



The vulnerability to climate change of Cotonou (Benin): the rise in sea level

KRYSTEL M R DOSSOU and
BERNADETTE GLÉHOUEYOU-DOSSOU

Krystel M R Dossou holds an MSc in agronomic engineering and is an agricultural socioeconomist. He is Coordinator of the Energy and Environment Programme at the Organisation des Femmes pour la Gestion de l'Énergie, de l'Environnement et la Promotion du Développement Intégré (OFEDI). He is also a CLACC Fellow (Capacity Strengthening of Least Developed Countries for Adaptation to Climate Change – CLACC) in Benin.

Address: e-mail:
krystod7@yahoo.fr and
krystod@gmail.com

Bernadette Gléhouenou-Dossou holds a Doctorate in forestry and an MSc in rural development. She is a Lecturer and Researcher at the Faculty of Agronomic Sciences (University of Abomey-Calavi) and President of OFEDI. She is currently the Head of General Direction of Public Environment in Benin.

Address: e-mail: bebe_dossou@yahoo.fr

ABSTRACT In Benin, like most other coastal nations, a high proportion of the population and the largest city are on the coast. In Benin's case, half the nation's population (over 3 million inhabitants) is on the coast and in the city of Cotonou, in the Gulf of Guinea. The coastal location is important to Cotonou's economy but the coastal region is vulnerable to sea-level rise, with potentially catastrophic impacts on the economy, the population and natural systems. The continued advance of the sea, coastal erosion and the rise in sea level, exacerbated by human activity on the coast, have medium- and long-term consequences that are already threatening vulnerable communities and disrupting the least-protected sensitive ecosystems. This paper focuses on the erosion of Benin's coastal region, and analyzes biophysical and socioeconomic vulnerability to the rising sea levels and coastal erosion affecting the city of Cotonou and its coastal plain; it also discusses the ways in which vulnerability could be reduced.

KEYWORDS adaptation / Benin / coastal erosion / Cotonou / urban development / vulnerability

I. INTRODUCTION

Climate change has an impact on the development of West African cities like Cotonou, which are located right on the coast. Cotonou's vulnerability to rising sea levels and exposure to coastal erosion currently threaten the city's economy and development as well as the coastal and lagoon ecosystems. This vulnerability is exacerbated by the socioeconomic and political constraints affecting the city, especially rapid demographic growth and inadequate resources for urban development. This paper examines the potential and actual effect on the city of the rise in sea level, and considers what possible adaptations could reduce its vulnerability to the effects of climate change.

II. COTONOU

Cotonou is the economic capital of Benin and one of the largest cities in West Africa, with a population now in excess of one million. The city is located on the coast of Benin, which stretches for 125 kilometres between Nigeria to the east and Togo to the west, and extends for 79 square kilometres on either side of the Cotonou Lagoon (Map 1). Lake Nokoué lies

to the north, covering 200–300 square kilometres, the Atlantic Ocean is to the south, Godomey to the west and Agblangandan to the east.

The coastal strip on which Cotonou is built is composed of alluvial sand with a maximum depth of four metres. The strip's relief features longitudinal depressions parallel to the coastline and swamps (valley bottoms) fed by rainwater. The channel⁽¹⁾ (or Cotonou Lagoon) links the sea with Lake Nokoué, and divides the city into two unequal parts (Map 1). According to the National Statistics and Economics Institute, in 1992 Cotonou had a population of 536,826 inhabitants; in 1998, it had an estimated 850,000 inhabitants and in 2005, an estimated 963,031 (this included the western and eastern extensions of the city).⁽²⁾

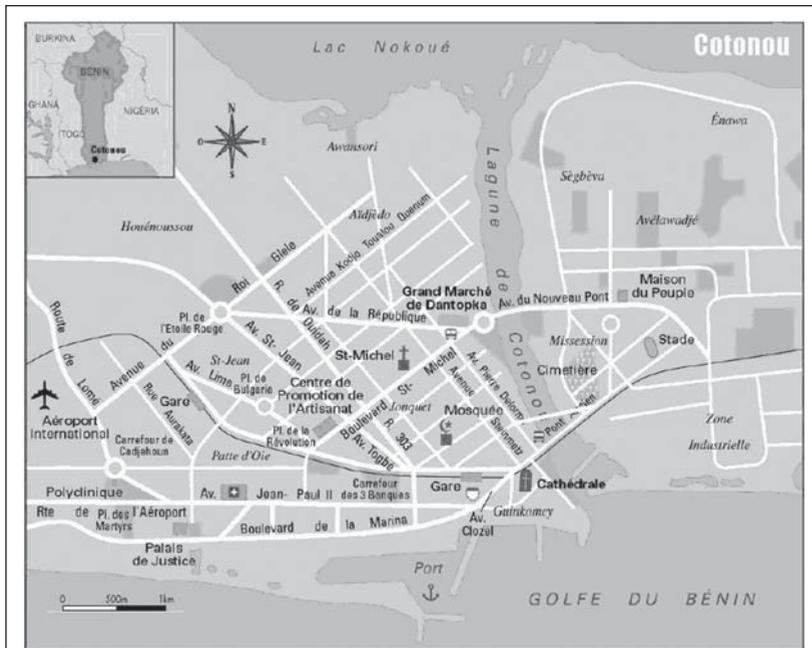
Cotonou has a sub-equatorial climate with two rainy seasons (April to July and September to November) alternating with two dry seasons (December to March and August). The sea ensures a mild climate, and average temperatures in the city (around 27°C) do not vary very much. There is an average of around seven hours of sunshine per day. Relative humidity is almost constant (around 85 per cent) due to the influence of the sea. The city receives an average annual rainfall of 1,309 mm (calculated over 40 years, 1945 to 1995). The prevailing coastal winds are southerly, with speeds of around 3–7 metres per second. The tide cycle is approximately 12 hours and the height range generally around one metre.⁽³⁾

Benin's economic potential depends to a large extent on that of Cotonou, which hosts a large number of tertiary sector activities and trading centres of international importance, as well as supplying financial

1. The lagoon (channel) was dug under French colonial rule in September 1885.

2. Institut National de la Statistique et de l'Analyse Economique, Cotonou, database accessible at www.insae-bj.org

3. Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU) (1998), "Profil de la zone côtière du Bénin", MEHU, Cotonou, 109 pages.



MAP 1
The city of Cotonou

SOURCE: Scanned from road map.

4. Local currency, equivalent to around US\$ 700 million.

5. Laboratoire d'Analyse Régionale et d'Expertise Sociale (LARES) (2001), "La problématique de l'intercommunalité dans le fonctionnement des communes béninoises", Coopération Suisse, 245 pages.

6. FAO (2004), "Profil de la pêche au Bénin", accessible at <http://www.fao.org/fi/fcp/fr/BEN/profile.htm>.

7. Voglozin, A (1999), *Etude des Problèmes Liés à la Circulation Urbaine: Aspects Organisationnels, Institutionnels et Économiques*, Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU), Cotonou, 30 pages.

8. Groupe Intergouvernemental d'Experts sur le Climat (GIEC/IPCC) (2001), *Bilan des Changements Climatiques: Rapport de Synthèse*, Cambridge University Press, Cambridge, 205 pages.

9. Bokonon-Ganta, E (1999), "Vulnérabilité et adaptation du secteur santé – établissements humains – littoral au changement climatique", Université Nationale du Bénin/ Faculté des Lettres, Arts et Sciences Humaines, 54 pages.

10. MAGICC has been the primary model used by IPCC to produce projections of future global mean temperature and sea-level rise. The climate model in MAGICC is an upwelling–diffusion energy

resources to the country and the municipality. Activities undertaken in the city are essentially non-agricultural (apart from inland fisheries), particularly along the coast and the city's major roads, where activities are primarily commercial and services-oriented. This dynamism is facilitated by infrastructure, including the port of Cotonou and Dantokpa international market. Cotonou's self-governing port accounts for 90 per cent of the country's customs receipts, while Dantokpa market has an annual turn-over of 350 billion Francs CFA.⁽⁴⁾ This market is the trading hub of West and Central African countries and Benin. In addition, service and craft production activities in the city, tourism, transport and small trades (artisan services) produce substantial income.⁽⁵⁾

Coastal fishing is also a mainstay of Cotonou's economy, providing a livelihood for more than 15,000 people (those engaged in fishing and also associated jobs such as fish wholesaling and boat repairs). Traditional fishing is undertaken by people of different ethnic origins (Toffin, Xwla, Aïzo, etc.) on Cotonou Lagoon and Lake Nokoué and on inshore waters (up to five nautical miles from the coast), as well as in the inter-dune depressions that are temporarily submerged at high tide. Authorized, more sophisticated foreign vessels also undertake industrial fishing on the continental plateau beyond the five nautical mile zone.⁽⁶⁾

The city of Cotonou is laid out in a conventional grid pattern and is divided into residential areas, administrative and social facilities, the military camp and industrial/commercial areas. The built-up area accounts for 74 per cent of the total area; 80 per cent of housing is located within the built-up area and constitutes 60 per cent of the city's surface area.⁽⁷⁾ The city has developed along an east–west axis because of the natural constraints imposed by Lake Nokoué to the north and the Atlantic Ocean to the south. The bulk of the population (around 75 per cent) is concentrated in the western part of the city. Environmental problems include air pollution, greenhouse gas emissions and water and soil pollution.

III. COTONOU'S VULNERABILITY TO SEA-LEVEL RISE

One of the main climate hazards facing Cotonou is the rise in sea level (or the net increase in the level of the ocean in relation to the level of local terrestrial movements). A GIEC/IPCC report predicts: "*The rising sea level... will have a detrimental effect on coastal human settlements, especially in the Gulf of Guinea...*"⁽⁸⁾ This prediction is very relevant to Cotonou, which has some areas that are at, or below, sea level. A rise in sea level could trigger a number of climatic phenomena such as coastal and riverbank erosion, flooding and salt water intrusion into Lake Nokoué. Furthermore, there has been decreasing rainfall in Benin, especially in the south,⁽⁹⁾ with precipitation decreasing by 9 per cent over 20 years in Cotonou. Each of these hazards undermines human systems (land use, livelihoods and human settlements) and disrupts the functioning of coastal and lagoon ecosystems.

According to climatic simulations based on increased temperature carried out by MAGICC,⁽¹⁰⁾ the sea level along the coast of Benin could rise gradually (according to IPCC scenario IS92a) between now and 2050 and 2100. Table 1 shows the basic, average and extreme scenarios.

TABLE 1
Assessment of the rise in sea level

Timeframe	Sea level rise (centimetres)	
	Year 2050	Year 2100
Average scenario	20	49
Extreme scenario	39	59
Basic scenario	7	20

SOURCE: Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU) (2001), "First national communication of Benin", UNDP, 76 pages. (This governmental paper was submitted to the United Nations Framework Convention on Climate Change. It described the inventory of processes emitting greenhouse gases in Benin and characterized the country's vulnerability to climate change.)

Table 1 shows a predicted rise in sea level in the medium term (2050, 2100). Although these are hypothetical scenarios, the predicted rise in sea level (based on temperature data recordings taken in Benin between 1961 and 1990) could impact quite heavily on human and natural systems, as noted above, and the figures show that urgent measures are needed in respect of preparedness, prevention and adaptation.

IV. IMPACT OF RISING SEA LEVEL

Rising sea level has many potential effects on natural systems and their operation as well as on human systems. These related phenomena reflect such climatic stresses as riverbank erosion, flooding, coastal erosion and salting up of lagoon waters, among others. Figure 1 shows clearly the consequences of a rise in sea level for Cotonou and its surrounding area.

These phenomena are already occurring, with serious consequences for the affected communities in Cotonou and its surrounding area as well as other coastal and lagoon areas.

V. COASTAL EROSION IN COTONOU AND THE SURROUNDING AREA

a. Definition of the most vulnerable areas and people

In Cotonou, the area most vulnerable to coastal erosion comprises the first and fourth *arrondissements* (districts of Tokplégbé, Finagnon, Donatin, Akpakpa-Dodomey and JAK) (Map 2). According to the 2002 census, the number of people affected in the threatened area of Cotonou is estimated at 94,425, around one-tenth of the city's population.

b. Overview of causes

The coastal erosion to which Cotonou and other places are exposed is a dynamic sub-regional phenomenon resulting from the disruption (by upstream (dams) or shoreline (ports) development) of the coastal currents carrying sand. In fact, the coast is subject to ocean swells of distant origin,

balance model that produces global and hemispheric mean output. IS92a is widely adopted as a standard scenario for use in impact assessments when using MAGICC, although the original IPCC recommendation was that all six IS92 emissions scenarios be used to represent the range of uncertainty in emissions.

VULNERABILITY TO CLIMATE CHANGE OF COTONOU

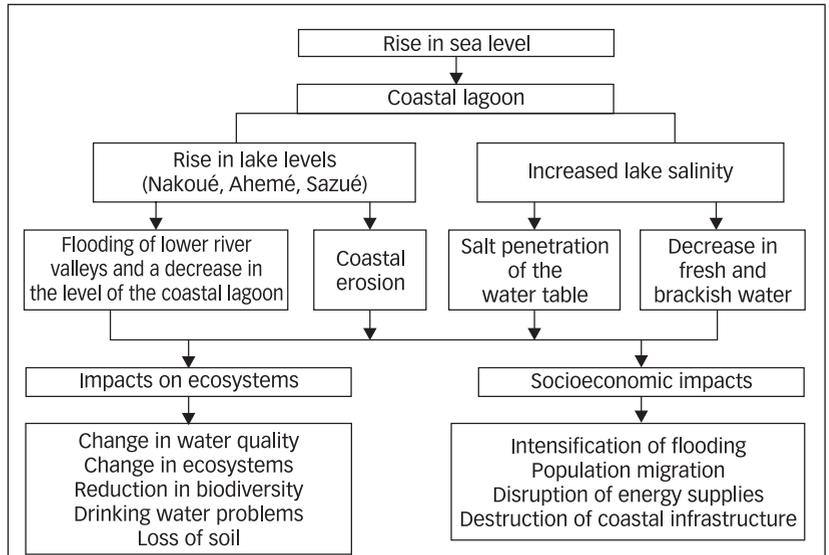
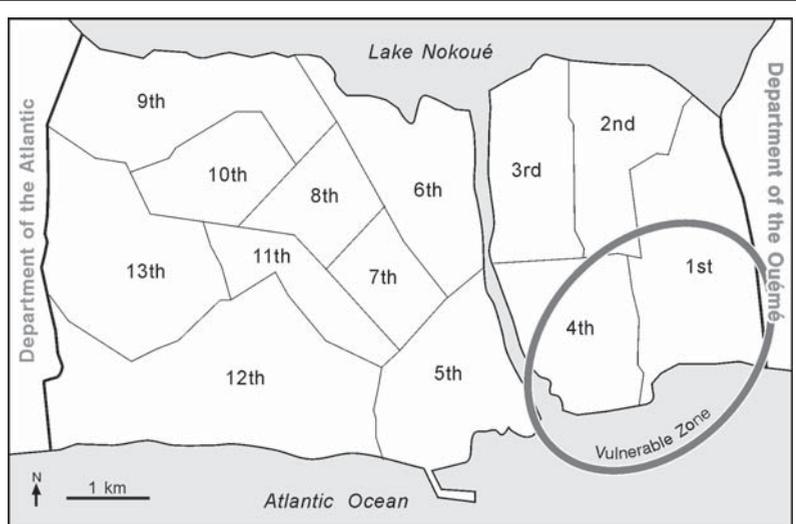


FIGURE 1
Summary table showing the impact of climate change on the coastal lagoons

SOURCE: Adapted from Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU), (2003), "Stratégie nationale de mise en oeuvre au Bénin de la convention cadre des Nations Unies sur les changements climatiques", UNDP and UNITAR, 80 pages.



MAP 2
The most vulnerable area of Cotonou

SOURCE: Adapted from scanned road map.

with waves measuring 160–220 metres long arriving at intervals of between 10 and 16 seconds. The oblique angle of the swell in relation to the shore varies between 4° and 9°, causing coastal drift (also known as coastal transport) from west to east. This coastal transport carries 1,500,000 cubic metres of sand every year from Lomé to Cotonou. The construction of ports in the two cities has diverted sediment upstream (i.e. to the west of the port of Cotonou) and reduced the sandy deposits that should enrich the coast of the first and fourth *arrondissements* and beyond. Until recently, this erosion has been exacerbated by the operation of marine sand quarries along the Cotonou coastline (Jacquot and Tokplégbé beaches, PK10, etc.)

c. Threats to residential districts and road infrastructure

In the first *arrondissement*, some very smart residential districts (JAK and Tokplégbé) with prestigious buildings are inhabited by expatriates, senior government officials and other eminent persons. Camps set up by fishermen and homeless people can be found all along this portion of the coast. Population densities are very high in the dormitory suburbs of Donatin and Akpakpa-Dodomey in the fourth *arrondissement*. Here, some former roads and other amenities (drains, pavements and coconut plantations) have now disappeared, swallowed up by the sea as the shoreline retreats (Map 3).

d. Exposure of the industrial sector

The bulk of the industrial area of Benin is in Cotonou's fourth *arrondissement*, which is exposed to coastal erosion. Consequently, industrial activities are threatened. So too are the livelihoods of around 1,500 people working in more than 30 state enterprises (brewery, textiles, gas, agricultural development, cement works and many others), as well as private or small-scale enterprises specializing in various kinds of production and service provision – the sale of drinks, cotton hulling, building and public works, printing, the manufacture of cement, textile production, the timber industry, gas production, painting and pharmaceuticals. Although industrial activities are not very developed, they make a considerable contribution to the national economy.

e. Threats to the tourism sector

Hotel infrastructure is being undermined and destroyed by the sea (for example, the Hotel Eldorado has been severely damaged, and the Hotel du Lac, PLM Aledjo, Palm Beach and other establishments have also suffered). The disappearance of these facilities would represent a loss for the tourism-based economy, especially as Benin does not have enough of these kinds of facilities.

Other coastal cities in Benin also have vulnerable infrastructure (whether administrative, health, hotel, industrial or socioeconomic), where the coastal erosion exhibits other features and affects different socioeconomic groups to varying degrees (for example, in Sèmé, Grand Popo and Ouidah).

f. Signs and consequences of rising sea level and coastal erosion

A rise in sea level related to global warming is a factor that will considerably worsen coastal erosion. The shoreline of Benin is a fragile ecosystem exposed to the negative effects of climate change such as:

- rising sea and ocean levels;
- changes in average rainfall patterns;
- increased atmospheric temperature, affecting natural ecosystems, human settlements, water resources and coastal infrastructure; and
- the marked coastline regression to the east of Cotonou.⁽¹¹⁾

Coastline regression is one of the signs of rising sea level and encroachment. In fact, diachronic studies based on remote sensing to assess changes in the shoreline have revealed the vulnerability of the coast of Benin, especially the first and fourth *arrondissements* of Cotonou.

The first of these studies,⁽¹²⁾ conducted during an analysis of the kinematics of the coastline using remote sensing, compared a map of Cotonou dating from 1963 with a picture obtained 24 years later.⁽¹³⁾ This comparison reveals the impact of the rise in sea level. The area east of the port of Cotonou (first and fourth *arrondissements*) has been undermined by coastal erosion, the shoreline having retreated by 400 metres at a maximum speed of 16 metres per year, with a total loss of around 112 hectares of land.

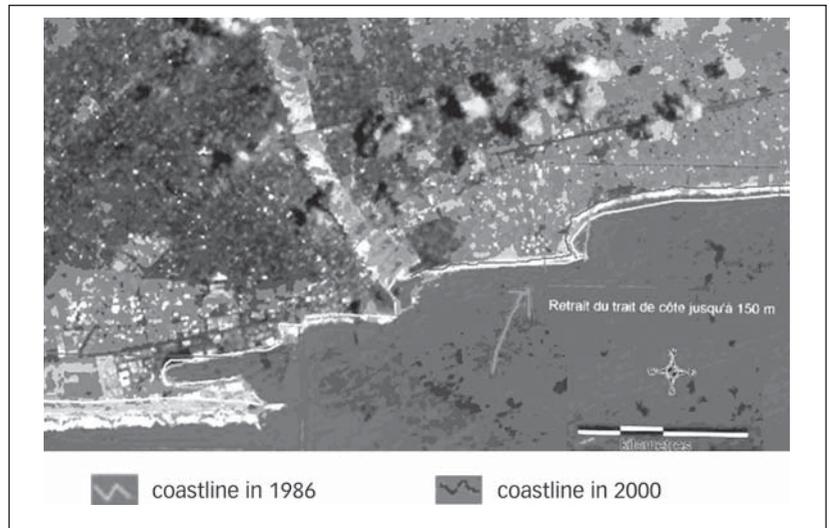
The second study,⁽¹⁴⁾ highlighting the same phenomenon, is based on computer processing of satellite pictures taken in 1986 and 2000. Map 3 has been prepared by superimposing the satellite images.

11. Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU) (2001), "First national communication of Benin", UNDP, 76 pages.

12. CODJIA, C L, J-M Dubois, J-P Donnay, A Ozer, F Boivin and A Lavoie (1997), "Application de la télédétection à l'étude des changements urbains et des transformations du littoral à Cotonou (Bénin)". Télédétection des milieux urbains et périurbains", *AUPELF-UREF* No 6, Liège, pages 299–306.

13. SPOT-1 HRV multi-band image, 22nd December 1987. See reference 12.

14. Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU), (2003), "Stratégie nationale de mise en oeuvre au Bénin de la convention cadre des Nations Unies sur les changements climatiques", UNDP and UNITAR, 80 pages.



MAP 3
Coastline regression in the east of Cotonou

SOURCE: Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU), (2003), "Stratégie nationale de mise en oeuvre au Bénin de la convention cadre des Nations Unies sur les changements climatiques", UNDP and UNITAR, 80 pages.

g. Loss of human settlements

In the Gulf of Guinea, the impacts of coastal erosion are often disastrous for the countries concerned,⁽¹⁵⁾ resulting in the disappearance of infrastructure along the coast.

Infrastructure to the south of Cotonou that is threatened with disappearance includes:

- the buildings of people living around Cotonou Lagoon;
- the self-governing port of Cotonou and its handling facilities;
- a number of hotels dependent on the self-governing port of Cotonou;
- the fishing port;
- the presidential buildings;
- the international conference centre; and
- the international airport.

Infrastructure and urban structures have been lost to the sea, including housing and some roads and earth tracks in the first and fourth *arrondissements* (Tokplégbé and JAK districts). Similarly, the villas (built by the Fagace Company) and hotels such as the Aledjo have seen parts of their installations swept away (Photos 1 and 2).

15. See references 3 and 11; also Blivi, A (2000), "Vulnérabilité de la côte togolaise à l'élévation du niveau marin: une analyse de prévision et d'impact", *Patrimoines* No 10 pages 643–660; and Kaki, C and M Oyédé (2000), "Implications of Accelerated Sea-Level Rise (ASLR) for Benin", in A C de la Vega-Leinert, R J Nicholls, A Nasser Hassan and M El-Raey (editors), *Proceedings of SURVAS Expert Workshop on African Vulnerability and Adaptation to Impacts of Accelerated Sea-Level Rise (ASLR)*, Alexandria University, Middlesex University, pages 31–38.



PHOTO 1
Hotel infrastructure (holiday village)
being destroyed by coastal erosion

SOURCE: Biagi, R (2002), *Erosion littorale à l'est de la lagune de Cotonou. Les choix énergétiques: de l'évaluation des impacts à l'évaluation environnementale stratégique*: Colloque de Cotonou du 24 au 27 avril 2001. Agence Intergouvernementale de la Francophonie, Institut de l'énergie et de l'environnement de la Francophonie, Agence de l'Environnement et la Maîtrise de l'Energie, pages 691–694.



PHOTO 2

An undermined (lateritic) beaten earth road in Cotonou showing an erosion micro-cliff (about one metre high) at the top of the beach, generated by the rapidly retreating shoreline

SOURCE: Biagi, R (2002), Erosion littorale à l'est de la lagune de Cotonou. Les choix énergétiques: de l'évaluation des impacts à l'évaluation environnementale stratégique: Colloque de Cotonou du 24 au 27 avril 2001. Agence Intergouvernementale de la Francophonie, Institut de l'énergie et de l'environnement de la Francophonie, Agence de l'Environnement et la Maîtrise de l'Energie, pages 691–694.

h. Impacts on human health

Submersion, causing flooding in the inter-dune areas, will have an impact on people's health. There is a risk of resurgence of endemic tropical diseases as a result of the development of breeding grounds for *anopheles* mosquitoes, which spread malaria,⁽¹⁶⁾ and tsetse fly larvae, adapted to salt water, as well as other threats to health amplified by climatic variability and change. There could be an increase in cardiovascular and cerebral diseases related to high saline levels in the water, which could increase mortality rates, especially among elderly people, pregnant women and children.⁽¹⁷⁾ This situation would exacerbate the poverty and the precariousness of the living conditions of inhabitants and have serious consequences for the city's economy and, indeed, the entire country, jeopardizing the achievement of development objectives.

i. Biophysical disruption

Geomorphological changes due to eustatic, neotectonic and sedimentological phenomena are altering the shores of Benin, which have a great variety of ecological zones colonized by very diverse plant formations, for example mangroves, freshwater marshy forests and hydrophytic and

16. See reference 9; also Bokonon-Ganta, E (forthcoming), "Changements climatiques et santé au Bénin: cas du paludisme à Cotonou", Capacity Strengthening in LDCs for Civil Society for Adaptation to Climate Change (CLACC).

17. See reference 14.

halophytic meadows. A 50-centimetre rise in sea level would cause a systematic reduction in the area colonized by these plant formations (especially mangroves), and a flooding of lowland areas. Currently, various animal species (for example, crabs and marine turtles) are experiencing disruption to their ecological niche. Those whose livelihoods depend on fishing have already declared some species of fish to be scarce, in both inshore waters and lagoons.

The level of the main lakes and lagoons (Lake Nokoué–Porto Novo lagoon complex and Lake Ahémé) will rise. Lake Nokoué is likely to double in size and a large part of its high-water bed will be flooded due to the geometry of its basin.

j. Impacts on traditional fishing

Fishing is under threat. It represents a major part of the livelihoods of more than 15,000 people in Cotonou, especially those living in districts on the coastal strip of Cotonou, along the lagoon canal and around Lake Nokoué. Many of the homes on the banks have been swept away by the sea. Many families in the fishing hamlets have been obliged to migrate, having no further room to retreat to protect their camps. Those determined to remain on the coast live in makeshift accommodation (from Placodji to PK6) (Photo 3).



PHOTO 3
Fishermen's camps threatened by sea erosion

SOURCE: Author's own.

k. Salt intrusion

The hyaline characteristics of freshwater will be changed permanently by salinization, with the concomitant risk of changes to and, indeed, the disappearance of freshwater ichthyological fauna. The shallow water table in Cotonou and its surrounding area (1–3 metres) could become brackish. This physicochemical change would be accompanied by the spread of many diseases among the local population. In the field of civil engineering (buildings and other structures), an increase in the salt content of the soil would alter the resistance properties of materials, attacking the foundations of masonry structures. An increase in salt content would also destroy some of the flora of the slopes and sides of the plateau, bringing about considerable ecological changes in the coastal zone.⁽¹⁸⁾

18. See reference 14.

VI. ADAPTING TO THE RISE IN SEA LEVEL AND ITS CONSEQUENCES

It is a matter of urgency to find ways for people and ecosystems to adapt so that they become less vulnerable. A brief description of the options is given below. It must be pointed out that adaptive measures are not confined to addressing the vulnerability in Cotonou, as the phenomenon is widespread throughout the Gulf of Guinea. An analysis of measures implemented so far shows that adaptation takes two forms, passive and active.⁽¹⁹⁾

19. See reference 3.

a. Passive adaptive measures

Passive measures call for the adoption of decisions or attitudes to avoid or alleviate the negative effects of rising sea level and coastal erosion. Such measures were implemented just after the port of Cotonou was built, and involved adding sandy sediment to vulnerable areas. For example, sandy sediments may be taken from well-stocked areas to areas that are deficient in sand, and beach rocks may be used to protect the shoreline (Photo 4).

b. Active adaptation

These measures involve building structures either along the coast or out into the sea. There are two types: lengthways structures such as breakwaters, seafront walls and beach defences; and transverse structures, such as groynes, that are constructed of different materials (wood, concrete, etc.) and that run perpendicular to the coastline (Photo 5).

In view of the obvious signs and scale of erosion in Cotonou, beach defences cannot work and breakwaters and groynes would appear more appropriate.

A concrete barrier was constructed at the entrance to Cotonou Lagoon to reduce sea encroachment on the lagoon and Lake Nokoué and to protect the first Cotonou bridge. When the lagoon was constructed in 1885, it was just a small canal intended to drain off rainwater following floods, but it is now more than 200 metres wide due to the force of water



PHOTO 4
Passive adaptation: using rocks in human settlements on the Benin coast

SOURCE: Author's own.



PHOTO 5
The concrete barrier on which fishermen stand at the entrance to Cotonou Lagoon

SOURCE: Author's own.

20. Colleuil, B (1984), "Un modèle d'environnement lagunaire soumis aux conditions des climats équatoriaux tempérés: le lac Nokoué", Université de Bordeaux, 135 pages.

runoff.⁽²⁰⁾ However, the barrier has now been re-opened to allow sufficient contact between the lagoon/lake complex and the sea and to avoid the accumulation of sediment from the banks of the lagoon and Lake Nokoué.

c. Technical measures

As part of its strategy to implement the United Nations Framework Convention on Climate Change, various technical measures are planned by Benin to adapt to the rise in sea level and coastal erosion. These adaptation options are the stabilizing of the coastline by constructing groynes; and moving the communications, transport and hotel infrastructure.

The construction of groynes to stabilize the coastline has the objective of making it possible to remain in the city of Cotonou in the event of a rise in sea level. For example, the Siafato groyne is designed to safeguard the substantial socioeconomic, administrative and residential infrastructure established beside the sea. Although effective in alleviating the local problems caused by erosion, the protective system would, according to the environmental impact analysis conducted in 2004, transfer erosion further along the coast to the municipality of Sèmé, and then on to Nigeria (to the east). The city's installations would be safeguarded but the impact study estimated that 195 hectares of land would be lost from the eastern coast in 20 years time. The project includes a plan both to resettle or compensate people affected by the transfer of erosion and to conserve the area vulnerable to erosion.⁽²¹⁾

The second option, involving moving infrastructure, has both psychological and financial constraints. Favourable factors are the moves towards decentralization already underway in Benin in response to the policy of administrative decentralization aimed at balanced development of the different regions of the country, especially municipalities with land on both the plateaux and the coast. With regard to Cotonou airport there are financial constraints, but an enabling factor is an already existing plan to construct a new airport in Glo-Djigbé on the Allada plateau (to the north of Cotonou). Such infrastructural development would have to be followed by a land use plan and an urban blueprint, registering all property around the airport within a radius of two kilometres.

All these measures require the mobilization of substantial financial investment as well as political will, and the communities concerned should participate in the decision-making process.

d. Adaptation in the health sector

The measures identified in the health sector to adapt to the rise in sea level and flood occurrence include:

- using impregnated mosquito nets to protect against malaria;
- developing more widespread vaccination against tsetse fly;
- developing health insurance and mutual health insurance companies;
- desalinating water to use for drinking; and
- recycling rainwater.

21. Ministère de l'Environnement, de l'Habitat et de l'Urbanisme (MEHU) (2004), "Projet de la protection de la côte à l'est de l'épi de Siafato: étude d'impact environnemental", MEHU, Cotonou, 112 pages.

e. Adaptation in the fisheries industry

Fish farming, as an adaptive measure, would help to reconstitute the ichthyological fauna and provide catches for those whose livelihoods depend on fishing. It would also improve the availability of fish and prawns in the Cotonou Lagoon and other bodies of water, which are experiencing problems of over-fishing and conflicts relating to the lagoon and lake ecosystems⁽²²⁾ and the use of prohibited techniques.⁽²³⁾

VII. DISCUSSION AND CONCLUSION

The city of Cotonou is vulnerable to climate change, which will cause a rise in sea level (with its associated impacts) due to global warming. This paper has analyzed its projected effects on human systems (activities, human settlements, health, etc.) and on the coastal and lagoon natural ecosystems.

In its national strategy to implement the UN Framework Convention on Climate Change, Benin has prepared two scenarios: technological adaptation through the installation of protective groynes to stabilize the coastline; and the relocation of activities, infrastructure and communities. However, the search for funding is delaying implementation of the first option, which will be extremely beneficial for coastal municipalities and towns such as Grand Popo, Ouidah and Abomey-Calavi, and especially the city of Cotonou. The phenomena described in connection with coastline regression and risks of rising sea level demand good planning. In this regard, advantage should be taken of the ongoing preparation of the NAPA (National Adaptation Programmes of Action) in Benin. The identification of priorities, as expressed by the most vulnerable communities, must be used to transform the selected, approved adaptation options into projects. With the support of national and international financial partners (World Bank, Global Environmental Facility, UNDP, non-governmental organizations), the proposed adaptive measures must be implemented as soon as possible to reduce communities' vulnerability and suffering.

Moreover, national NGOs must play their advocacy role, drawing politicians' attention to the other climatic hazards that could further impoverish the people. They should also raise the awareness of local communities and encourage them to take responsibility with regard to:

- the occupation of land already identified as affected (threatened coastal zone, swamps or valley bottoms, runoff routes); and
- the protection of the environment through the adoption of appropriate behaviour.

The vulnerability of the coastal region, particularly in the case of Cotonou, is real. This is why NGOs, communities, political leaders (local councillors, planners and funders) and scientists (natural resources specialists, climatologists, agronomists, etc.) must combine their efforts to:

- improve documentation of climate change and extreme phenomena at local, national and regional levels (such as the rise in sea level and its consequences); and
- plan and initiate effective, concerted action to adapt to future climatic conditions.

22. Dossou, D. and K. Dossou (2005), "Guide gestion concertée des écosystèmes partagés", Agence Béninoise pour l'Environnement, Cotonou, 57 pages.

23. For example, *médokpokonou*, *wan* and *acadja* are traditional technologies that are forbidden in Benin in order to reduce pressure on fisheries development. *Médokpokonou* employs nets with fine, tight stitches, which collect small and immature fish. *Wan* and *Acadja* are fish traps.

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