part of it back to the surface, thereby warming the globe. The most significant of the gases is carbon dioxide (CO_2). Other significant infrared-absorbing gases added to the atmosphere include chlorofluorocarbons, methane, carbon monoxide, nitrous oxides and ozone. Although carbon dioxide contributes significantly to the current warming of the earth's surface, these other gases are also important in changing climate (Figure 8). Indeed, it has been noted that these other gases could increase the greenhouse warming effects by as much as 50 per cent above the warming from CO_2 (Flohn, 1979; Ramanathan, 1980).

The climatically-induced sea-level changes would be the same everywhere on earth although relative sea-level rise will be affected by local geological and tectonic phenomena. In contrast to the expected global change in sea-level, there would be regional and local differences in the degree and rate of temperature change; the increase at low latitudes will be smaller than that in the middle and higher latitudes.

According to the assumptions accepted for this study, the rise in global mean surface temperature is expected to be in the range of about 1.5-4.5°C while the sea-level rise is expected to be between about 20 cm and 140 cm by the end of the next century. Based on these expectations, it is assumed that both evaporation and precipitation may increase to varying degrees and relative humidity possibly in the range of about 2-3 per cent for each degree of global warming (WMO/TD, 1988). Thus it is reasonable to expect that both precipitation and evaporation would increase, possibly in the range of 5-20 per cent in the humid tropical regions. This situation would however vary from place to place, and there may be a decrease in precipitation rate in some locations and in different seasons.

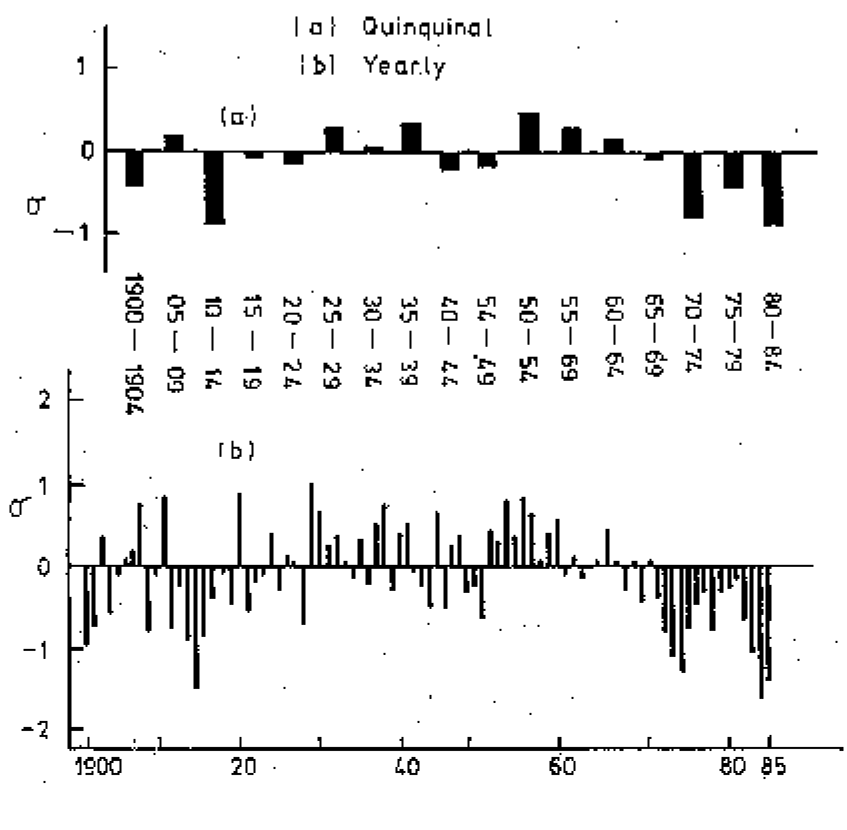


In the humid tropical region which is already too hot and too wet, the increase in both precipitation and temperature could have significant environmental impacts. The increase in rainfall may occur at the same time as increases in rainfall intensity and greater frequency of violent storms and of some tropical storms particularly hurricanes. Shifts in geographical patterns of rainfall and cloudiness may also be expected. Since the increase in temperature would increase evaporation and potential evapotranspiration, there would be a tendency towards more drought stress in many if not most of these humid tropical regions. With increased ocean temperatures, tropical storms (e.g. hurricanes and tornadoes) are likely to extend into some humid areas of the WACAF Region, where they are now less common. Where they already occur, increased intensity of winds and rainfall might be expected.

In contrast to the humid tropical regions, the savanna and semi-arid areas are likely to experience a decrease in precipitation rate. This, coupled with temperature increases would reduce soil moisture availability (WMO/TD, 1988). These savanna and semi arid tropical regions already suffer from seasonal and inter-annual climatic variability and there has been drought persistence and active desertification particularly since the mid-1960s. Future climate change could worsen the critical problems in these areas particularly with regard to food production and availability, water availability, fuel wood availability and changes in human settlements in response to impacts on ecosystems. Detailed analysis of these impacts is given below.

4.4 SHORT- AND MEDIUM-TERM CLIMATIC VARIATIONS

As already noted, a feature of climate change is its implications for relatively short- and medium-term climatic variations and their impact on the society. Over the past three decades, West and Central Africa have witnessed marked climatic and hydroclimatic events and their consequences. Episodes of "abnormal" climate have occurred, in some cases, lasting for several consecutive years. These events which result in droughts, or floods are characterized by temporal and spatial variabilities with regional and local differences in their impacts. The seriousness of such climatic events is likely to be intensified by climate change for the following reasons: (a) precipitation rates are likely to increase in the humid areas increasing the probability of floods; (b) precipitation rates are likely to decrease in the Savanna and Semi-arid areas decreasing soil moisture availability; and (c) the increase in temperatures will increase evaporation leading to loss of soil moisture and greater moisture stress for plants.



Figures 9 to 12 illustrate the temporal-spatial variations which climate may cause and whose characteristics are likely to be made worse with climate change. Figure 9 for example, shows the trends of the annual rainfall in West Africa between 1900-1985 averaged for 60 stations in West Africa (Ojo, 1987a, 1987b, 1988). In general, three major periods can be observed. First, a generally dry period which lasted between approximately 1901-1927, with breaks of relatively wet periods which lasted one or two years each. The second period is a relatively wet period which lasted from approximately 1928 to 1960. For most of this second period, two or three relatively wet years were generally followed by another two or three years, characterized by near normal but slightly drier conditions. During the third period between 1961-1987, the first six years, from 1961-1966 were mainly normal or slightly wet. From 1967, droughts have been relatively persistent and the indices for most of the years are between 0 and -2.

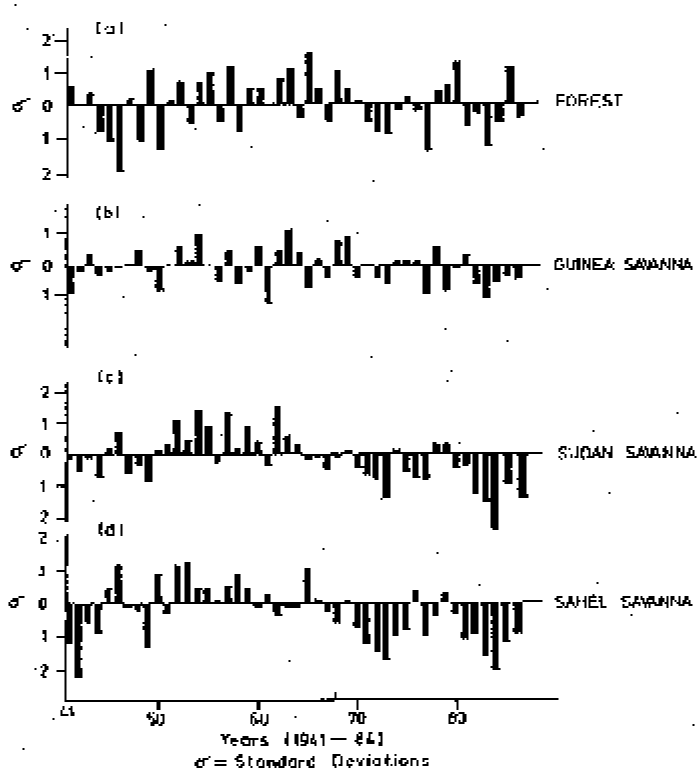
4.5 SPATIAL VARIATIONS

As already noted, the analysis of the problem also involves a consideration of the spatial variations in climatic elements, particularly rainfall. For example, Figures 10 and 11 show the spatial variations in rainfall for four of the climatic zones in West Africa. The figure shows that considerable variations occur between the different climatic zones.

For example, as can be noted from Figures 11 and 12 drought conditions were more persistent and more widespread in the Sudan savanna, the Sahel savanna and the Southern Sahara than in either the tropical rain-forest region or the Guinea savanna. Such spatial variability is important on a locational basis and within the same climatic region.

4.6 NATURE OF THE PROBLEM AS FEEDBACKS TO BE INTENSIFIED

The general impact studies involve dealing with a sequence or hierarchy of problem areas beginning with man and nature interacting with each other (Figure 13). Nature, which in this case is climate, interacts with the other components of the environmental systems, while man's activities, (for example, agriculture, lumbering and industrial and transportational activities) create man-made climates on global, regional and local scales. The resulting regional and local climate change and variations determine the effects on environmental processes and



specific activities as well as the characteristics of the economic sectors. Such changes and variations have consequences for agriculture, water resources, industry, energy supply and demand, fisheries and marine resources, human health, transportation, diseases, population processes, tourism and recreation. They also determine energy requirements on a national and regional basis. The effects on specific socio-economic activities in turn determine the perception of impacts, public awareness and the public demand for action or adaptation, and thus determine the probable or desirable responses of the societies. These processes result in "cascades" and

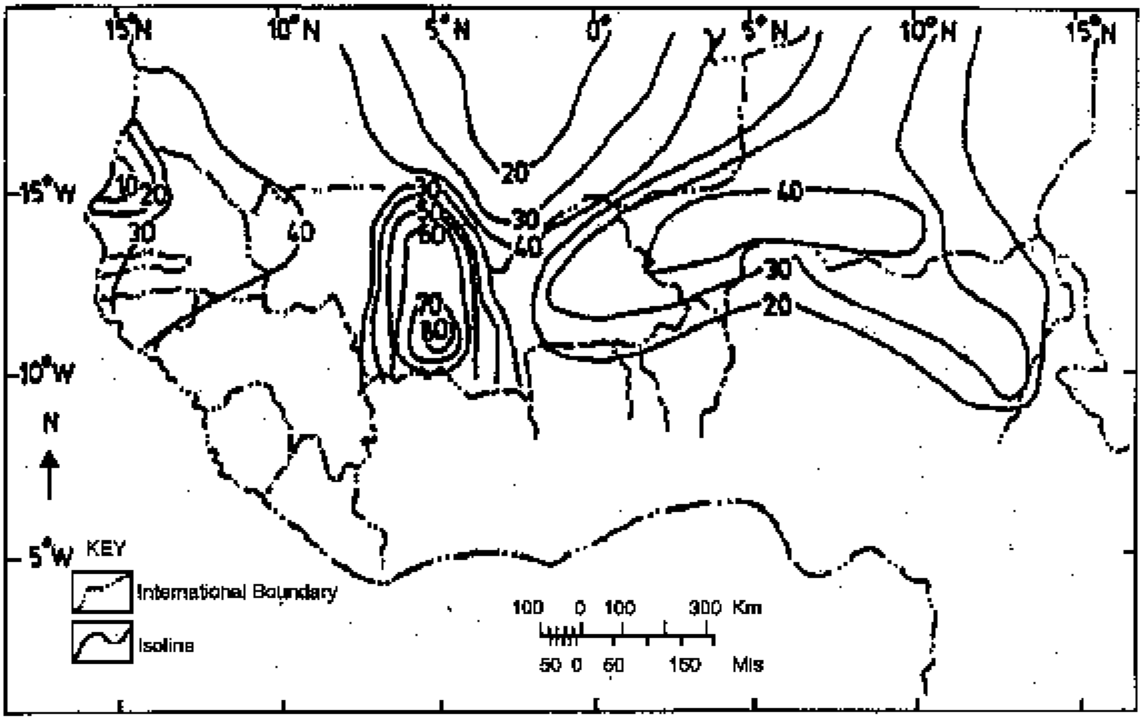
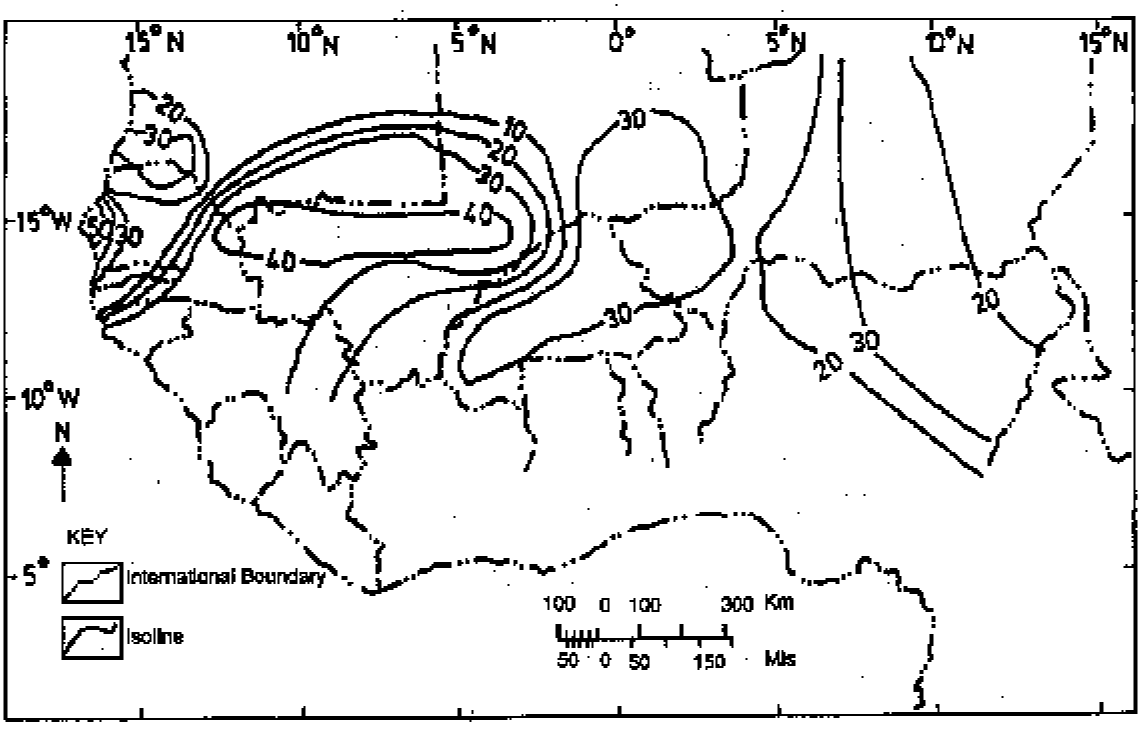


Figure 11: Percentage frequency of moderate droughts in West Africa (1961-89)



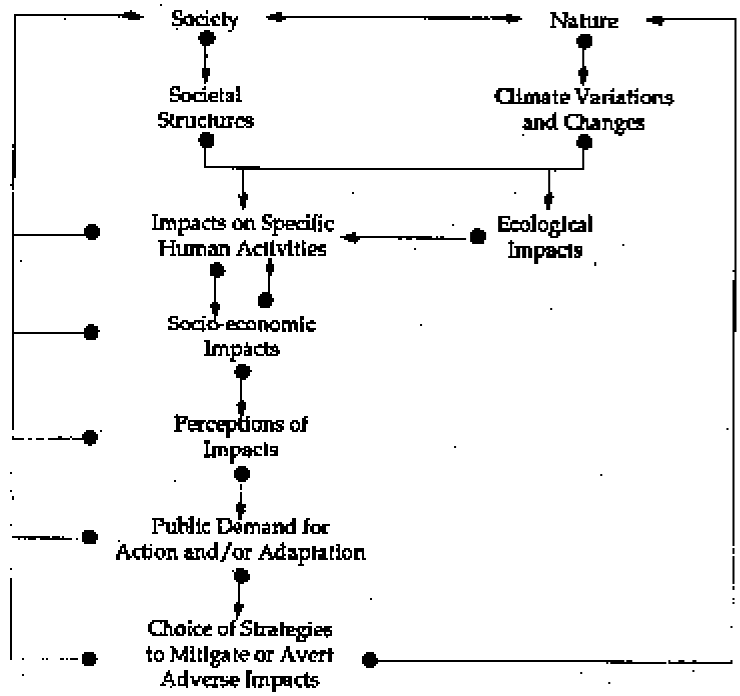


Figure 13: The inter-connected components involved in climate impac t studies

"feedbacks" of "cause and effects" which close back on themselves in the last step. These processes are likely to continue, but with man having greater influence on the mechanisms by quickening and intensifying the processes of climate and climate variations and change through his actions on socio-economic activities, which in the final analysis would create man-made climates.

5. PRESENT STATE OF THE ENVIRONMENT

The West and Central African Region faces many common environmental problems. Owing to the indiscriminate disposal of domestic and industrial wastes, pollution has become a serious problem particularly in the coastal areas where many of the inhabitants live and most industries are located. Again, by reason of the geological evolution and present geomorphology of the coasts, marine erosion and concomitant flooding have become scourges in the region particularly in the Gulf of Guinea area. The ecological damage associated with these phenomena is great with attendant disruptive socio-economic impact.

In the last four decades, the region has had more than its fair share of natural disasters including flash floods, drought and desertification brought about mainly through the vagaries of climate but which have been aggravated by poor land use practices such as over cultivation, over grazing, devegetation, bush burning, soil erosion and salinization of surface and groundwaters. General environmental degradation has become a serious problem with severe sub-regional variations.

5.1 POLLUTION

The marine contaminants of significance in the WACAF Region are pathogenic micro-organisms, petroleum hydrocarbons, organochlorines, polychlorinated biphenyls and metals.

The prevalent practice in the region is to discharge raw or partially treated sewage and night soil directly into estuarine and coastal waters. This poses a potential health hazard to man both through direct infection by pathogenic organisms and indirectly through ingestion of contaminated living marine resources (fin fishes, crustaceans and bivalves) (Ibe, 1986; 1988; Portmann *et al,* 1989).

Pesticides are used in the region to combat the multitude of pests that abound in arable and cash crop farming where they produce known deleterious effects for marine organisms and humans that consume them (Osibanjo and Jensen, 1980; Faulkner, 1985). More recently the massive switch from use of organochlorines to organo-phosphorus has resulted in the introduction of large quantities of phosphorus into coastal waters thereby increasing the periodic incidence of harmful algal blooms and eutrophication.

Hydrocarbon pollution results from exploration-exploitation activities, petroleum refinery products, and oil transportation and marketing operations. Most of the countries in the region are, to varying degrees, oil producers and some of them (Côte d'Ivoire, Gabon and Nigeria) have important refining industries and the region lies in the path of heavy international traffic of petroleum tankers. The incidence of tar ball loadings on some beaches in the region gives an indication of the high level of petroleum pollution in the region (Ibe, 1986). Results from a study of streams and rivers in the Niger Delta by Imevbore and Adeyemi (1981) showed oil levels in surface waters in the range of 10-65 ppm with increasing levels towards the sea coast.

There are very limited data on the levels of metals in waters, sediments and biota from the region. Chester and Stoner (1974) have reported values greater than 1 ug/l for Zn, Ni, Mn, Cd, Cu and Pb in water in the West African Region. Calvert and Price (1970) found values of 130 mg/kg for Cu, 460 mg/kg for Ni, 30 mg/kg for Pb, and 340 mg/kg for Zn in sediments off Namibia, although the authors attributed the rather high values to organo-metal complexes. Calvert and Price (1970) also found the following values (in mg/kg) in plankton in the Benguela Current: Cu, 300 - 6,000; Pb, 1200 - 1800; Zn, 6000 - 9000. Whitehead (1985) thinks that the high values may be partly attributed to contamination problems during sampling.

In addition to the major pollutants described above, other important pollutants in the region include greases, phenols, fluoride and ammonia (UNEP 1984).

5.2 COASTAL DEGRADATION

Recent region-wide reviews of the state of the coastal environment (UNEP, 1985; Ibe and Quelennec, 1989) have shown that marine erosion and inundation of the land by the sea are prevalent along the coasts putting life and property continually at risk. In some places, whole towns (e.g. Grand Popo in Benin and Keta in Ghana) have virtually disappeared.

The natural factors responsible for widespread marine erosion and flooding in the region include the low lying nature of much of the coastline, the high intensity of wave action along the coasts, vulnerable sediment type, the microtidal nature of the coastline which ensures that the waves act at a consistent level, the presence of offshore submarine canyons which act as chutes down which eroded sediments are carried to deep water sinks and are lost 'forever', the continuing subsidence of the major sedimentary basins in the region and the global rise in mean sea-level.

In many instances, the intervention of man in the natural environment has exacerbated the impact due to natural factors. The most obvious changes have been brought about through the construction of artificial structures along the coast particularly those associated with jetty and port development. At Cotonou (Benin), Lagos, and Escravos (Nigeria), and Lome (Togo), the construction of jetties and harbour protection breakwaters has led to phenomenal erosion problems on the downdrift side of these ports. More moderate erosion has been reported downdrift of the moles of the harbours of Monrovia and Buchanan in Liberia.

Such erosion releases great tonnages of sediments into the coastal and marine environment thereby increasing the turbidity of the water. This might impair light penetration and affect the migration pattern of coastal fishes particularly in their larval and juvenile stages. The sediment may directly smoother benthic organisms. Also, by causing shoreline retreat, such erosion allows the inland intrusion of salt water into surface fresh water and groundwater aquifers as well as killing vegetation. The water chemistry of adjoining spawning and nursery beds such as mangroves is also altered by such salt wedge intrusion.

Land reclamation of brackish and freshwater swamps and canalization of coastal lands are becoming regular practices in countries in the region. These practices produce a permanent alteration of the fragile coastal ecosystems. They generate high loads of suspended solids, the siltation from which smothers benthic organisms and in particular sessile forms like attached oysters. In Lagos between January and March 1984, intensive dredging of the lagoon as part of the city development project resulted in the phenomenal increase in the turbidity of the water of most of the embayments. The resulting siltation smothered fish nursery beds and damaged the entire provide hydroelectric power and water for irrigation. UNEP (1985) estimates that dam construction in the region has reduced the flux of sediments by approximately 70 per cent, through trapping sediments that would otherwise reach the coastline. Retreat of coastal land is an obvious consequence of dam construction, and has been reported in the coastal settlements in the Niger Delta (Mcdowell *et al*, 1983; Ibe and Antia, 1983) and in Ghana where the construction of the Akosombo dam on the Volta River has contributed to the partial disappearance of the coastal town of Keta due to marine erosion (Ly, 1980). Many dams also exist in Angola, Benin, Cote d'Ivoire, Mauritania, Senegal, Togo and Zaire and have been reported to have had similar impacts on the coastline (Ibe and Quelennec, 1989).

The reduction in freshwater discharge to the lower estuarine reaches of rivers due to dam construction results in pronounced intrusion of salt water wedges further inland. Such salt water intrusion can have important ecological effects on the fauna and flora of the coastal and nearshore zone. Destruction of mangrove and rain forest swamps in the region due to salt water intrusion has been reported (Ibe, 1988).

The reduction in freshwater discharge and its load of dissolved nutrients to coastal and nearshore zones has led to highly significant decreases in local fish productivity along some parts of the Nigerian Coast (Ibe, 1986). Deforestation of the coast and in particular the cutting of mangroves for fuel wood, building, staking fish traps etc. or for salt mining operations as in Benin, Ghana and Togo, as well as sand mining on or near the beach are additional sources of coastal degradation in the region.

An increase in freshwater and reduction in salt-water intrusion has occurred in the lower Volta, as a result of serious blockage of the Volta mouth in Ghana, following the construction of the Akosombo Dam. Long periods of drought from 1974 have not allowed spilling from the dam for the past 15 years, a situation which has virtually eliminated peak flows in the lower reaches of the river which are necessary for periodic breaching of the sand-bar formation. The previous process of cyclic bar formation is being turned into a permanent one, which has brought about a change in the ecology of the estuary, with its attendant problems of weed growth and bilharzia infestation due to drastic reduction in salinity in the area.

5.3 DROUGHT AND DESERTIFICATION

Droughts have been relatively persistent in West and Central Africa since the mid-1960s. These droughts have been caused by departures from normal climatic patterns and constitute climate hazards which increase desertification and disrupt economic and social development and imperil human lives in the desert-prone areas. The climatic elements of significance include rainfall, solar radiation, temperature and wind.

The spatial variations of the climate of the WACAF Region show that the Savannas and Semi-arid climates are to the north and south of the 1,110-mm isohyet. It is in these areas that the impacts of drought and desertification are most noticeable. The most severely hit areas are those to the north of about 600-700-mm isohyet. In the WACAF Region, the drought-prone areas are mainly in the Sahel region, to the north of Senegal and along the Mauritania coastlands, and to the south of Angola and along the coast of Namibia. In these areas, the ecosystems are extremely fragile and develop under very extreme environmental conditions and recover only very slowly when these conditions are disturbed. The fragility of the arid, semi-arid and Sahel ecosystems is associated with a soil moisture deficit. In many cases, these drought-prone areas suffer erratic rainfall and are characterized by high rainfall variability and unreliability. In any particular year, the rainfall amount and distribution is never adequate to provide sufficient water to balance evapotranspiration losses from the environment. Droughts also occur in the sub-humid and humid climatic regions and in these areas the occurrence of rainfall below normal and the intensification of human activities have increased the incidence of drought and desertification. However, the frequency, severity and widespread nature of these droughts and desertification are less than in the arid, semi-arid and Sahel regions of the WACAF Region.

Among man's activities which significantly disturb the ecological balance and cause desertification are agricultural and grazing activities, deforestation for fuel wood or for construction timber and bushfires. Once exposed after clearing for agriculture, the soil surface remains unprotected from water and wind erosion. Overgrazing arises because the carrying capacity of the arid and semi-arid areas is exceeded particularly during periods of water stress. The increasing pressure on wood for fuel and construction makes wood species scarcer, reduces the shading by trees of the soil surface and causes disturbance of the soil cover and greater exposure to wind and water erosion. The use of fires for clearing in preparation for the growing season or for hunting wild animals results in destruction of the soil cover including debris and layers of organic matter in the upper horizon where population pressure is high; and secondly, human activities influence climate and the environment. With human interference, the microclimatic conditions on which the natural vegetation and crops depend are adversely altered. Both of these factors apply in the WACAF Region.

6. IMPACT OF CLIMATE CHANGE ON PHYSICAL PROCESSES

6.1 EROSION AND FLOODING

As stated above, erosion and flooding of coastal lands are twin scourges along the West and Central African coasts. In some places, the rate of shoreline retreat and the frequency of inundation of land by the sea are putting lives and property continually at risk. This worrying situation will be exacerbated by a rise in sea-level. The seriousness of the predicted rise in sea-level with respect to erosion can be deduced from the data of Brunn (1962) which showed that even a rise of 0.3 m (1ft) will cause shoreline recessions of more than 33 m (100ft) with the possibility of much higher recessions in marsh and other low shore areas which are common in this region.

A rise in sea level will result in the over topping of low lying beach ridges along the WACAF coast. This will become even more threatening whenever storm surges coincide with spring tides. Barrier islands in Benin, Côte d'Ivoire, Ghana, Nigeria and Togo and low lying areas in Angola, Guinea-Bissau, Guinea Conakry, Liberia and Sierra-Leone will be very vulnerable to flooding. Many of the barrier islands protect the rich, low-lying coastal lands against storms and enclose and protect the rich natural resources of estuaries, marshes and mangroves.

Many of these barrier islands are heavily developed and urbanized with most country capitals situated on them. Flooding of these urban areas will cause destruction of property and lives. Many industries and oil handling facilities built near the coastline will also be affected by flooding. Surface freshwater on which many coastal activities depend will increase in salinity with rising sea-level.

Lagoons and mangrove and delta ecosystems which are very productive are found in many parts of the WACAF Region. Sea-level rise will result in flooding and disruption of these fragile ecosystems.

Agricultural land situated close to the coast will be flooded and increased salinity of water and soil will lead to reduced food production and cash crops. For example the rice field project in Koba-Guinea is situated just behind the beach ridge which if flooded will deprive Guinea of its income and food from this source.

The impact of sea-level rise along the West and Central African coasts will be worsened by the continuing subsidence of the great sedimentary basins that occur in the region. Subsidence phenomenon occurs not only because the sediments of the basins were rapidly deposited and therefore are still undergoing dewatering and compaction but also because of man's intervention in the natural environment through the extraction of fluids (including oil and gas) from the coastal zone.

Specific information relating sea-level rise to subsidence phenomenon has come from the paleo-data of Allen and Wells (1962) who used a series of dead coralline banks in shallow water off the Nigerian Coast to identify subsidence stages over the last 4,000 years. All the observed subsidence (approximately 80m in about 15,000 years) in the south western Niger Delta has been explained by Burke (1972) as having resulted from the eustatic sea-level rise and the associated isostatic adjustments to water load.

6.2 ATMOSPHERIC AND OCEAN DYNAMICS

Owing to the fact that the waters of the Tropical Atlantic are under the influence of the tropical atmospheric circulatory system, the potential impacts of global warming could be highly variable. One impact could be the modification of the wind patterns, in terms of intensification of the winds and consequently the currents as well. Loss of heat through evaporation from the sea may further increase wind strength. The high sea temperature and the increased wind force may lead to frequent occurrences of thunderstorms, and may also bring about more intensive upwelling in the area and a consequent lowering of surface water temperature in the coastal zone. The development of larger waves due to increased wind force and an increase in the velocity gradient of the current in the upper water layer may result in an increase in the depth of the upper mixed layer as well as a decrease in its temperature.

Consequently, the strengthening of the trade winds could be followed by the appearance of negative anomalies

A significant feature of this region of the Equatorial Atlantic is a surfacing thermocline whose movements induce important variations in sea surface temperatures which can have great climatic consequences. Seasonal displacement of this thermocline is linked to an equatorial and coastal upwelling phenomenon not yet clearly explained by the classical concepts of Ekman's theory and/or of advection. At present neither the role of the local wind forcing, nor solar radiation, nor even the increase in vertical mixing at the equator adequately accounts for the phenomenon. Along the Northern coast, part of this upwelling could be induced by the intensification of the Guinea current either directly with the geostrophic adjustment elevating the thermocline or indirectly via a dynamic effect at Cape Palmas in Côte d'Ivoire and Cape Three Points in Ghana. The possible impact of global warming on this thermocline might be to increase the vertical extent of the upper mixed layer with its consequent depression.

It has also been suggested that sea-level rise will cause a continued deepening of the continental shelf beyond the depth of closure resulting in an increase in effective wave height due to a reduction in bottom friction as a result of greater depths. It is thus to be expected that the present ocean dynamics (wave height, period, breaker length, longshore current direction and magnitude, etc.) influencing the coastal zone will change. A change or modification of ocean dynamics, particularly nearshore dynamics, will affect the sediment fluxes and hence sediment budgets along the coast.

The above impacts are a few of the possible consequences of global warming on the ocean dynamics of the WACAF Region, they can only be further elucidated through the collection of more observational data, and the development of regional oceanographic models.

6.3 DROUGHT AND DESERTIFICATION

As already noted elsewhere climate change would increase precipitation and evaporation in the very humid areas, particularly the coastal areas of the WACAF Region. Since the rise in temperature would increase evaporation and potential evapotranspiration rates, there would be a tendency for droughts and desertification to occur in many areas, particularly in savanna areas where increased evaporation rates are likely to be considerably greater than the increases in precipitation.

It has been noted already that short-term climatic variations and human interference are significant factors in enhancing the impacts of droughts. It is also reasonable to expect that the current relative persistence in drought conditions is likely to continue until the beginning of the twenty-first century and that unless adequate measures are taken to avert or reduce the consequences, the adverse impacts of the droughts may be considerable. This assumption is based on the projection that population pressure and human interference would be considerably higher than at present. Vegetation is likely to become more degraded than at present while soils are likely to suffer reduced fertility and erosion. Savanna will be affected by encroaching by sand dunes and desertification while most of the current areas used for nomadic herding are likely to deteriorate, causing considerable losses of livestock. Both surface and groundwater are likely to decline resulting in high soil moisture deficits which will be enhanced by the high intensity of solar radiation received and absorbed and high temperatures, creating problems for human activities particularly agriculture. Salinization and alkalinization may increase and because of the exposure of soil surface to atmospheric processes, water and wind erosion is likely to increase.

7. IMPACT OF CLIMATE CHANGE ON RENEWABLE AND NON-RENEWABLE RESOURCES

7.1 EFFECTS ON HYDROLOGY, WATER RESOURCES AND WATER RESOURCES MANAGEMENT

The implications of climate change and sea-level rise on water resources and water management must be of great concern to scientists, governments and the general public of the WACAF Region because of their significance to the life and economy of the region. The development of agriculture and industries as well as a large proportion of domestic activities largely depend upon water supply. Indeed, in the WACAF Region, agricultural production depends on water supply either through rainfall or some form of irrigation. Unfortunately, a large proportion of the population in the region lacks access to adequate fresh water supplies, and in the face of rapid population growth and rising standards of living, with increased demands for water resources, this situation is likely to deteriorate.

As for other ecoclimatic systems and other physical processes, the implications for water resources depend systems, especially precipitation, would alter the availability of water resources. This in turn leads to changes in management strategies and characteristics of water resources in order to balance water supply and demand.

In general, five types of water supply systems are important in the WACAF Region. The first category includes those that depend mainly upon precipitation concentrated in the wet season of six months or less. The second category includes water supply systems which are based on river regimes or flows that do not store significant amounts of water for use during periods of deficiency. The variations in these regimes depend mainly on the variations in rainfall. In each of these two categories, decreased precipitation leading to greater water stress would lead to considerable economic losses and/or financial stress, as well as adverse consequences on socio-economic activities and population processes.

The third category of water supply systems which may be affected by climate change and sea-level rise and which may have significant socio-economic and socio-cultural implications are those based on precipitation which occur in most months of the year (i.e. for more than six months). The impact of decreased precipitation may be less in the areas under this category of water systems, as there may be the tendency for increased precipitation. However, increased precipitation and sea-level rise may cause floods and soil erosion in these areas. The new hydrometeorological and water management systems would therefore need to find solutions to the problems created by these hydrometeorological and hydroclimatological events, namely, floods and erosion and salinization of water systems.

The fourth category of water supply systems which may be affected by climate change and sea-level rise are those based upon man-made reservoir systems which smooth out intra- and inter-annual variations in runoff and water storage. For this category, water is released as and when required for agriculture and other purposes. Examples of this category include such man-made lakes as those of the Kainji and Akosombo dams. In this category, decreased precipitation may have serious implications as there may be water shortages to maintain needed storage capacity for later release. Water shortages in these reservoirs may adversely affect socio-economic activities with considerable socio-economic stress. They may, for example, have considerable financial implications and lead to hunger, famine and death.

The fifth category of water resource systems are those based on the groundwater resources. In this case, decreased precipitation would lead to increased depth of water tables and greater difficulties in obtaining the groundwater for socio-economic activities as well as fouling this water through salinization. Thus, as for the first two categories, such a decrease would lead to increased water stress, socio-economic problems, changes in the man-environmental systems, and dislocations of settlements which could result in dislocations of the socio-cultural characteristics of the area.

7.2 EFFECTS ON ENERGY RESOURCES AND UTILIZATION

As already noted in Section 1, climate change due to the greenhouse effect may result in changes which may have significant impacts on energy resources and energy utilization in the WACAF Region. Among the impacts which could be of significance are: (a) increases in temperature; (b) sea-level rise; (c) increase in precipitation in the tropical humid areas and a decrease in the savanna and semi-arid areas; and (d) increase in evaporation. As already noted, these consequences of climate change would have significant impacts on environmental and population processes which in turn would influence ecological conditions which would become less favourable to the existing biome. Because many areas would be characterized by increasing drought stress caused by the climate change and man-made impacts, there would be greater stress on the forests for fuel wood. This fact coupled with the inundation of the coastal areas which would result from a combination of increasing sea-level, greater chance of storm surges and rising peak runoffs would decrease the areal extent of forests and consequently the availability of trees for fuel wood. Submergence of the coastal areas would also be significant by making the onshore development of petroleum industry more difficult and more expensive. Thus, in general, areas of biomass production would shift and possibly become compressed and reduced in areal extent.

Climate change and the consequent impact on human processes leading to migration are expected to lead to increased population pressure and greater intensification of the use of fuel wood in many areas. This would in turn aggravate environmental problems commonly associated with deforestation and degradation of the land surface through man-made microclimates and desertification.

some parts of the WACAF Region and this would lead to a decrease in the supply of hydroelectricity leading to many socio-economic problems.

7.3 EFFECTS ON VEGETATION AND ECOSYSTEMS

Coastal vegetation and ecosystems will be particularly vulnerable to the impact of an accelerated rise in sea level. The impacts may be direct or indirect through the alteration of the hydrological regime.

Mangroves are the characteristic littoral plant formations of sheltered coastlines in the estuaries, bays and lagoons but their survival depends on the right mix of fresh and saline conditions. Sustained flooding as a result of sea-level rise will impose salinity stress that will lead to the decimation of the mangroves. For the same reason the trees, shrubs, grasses, etc. that characterize the freshwater swamp zone further inland will shrivel and die. Ibe *et al* (1985) and Ebisemiju (1985) have reported massive vegetation kill along the transgressive mud coast of Nigeria as a result of salinity stress consequent upon the continued rapid retreat of the coast and the influx of sea water. It is therefore expected that the distribution and composition of the coastal vegetation will be affected with salt-loving species increasing. This may profoundly affect the present distribution and importance of economic plants in coastal areas.

The mangrove habitat presently provides fish, oysters, fuel wood, charcoal and construction materials for the communities living in the coastal areas. These materials are used in the growing of rice, industrial and artisanal fishery and honey production. Restricted areas are grazed. Plantations of rubber, bananas, palm oil, raffia palm and pineapples are found on the upland soils along the borders of the mangrove ecosystem and on connected sandy ridges within the mangroves. This vast socio-economic significance of mangroves will be lost in the event of the accelerated rise in sea-level.

7.4 EFFECTS ON FISHERIES

A sea-level rise of the magnitude predicted will mean an inundation by sea water of low lying areas, including brackish and freshwater swamps. The mangrove ecosystem, which is of particular significance to the regeneration of the coastal fishery, will be adversely impacted because this particularly sensitive ecosystem constitutes the spawning and nursery grounds for much of the coastal fishery. It also serves as the habitats of some crustaceans and molluscs.

Salinity stress consequent upon the ingress of seawater would lead to the disruption of the coastal fishery by causing disorganization in the faunal assemblages in estuarine, deltaic and lagoonal environments resulting in the redistribution of species and failures in the reproduction and survival of their eggs/spores and larvae/sporophytes. Predator/prey relationships would be altered to the advantage of predators. However, a study of some of the living resources of these ecosystems reveals that most of them are euryhaline and prefer warm waters. It is probable therefore that elevation of water temperature may not seriously affect them except those that cannot stand temperatures beyond the range of their normal metabolism.

In the marine environment, because of the presence of a shallow thermocline and upwelling in the region, the living resources tend to occupy habitats with well-defined characteristics of salinity and temperature. Consequently any elevation of water temperature could produce diverse effects depending on habitat characteristics. For instance, it is possible that the range of pelagic and demersal species may move inshore in response to salinity changes or that those species which are limited to well-defined temperature and salinity ranges may be eliminated or change their location. The fisheries of the region comprise important pelagic species like *Sardinella aurita, S. madarensis* and *Ethmalosa fimbriata*. With the exception of *Ethmalosa,* the sardinellas appear not to be abundant in the two sectors where the mixed layer is of low salinity, warm and present all the year round ($T > 24°C$, $S < 35$ ‰). With global warming it is likely that the sardines may not be found in the Grain coast and Bight of Biafra sectors. Similarly it has been observed that the yellow fin tuna, *Thunnu albacora,* migrates to the Mauritanian coast in waters above 22°C and thrives in those at 23°C. With global warming this fish may not longer migrate to the Mauritanian waters.

In the case of the demersal species examples can be found where global warming can lead to a disappearance of some species from the region's waters, e.g. the croakers found in the littoral and below the thermocline where

The joint Soviet-Sierra Leone oceanographic cruises in Sierra Leone waters in the past two years (1987/88) have reported a warming up of the waters and a change in the composition of the fish stocks but longer term data are required before any definite inferences can be made concerning the short-term trends.

8. IMPACT OF CLIMATE CHANGE ON SOCIO-ECONOMIC ACTIVITIES AND STRUCTURES

8.1 CLIMATE CHANGE , AGRICULTURE AND LIVESTOCK PRODUCTION

Crop and livestock production and development in the region depend on climate. In the WACAF Region the following climatic parameters are particularly important:

(a) Air temperature;
(b) Rainfall;
(c) Relative humidity;
(d) Radiation; and
(e) Windspeed.

Although temperature and rainfall are the most important variables, all five acting together determine distribution and yield of crops and population of livestock. Changes in the above climatic characteristics will therefore affect agriculture and livestock production. Among the important expected climate changes that will directly or indirectly affect crop and animal production in the West and Central African Region are the following:

(a) Increased rainfall and rising temperatures;
(b) Increased variability and droughts and longer runs of either wet or dry years;
(c) Changes in agro-climatic zones and poleward shifting of agro-ecological zones; and
(d) A rise in sealevel which is expected to accompany the change in climate.

The above climate change will affect crop and livestock production through their effects on changes in:

(a) The period of the potential growing season and changes in plant growth rates resulting in changes in required growing period;
(b) Crop yield and variability of yield;
(c) Level of crop certainty;
(d) Yield quality; and
(e) Sensitivity of crops to differing levels of application of fertilizers, pesticides and herbicides.

Increased rainfall and rising temperatures

Increased rainfall will give rise to increased crop production in the West and Central African Region. Staple crops like maize, sorghum, millet, rice, cassava, plantain, yams, cocoyam and tree crops such as palm oil, citrus, avocado pear, coconut, cocoa and rubber are likely to achieve or be close to achieving their full potential yields. Grass and fodder legume production will also increase. The level of yield response to higher precipitation will however, not be the same for all crops. The level of yield response of crops such as banana, plantain, cocoyam and upland rice whose water requirements are greater will be higher than that of maize, sorghum and millet with lower water requirements.

High rainfall may however, render some areas less suitable for the cultivation of crops which are grown at present. For instance, in parts of tropical rain forest zone of the equatorial climatic zone, increased rainfall will render near neutral soils acid, rendering them less suitable for the cultivation of traditional crops like cocoa. Palm oil and rubber rather than cocoa may be more economically grown in such areas. Increased rainfall may also render parts of the Guinea savanna zone of the north and south Arid zones too humid for the cultivation of crops such as millet and sorghum.

Increased rainfall may also lead to increased leaching of soil nutrients rendering them less productive. Thus the already low nitrogen and phosphorus contents of the soils of the region will be further lowered. This will call for the application of mineral and/or organic fertilizers and drastic modification of soil and crop management practices.

lead to rapid growth and maturity of grasses rendering them less nutritious and less palatable. The lowering of the feed value of forage plants will adversely affect livestock production.

Increased humidity and temperature will create more favourable conditions for rapid multiplication of pests such as mosquitoes, tsetse fly, ticks, fungi and weeds. Malaria may reach epidemic proportions in many areas. Trypanosomiasis amongst livestock and sleeping sickness among humans will increase. And temperature- and humidity-sensitive plant diseases and weeds may increase to cause greater economic losses. Crop and livestock husbandry practices will have to be intensified and improved otherwise food and livestock production will be drastically reduced.

Variability in rainfall and temperature

Climate change in the tropics is expected to result in greater variability in rainfall and temperature both within seasons and between years with more frequent floods and droughts and longer runs of wet and dry years. The greater variability in rainfall and temperature will give rise to more frequent changes in agroclimatic zones. This will increase the variability in yield of crops in the different ecological zones. During wet years marginal areas with fragile soils unsuitable for arable farming may be brought under intensive cultivation rendering them more susceptible to desertification during periods of drought.

Frequent floods and long wet periods may cause some hardships, e.g. reduced yields, flooding of irrigated lands, etc. However, they will create more favourable conditions for crop production. They are likely to give rise to higher yields of crops in most areas. More frequent droughts and longer dry periods on the other hand will have adverse effects by decreasing food and livestock production. The effects of the recent droughts in the Sudan and Sahel zones give us a fairly good idea of what will happen under these conditions. If effective measures are not taken to ensure food security, famine due to crop failure, will cause untold suffering and inflict death on man and livestock as well as wildlife.

The long periods of drought will be characterized by higher temperatures, light intensities and moisture stress, which will necessitate a shift in emphasis to the cultivation of crops that will grow and give relatively high yields under the above conditions. Thus C_4 plants such as maize, sorghum, and millet may be more widely grown rather than C_3 plants such as cassava, sweet potato, beans and rice.

This is due to the fact that C_4 plants:

(a) Grow better under prolonged dry conditions;
(b) Have the ability to maintain photosynthesis at a high level despite relatively low carbon dioxide concentrations caused by reduction in stomata opening resulting from moisture stress;
(c) Have high assimilating rate at high radiation intensities - about twice as fast as C_3 plants;
(d) Have a higher temperature optimum; and
(e) Have higher water use efficiency - about double that of C_3 plants.

The long dry periods will give rise to drastic reduction in the yield of grasses. Thus livestock that are browsers e.g. camels, donkeys and goats rather than sheep and cattle will have to be reared on a larger scale.

Change in agro-ecological zones

Climate change could result in a shift polewards of agro-ecological zones of between 200 - 700 km (FAO 1988). In the West and Central African Region, the arid areas of West Africa may move northwards into the Sahara desert while that of Central Africa may move southwards. Due to the more favourable climatic conditions, especially increased rainfall, the land area suitable for crop production may increase. Thus parts of the Sahel zone now unsuitable for crop production could be brought under cultivation.

The shift in agro-ecological zones is likely to affect the distribution of crops. For instance, in West Africa, areas suitable for the cultivation of maize will extend northwards into areas hitherto unsuitable for growing of this crop. The plantain, banana, cassava and tree crop belts may likewise extend northwards, while the millet and sorghum belt could also shift northwards.

The shift in agro-ecological zone is likely to affect ruminant livestock production in the north and south arid increased humidity could provide the habitat requirements for the invasion and multiplication of tsetse flies. This will lead to increased infestation of these insects which carry the trypanosome parasite, the biggest single obstacle to ruminant livestock production on a permanent basis in most parts of the region. Thus parts of the Sudan and Sahel savanna zones may be rendered unsuitable for non-trypanosome-tolerant breeds like the White Fulani or Zebu cattle at present reared there. Trypanosome-tolerant breeds like the N'Dama, a less productive breed will then have to be introduced into these zones. The above changes will have major social and economic implications and consequences.

Bush fires and the long runs for wet and dry years

The savanna of the West and Central African Region are fire pro-climax. Their presence is due to the annual burning of the vegetation. Burning is possible because of the unimodal rainfall pattern. During the wet season relative humidity is high and the vegetation is wet and does not burn when set on fire. On the other hand, in the dry season, relative humidity is low, the vegetation is dry and therefore highly combustible especially from the middle to the end of the dry season. Burning at this time of the year is therefore harmful to seedlings and young trees and generally retards the growth of woody vegetation and encourages the growth of grasses. Thus a grass savanna vegetation is created.

The long runs of wet years alternating with long runs of dry years may create conditions similar to those existing in the unimodal rainfall/ecological zones. Due to the favourable conditions for plant growth during the long wet periods, there may be an accumulation of a large amount of biomass. This will dry up into a highly combustible material during the long dry periods and thus considerably increase the fire hazard. Burning will produce very hot fires that will do great damage to trees, shrubs and even herbaceous vegetation which may also become degraded creating desert conditions in the Sudan and Sahel vegetation zones.

The effects of past hot and fierce fires that have swept through the forest and savanna areas of the countries in the West and Central African Region support the above view. Although in most areas the original forest and savanna vegetation have regenerated, other areas with shallow soils, hill sides and other marginal areas have yet to recover. Cultivation and burning in the marginal areas are gradually turning the vegetation into poor forests, scrub land or savanna.

Increased carbon dioxide concentration

The effects of expected climate change on forests and crops would be compounded by increased CO_2 concentration in the atmosphere. For instance, increased CO_2 concentration accompanied by high temperatures and rainfall in the West and Central African Region is likely to lead to faster vegetation growth, denser vegetation and bigger trees which may reduce CO_2 concentration in the atmosphere. It has been reported that the doubling of CO_2 concentration is likely to increase the growth of C_3 and C_4 plants by 10-50 and 0-10 per cent respectively. Thus three of the most important staple crops of the West and Central African Region - maize, sorghum and millet which are C_4 plants - are likely to face more intensive competition from C_3 weeds. The same may be said for sugarcane, an important cash crop and several forage grasses. On the other hand rice, a C_3 staple widely grown in the region, may be better protected from weeds since 14 of the world's most noxious weeds are C_4 plants and may not respond to carbon dioxide as vigorously as rice.

Laboratory studies have indicated that food quality tends to deteriorate as CO_2 levels increase. This is likely to increase the cost of food storage. Studies have also shown that leaves became richer in carbon and poorer in nitrogen and pests have to consume more in order to gain the required nitrogen levels thus causing greater damage in a carbon-rich environment. Farmers may also have to use higher levels of fertilizers due to the faster growth of crops. This may call for increased inter-cropping with nitrogen-fixing legumes in order to reduce the use of purchased nutrients.

Rise in sea level

As a result of the warming of the atmosphere, there would be an accelerated rise in sea level of 20-140cm before the end of the twenty-first century. This will profoundly affect the flora and fauna of the West and Central African Region. It will also affect agriculture and livestock production as well as wildlife. The area under the influence of flooding will enlarge. That under mangroves may be extended landwards especially in the Sine Saloum, the

The areas of saline soils may increase making them unsuitable for the cultivation of crops like maize, banana, pineapple etc. Coastal plantations are likely to suffer from salinization.

8.2 EFFECTS ON FISHING

There are indications that anticipated sea-level rise would affect aquatic life especially in brackish waters. The change in water level, when it occurs, is likely to upset the breeding habits of some fish already used to existing habitats while new species may or may not survive in the new environment. It is also expected that by possible reduction in upwelling in areas such as Mauritania and Senegal, certain types of fish production will be reduced.

It is therefore, argued that many coastal areas of the region would suffer loss of their usual fishing activities. This would, in all probability, spread to the surrounding populations that are largely dependent on the sea areas for their fish supply. Such a loss would deplete the protein intake of the people and consequently lower their resistance to diseases.

The alteration in the fishing activities of the coastal people would most likely involve some change in their fishing technology. For instance, increase in water level might result in the need for fishermen to devise more durable and probably more sophisticated nets than had existed hitherto. Furthermore, it might require changes in the methods of catching different species of fish that would be found in their waters. Such changes will require time and training. They will also require money and a basic change in habits and traditional ways of doing things. These are difficult to achieve without taking seriously the warning on possible adverse effects of climate change and making adequate preparations to mitigate them.

8.3 EFFECTS ON OTHER SOCIO-ECONOMIC ACTIVITIES

Climate change and sea-level rise would also have significant implications on the sectors of socio-economic activities in the WACAF region. Indeed, such a situation would destabilize the already shaky and fragile economy of the region. Among the socio-economic activities that would be affected are transportation, commerce and industry, tourism and recreation.

Transportation

Generally, the big cities located near the coastline are major road and railway termini as well as the main sea and air ports of their countries. Consequently they handle a large proportion of their countries' transportation and freighting needs, and serve vital economic, social and communication functions. In some countries, the economic life of the nation would virtually come to a standstill if coastal towns or cities were closed to traffic for a few days. This is true of Douala (Cameroon), Abidjan (Cote d'Ivoire), Lagos (Nigeria), Dakar (Senegal) and Lome (Togo), to mention but a few of such cities.

Given the strategic positions of these cities in the economic life of their countries, it is very likely that if there is sea-level rise which adversely affects their transportation system, there would be chaos as the movement of goods and people would be badly undermined. Put differently, if the nations are caught unprepared and suddenly find much of their railway lines, roads, ports and airfields washed away the destruction might be such as would require decades to rectify.

Commerce and industry

It has been earlier stated that as a result of colonial legacy fueled by the preferences of successive administrations during the post-independence era in most countries in the region, a disproportionate percentage of commercial and industrial concerns are located on, or near, the coast.

Accelerated retreat of the coastline and increased incidence of flooding would have a disruptive impact on commercial and industrial activities. Most businesses might be forced to relocate with attendant economic and human misery. In cases where a high level of investments makes it impracticable to relocate, costly shore protection measures would need to be put in place.

In certain instances, commerce and industry are shore-based on account of their proximity to the sources of raw materials which are in the coastal zone. Examples are the seafood processing factories and the plywood and from the coastal swamps and nearshore areas. The inundation of coastal swamps would mean shutting off productive wells which can have an effect on the consumption and export patterns of countries in the region.

Tourism and recreation

It is obvious that the tourism and recreation industry in the region is in a fledgling stage in spite of the huge potential it has as a foreign exchange earner. An accelerated rise in sea-level would considerably reduce the extent of the generally narrow beaches in the region. For an industry that thrives on the existence of fine beaches, the implication of worsening erosion and flooding consequent upon sea-level rise would be negative and enormous. The few facilities that are already present are very close to the shore and would be lost; this would aggravate the problem to the industry posed by a lack of appropriate tourist infrastructure. Concomitant increase in pollution of the beaches will render those strips of beach that are left unusable or unsafe.

The next impact is indirect but no less crippling. Governments in the region, faced with solving the problems associated with the expected increase in sea-level in addition to existing problems will be sufficiently distracted to prevent them putting money into a sector of the economy generally perceived by the populace at best as "upper class" or at worst "irrelevant". This will deal a shattering blow to present attempts on the part of governments in the region to inject more money into the industry for its development.

9. IMPACT OF CLIMATE CHANGE ON POPULATION PROCESSES AND HUMAN SETTLEMENTS

9.1 DISLOCATION AND RELOCATION

Unfortunately, given the settlement locations of the various towns and villages of the WACAF Region, these are the areas that would be seriously affected in the event of expected climate change. The effects of sea-level rise may not be equally spread across all the areas. Human settlements such as Abidjan, Banjul, Cotonou, Freetown, Lagos, Lome and Monrovia, which are coastal, stand the greatest risk of flooding consequent on sea-level rise. The many socio-economic structures located in these cities will also be threatened.

In Opobo town (Nigeria) for instance, a football pitch and the surrounding grounds which were in active use not quite twenty years ago are now under water. Even the recent concrete embankment that was constructed could not save much of the lost grounds. Similarly, in Banjul (Gambia) both the Muslim and Christian cemeteries are being lost through marine erosion. In Monrovia (Liberia) the prestigious OAU village is being encroached upon by the sea. In Lome (Togo) a magnificent holiday resort, Tropicana Hotel, is under threat from repeated flooding by the sea.

Many residential areas along the WACAF coastal region which do not have great economic investments may also need relocation in the event of a substantial rise in sea level. These include the many creek towns and villages where settlers are literally living on the water. Their houses, usually of thatch, are on wooden stilts and can easily be washed away. People in these locations should, as a matter of right, be made aware of the impending sea-level rise which would most certainly involve their relocation if loss of life is to be avoided.

Relocation of such people involves loss of their homes and land, since the inundated areas would be abandoned and new acquisitions in other areas would need to be negotiated for resettlement. This is neither an easy process for the governments nor for the people being resettled. Where the receiving community is already congested, absorption of the newcomers might create a host of social problems. These may include hostility and suspicion between the existing and the in-coming communities.

It has been extensively documented that those who leave their communities suffer considerable social discomfort apart from the obvious economic costs. For instance, native Africans tend to be sentimentally attached to their homesteads especially if those homesteads house the graves of their ancestors. Movement away from such lands creates frustrations and feelings of estrangement. If the movement is permanent, as would be the case for many coastal peoples if there is significant sea-level rise, it would take a long time for the evacuees to settle down in their new locations.

Part of the problem of settling down, no doubt, would be economic. For example, resettling riverine peoples entirely new way of life which is not at all easy. Indeed, history is replete with the stories of relocated communities that did not fare well even where the state had intervened with sizeable resource inputs and aids.

9.2 NORMS AND VALUES

As was implied earlier, communities develop sets of norms and values that relate to and regulate their way of life especially with regard to their economic activities. They socialize their citizens into those complex codes of conduct which are intended to guide their people to conform to societal demands. Such cultural patterns of behaviour tend to be localized. That is, they apply to specific groups of people. In the event of dislocation from the group's cultural base and resettlement in other places, the resettled people would most probably suffer cultural shock. This, they would have to adjust to while modifying their cultural heritage to accommodate that of their new location.

Obviously, it is not everybody who can effectively and adequately adjust to new ways of life. Those who fail to do so would be seen as deviants. Generally, they would constitute a socially difficult group to deal with. They would thus, become another source of social disharmony to the host community that is already saddled with its own varied problems.

Though cultural issues such as those discussed above may not be seen by some as direct consequences of climate change, particularly of sea-level rise, there is no denying the fact that they constitute serious resettlement problems for both the incoming and existing communities. In view of this interrelationship between climate and some cultural aspects of a people's life, there is a need for proper planning by policy makers in order to minimize the expected impact of climate change for displaced persons.

9.3 HEALTH CONCERNS

Another major area which deserves emphasis is the health implications of climate change. Increase in temperature will have largely detrimental effects on people and livestock in areas most severely affected, in the hot tropical coastal areas of the WACAF Region where the incidence of sunburn, heat stroke, heat rashes and other skin blemishes will increase. Furthermore, it is argued that with ozone depletion, the incidence of skin cancers would most probably increase.

Similarly, it is feared that livestock might suffer from many heat-related diseases. Temperature increase would not only reduce the number of livestock due to water shortage and heat stress, but would in all probability precipitate the occurrence of animal diseases for the surviving ones. Thus, for both human beings and livestock, increase in temperature would mean reduction in well-being.

10. STRATEGIES FOR ADDRESSING CLIMATE CHANGE AND ITS IMPACTS

Higher atmospheric temperatures and increased sea-level rise as a result of climate change are realities that humanity has to cope with both now and in the future. It is thought that even if all measures suggested to stop the further introduction of greenhouse gases were put in place now, the world would still experience a lot of the anticipated impacts due to the time lag in the response of the ocean and climate system to CO_2 concentration in the atmosphere.

In planning strategies for tackling the problems created by climate and climatic variations, it is important to note that both gradual climate change influenced by CO_2 and the other greenhouse gases are of significance particularly to the WACAF Region. In order to mitigate or eliminate the effects of adverse impacts, simultaneous planning and design to cope with the two aspects of climatic variations and change must be made. For the long-term climate change caused by carbon dioxide and the other gases, two sets of strategies may be recognized, including: (a) strategies for averting the change; and (b) strategies for mitigating the effects (Kellogg, 1987). In both these cases, the WACAF Region has a very important part to play.

10.1 STRATEGIES FOR AVERTING THE CHANGE

Measures to avert climate change induced by carbon dioxide and the other gases fall into three categories. These measures include: (a) those for reducing the demand for fossil fuels, especially by conserving and using

Strategies which involve reduction of demand for fossil fuels involve the use of conservation measures and alternative sources of energy. These measures are particularly important for developing areas like the WACAF Region because the relative contribution to the atmospheric flux of gases has been increasing since 1950. Reducing energy demand will reduce burning of fossil fuels. Reducing or banning bush burning, a common practice in the region and one which has increased recently because of the pressure to clear more land for agricultural use, will curtail this source of CO_2 input into the atmosphere. Technical solutions, which include those for controlling atmospheric concentration of carbon dioxide, are linked with world, regional and national energy policies, forest management and personal and societal values. Examples of such solutions are those for controlling carbon dioxide at their sources, for example through measures for controlling the production and use of coal and petroleum, controlling emissions from power plants or at the point of combustion. This may involve a complete social change through a centralizing complex, large-scale production facilities and converting the societies to an all-electric economy.

The third category of measures for averting the changes involves increasing biomass production including afforestation. This measure will serve as a natural sink which will absorb carbon dioxide. Cooper (1978) for example noted that an increase of just one per cent in the plant life on earth especially forests, would be sufficient to absorb one year's release of carbon dioxide at the present rate (Kellogg, and Schware, 1982). The tropical areas in general, and the WACAF Region in particular, are of significance in this regard because of the need to reduce the rate of deforestation and reforest the deforested areas. However, it is also important to note that reforestation implies ecological changes and climate change may limit these opportunities.

10.2 STRATEGIES FOR MITIGATING THE EFFECTS

The second group of measures for addressing the problems of carbon dioxide-induced climate change are those for mitigating the effects of these changes. Such measures include those that protect ("protective" also called "preventive" options) and those that would help to increase man's resilience to impacts of climate change ("adaptive" options).

In relation to sea-level rise, there will be a need to protect heavily built-up areas with high value installations and population densities where the option of relocation is not a reasonable economic proposition. But there is a snag here in that many of the engineering countermeasures which are feasible for shoreline protection in the face of sea-level rise are economically impractical in view of the financial disabilities of most countries in the region. The approach here should be towards the adoption of low cost, low technology, but effective measures such as permeable non-concrete floating breakwaters, artificially raising beach elevations, installation of rip raps, timber groynes etc. from locally available materials. Similar measures can be employed in the protection of important arable lands. Fortunately, outside of the urbanized centres, the coasts are in almost pristine condition and largely uninhabited except perhaps for small fishing settlements which in any case, are highly mobile in disposition. In such situations, resettlement of existing populations and the enforcement of set-back lines for any new developments on the coast should be applied. Where coasts are deemed highly vulnerable a total ban on new development is necessary.

Strategies for increasing resilience to the impacts of climate change include the protection of arable soils, improvement of water management, application of agrotechnology, improvement of land use policies, maintenance of food reserves and the introduction of disaster relief measures. In the WACAF Region, the loss of arable soils through erosion and salinization has been tremendous in recent years. This has been due to poor management practices, overgrazing and poor agricultural practices. These in turn have led to desertification, a process which has been accelerating because of the relative persistence of droughts in the region as already noted. Improved water management techniques, for example, through building of dams, aqueducts, reservoirs, irrigation systems and diverting rivers, which can provide adequate and reliable water supply in times of drought, and which can protect against river flooding are all measures which can increase resilience to climate change and variability.

The application of agrotechnology is of particular importance for increasing food production. This measure is of great significance in the WACAF Region where some of the nations are characterized by monocultures that account for most of their food production, and which unfortunately are generally more susceptible to both short- and long-term climatic variations and changes than areas with diversified crops. Thus, the region needs to develop agrotechnology such as more efficient irrigation systems, salt water crops, higher temperature-tolerant varieties of plants and animals, new forms of nitrogen fixing plants and plants that would be adapted to changing climates or climatic variabilities in the region.

Improved coastal land use policies, other measures that could mitigate the effects of climate change and expected, for example, that a future sea-level rise would increase flooding and other environmental hazards. It is therefore important that it should be one of the factors to be considered in planning, which might for instance provide for the conversion of flooded agricultural lands to aquatic uses such as mariculture. By its nature, methodology, process and regulations, urban and regional planning offers the greatest scope for incorporating land use policies.

Maintenance of food reserves and provision of disaster relief are other measures which could mitigate the effects of climatic variations and climate change. The WACAF Region, like any other part of the world, requires a reliable food supply and since any future variations and change in climate could adversely affect food production in the region, it would be prudent to be prepared with adequate food reserves (Kellogg and Schware, 1982; Schneider and Mesirow, 1979) even though countries in the region are far from meeting their present food requirements. Much can also be achieved through provision of disaster relief, as is now being done by international organizations, to help the countries adversely affected by the recent climatic variations. Advanced readiness may mean all the difference between survival of large populations and calamity.

Other strategies for mitigating the effects of increased atmospheric carbon dioxide include measures involving conservation of energy, use of renewable energy resources and reforestation. Other strategies are those that lead to improved choices. Such measures include those employed for: (a) environmental monitoring and warning systems; (b) providing and applying improved climatic data; (c) providing public information and education; and (d) the transfer of technology. On the global scale, the acquisition of climatic data and the global monitoring of the environment are functions of international bodies such as the World Meteorological Organization (WMO). But on the national and regional scales meteorological and water resources development institutions are expected to provide meteorological and water resources data and information as well as assistance in public information and education. Unfortunately, the provision of climatic and water resources data is difficult in the WACAF Region. For example, in many of the WACAF countries, a basic problem is that climatic and other climate-related data are available from a variety of sources not always known to scientists interested in climate application and impact studies. Many of the data are, for example, held by agencies other than meteorological, hydrological and oceanographic service units. Part of the data are scattered in libraries, record offices and in most cases, they are incomplete, inaccurate and of no use for meaningful research or impact studies. Also, there are always the problems associated with administrative bureaucracy which have long been recognized in many of these countries, but for which no solutions have been found.

Added to the problems associated with the characteristics of the sources where the necessary data can be found are problems related to inadequate networks of meteorological stations and coverage of the data. For example, in Nigeria, average rain gauge density is only about one guage per 900 km^2, in contrast to the situation in Europe where the density is usually one gauge per 50 km^2. The situation is even worse for other climatic parameters such as evaporation, and solar and net radiation, for which there are fewer stations that measure them. The need to provide appropriate data acquisition infrastructure in the countries of the region is overwhelming, which would bring the provision of regional climate change scenarios closer to reality. This will provide an appreciation of the problem of global climate change at the regional level and lead to more realistic and fruitful proposals for dealing with the problem.

The provision of public information and education will allow the population to become fully aware of the ecological effects and socio-economic impacts of development, climate change and climatic variations. For this measure, it is important to ensure wider participation of the population in the preparation, implementation and evaluation of the programmes aimed at combating the consequences of climatic events resulting from climate change. It is also important to consider the cultural heritage and leanings of the different groups in finding solutions to the problems created by climate change.

It seems a fairly evident proposition that the solution to most of the WACAF Region's economic, social and ecological problems arising from the consequences of climatic variations and climate change depends to a large extent on the transfer and the application of science and technology. For example, immediate investment in applied climatology and weather and climate prediction techniques is highly desirable in the WACAF countries. There is also a need for investment in the transfer and use of appropriate adaptive technology in areas such as agriculture, water supply, energy resources, fisheries, forestry and land use planning.

Most of the above discussed measures are significant, not only for long-term changes in climate, but also for short-term climatic variations. Even if climate change or climatic variations did not occur, the measures would

11. CONCLUSION

In the past, the coasts of the West and Central African Region were often exclusively used for agriculture, animal husbandry, fisheries and trade. However, there has been the more recent establishment of industries, transport terminals, military installations and residences as well as recreational areas along the coastal fringe. The economic, social, strategic and recreational values of the marine environment and coastal areas have risen so highly over the years that competition for more intensive land uses has also increased. Periodic variations in climatic conditions have exposed the WACAF coastal environment as well as human activities and structures to insecurity and destruction. A future climate change that leads to warming of the earth and rise in sea level threatens great danger for the coastal areas and marine environment of the WACAF Region. The enormity of the various expected impacts dictates that great adjustments be put in place to make the coastal zone habitable and to preserve its important role in the socio-economic development of the region.

Given the financial disabilities of these countries in the region, only well planned anticipatory actions by these countries would ensure that much stress, hazards and resource losses would be avoided or minimized as the expected changes occur. It is hoped that governments in the region, while pursuing policy options at the national level, would appreciate, even more than ever before, the distinct advantages for a regional approach to the problems associated with global warming. The Abidjan Convention (April, 1981), signed under the auspices of UNEP's Regional Seas Programme for the West and Central African Region provides a vantage platform for discussing and institutionalizing a regional plan of action to address expected climate change in the region.

Looking beyond the need to package anticipatory and reactive actions for the impending effects of the global climate change, it is pertinent now, as it always was, to call for an end to the present "crisis management" approach to solving problems of environmental degradation in the region's coastal zone.

As has been emphasized repeatedly by various authors the coast is not only a wasting resource composed of various fragile ecosystems, it is also a zone for a wide variety of often conflicting uses. The inherent attraction of some uses of the coastal zone can also be a source of environmental degradation. Resulting conflicts are sometimes difficult to solve unless institutionalized frameworks exist. The need is therefore urgent for countries in the region to establish coastal zone management policies. Such policies should state clearly not only the concerns of the countries for rational coastal zone development but also the controls and procedures to be applied in the future in coastal areas.

In this regard, inspiration and lesson can be drawn from the prevalent practice in the industrialized countries where, despite a wide variety of existing urban and regional controls to reduce the tremendous pressure on the use of coastal areas, specific laws have been passed to give greater precision to the legal status of shoreline management and control. The Coastal Zone Management Act of 1972 in the United States of America and the Decree No. 79-716 of 17 August 1979 in France, are particularly instructive.

For the region, the broad objectives of Coastal Zone Management policies should be to:

(a) Evolve and implement regionally sound coastal protection measures;
(b) Stop the haphazard urbanization of shorelines. This calls for the establishment of set-back lines in front of which no settlements or facilities should be located;
(c) Preserve the ecological characteristics of non-urbanized areas including agricultural, as well as wild sections of the coastline. This requires a ban on the mining of any mineral resources, such as sand or gravel, from the shore, except in designated quarries. This is vital in marine areas used for aquaculture/mariculture, all mangrove swamps, marshes and tidal flats which should remain in their natural states. Where development is imperative (e.g. dredging for access to oil locations), proper environmental impact assessments should be carried out prior to execution of the job. In fact, extensive anti-pollution measures are called for under this objective; and,
(d) Promote sustainable development of the coastal zone. Such Coastal Zone Management Policies are essential for comprehensive and long-range coastal management planning in the region. They would hopefully sow the seeds for the rational control of hazards in, and the equitable development of, the coastal zone in the WACAF Region.

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APPENDIX I

Written Contributions by Task Team Members which formed background materials for this Overview

Ajayi, T.O. and Findlay, I. Aquatic living resource and climate change in the WACAF Region.

Akle, M. Some Aspects of the predicted impacts of climatic change in West and Central African Region in Site specific study in Queme Estuary in Benin Republic.

Akle, M. Some aspects of climatic change in connection with drought and desertification occurring, case study in West and Central African region.

Asare, E.O. Implications of expected climatic change in the WACAF region: Implications for Agriculture, Livestock and Forestry.

Awosika, L.F. Coastal Geomorphology and implication of Sea level rise in the West and Central African region.

Egunjobi, R.O. and Ogbuagu, S. Urban and regional planning in the light of expected climate change.

Findlay, I. and Ajayi, T. Ocean Dynamics and climate change in the WACAF region .

Ibe, A.C. The Niger Delta and the accelerated global rise in sea level.

Koffi, K.P., Zabi, S.G. and Abe, J. Embouchwedu Bandama. Variations morphologiques et processus sedimentaires

Niang, I. The Senegal delta.

Ogbuagu, S. Anticipated impacts of climate change on the socio-economic structures of the covered areas of the West and Central Africa Region

Ogbuagu S. and Egunjobi, T. Implications of climatic change for the population of the West and Central Africa region.

Ojo, S.O. Climatic Changes in the West and Central African region: past, present and future.

Ojo, S.O. Droughts and climatic changes in the West and Central Africa Region.

Ojo, S.O. Desertification and climatic changes in the West Central African Region.

Ojo, S.O. Impact of climate on energy resources and utilization in the West and Central African Region.

Zabi, S.G. Major ecological trends of the benthic microfauna of the lagoons in regard to climatic changes in the West and Central Africa Region.

Zabi, S.G. An overview of the coastal lagoons morphogenesis in the West and Central African Region: Case -study of the Ebrie Lagoon (Côte d'Ivoire).

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