Causal chain analysis

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involves a step-by-step process that identifies the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis also recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. In order to ensure that the final outcomes of the GIWA are viable options for future remediation, the Causal chain analyses of the GIWA adopt relatively simple and practical analytical models and focus on specific sites within the region. For further details, please refer to the chapter describing the GIWA methodology.

Modification of stream flow: Case of the Volta Basin

Introduction

The Volta Basin has been selected as a typical example of an international river system facing severe freshwater shortage, partly due to the climatic characteristics of the Sahel region, partly due to the increased water demand caused by a rapidly growing population.

The Basin is dominated by two countries: Burkina Faso in the upstream waters (42%), and Ghana in the downstream catchment (40%). They constitute the key players in the international aspects of water management, but Benin, Côte d'Ivoire, Mali, Togo, also have minor shares in the Basin.

The Causal chain analysis identified the following basic root causes of freshwater shortage:

- Climatic evolution has caused a reduction of average rainfall in the headwaters in the Sahel of about 30% over the last four decades.
- During the same period, the population has multiplied by more than a factor of 3, and the water demand by almost a factor of 6. This increase in water demand, in combination with the precipitation reduction, depleted the stream flow by approximately 50% or more in certain catchments.
- Inappropriate technologies for urban water supply and for water-efficient agricultural practices in both rain-fed and irrigated agriculture have further aggravated the water shortages.
- Lack of efficient governance has aggravated the situation by not being able to address the extremely severe water management issues efficiently.

System description

The Basin

The Volta Basin is described in detail in the first section of the report. The Volta River drains a catchment area of about 410 000 km^2. At the outlet, the River has an average annual flow of 700 m^3/s. However, this average figure hides the extreme annual variation from high waters in the rainy season to low waters in the dry season. Also, it is important to realise the huge difference between the arid and semiarid headwaters in the Sahel, and the much more humid coastal conditions in the south along the Atlantic coast.

The upper basin, primarily located in Burkina Faso and northern Ghana, is characterised by huge arid plains with very flat topography. To the north, the Sahara desert is encroaching on the catchments, gradually

changing into grass savannah, and eventually into bush savannah. The rainfall in this region is highly erratic from year to year and occurs during two to four months of the rainy season. The rest of the year, rainfall and river inflow is extremely scarce. This implies that the flow during the dry season is close or equal to zero in many tributaries. This is the case in White Volta and Red Volta in Burkina Faso. Only the Black Volta (Mouhoun) has a permanent flow throughout the year (MEE/DGH 2001).

This general lack of run-off water is further aggravated by a marked decline in rainfall over the past 40 years (Figure 5, 6, 28 and 29). The actual reason for this decline is not known with any certainty, and it can be seen that the beginning of the 20th century had similar drought conditions. Three basic explanations have been proposed:

- The decline is related to a natural long-term cycle, where the rainfall may eventually recover. There is no scientific documentation to explain this cycle;
- The decline is related to the land degradation, caused by a proposed feedback between over-grazing, land degradation and run-off;
- The decline is related to the global change caused by emission of greenhouse gases.

Presently, scientists have not reached consensus on the selection of a single specific explanation.

The lower basin, primarily in southern Ghana, is in a much better condition with much more frequent and plentiful rainfall. Natural vegetation cover is woodland savannah, deciduous forest or coastal rainforest, and as such, the southern basin does not face the same severe water shortages and water management problems as the north.

Groundwater is an important source of water during the dry season. But aquifers have low yields, particularly in the crystalline basement. A reduced recharge due to the climate evolution, combined with increased pumping to satisfy the water supply needs of the growing populations, has caused a significant lowering of the groundwater table (Figure 30).

The people

The total population of the Basin is approximately 20 million inhabitants (GIS analysis based on ORNL 2003). This figure is expected to almost double to 34 million by 2025. Population density varies significantly from a few inhabitants/km^2 in the semi-arid lands in the north to about 100 inhabitants/km^2 in the south.

About 75% are subsistence farmers and depend directly on the productivity of the natural resources in their direct neighbourhood, in particular the water resources. Poverty is the norm, with annual incomes ranging from 100 to 700 USD per capita in the more fortunate south. In the north, population growth and lack of rainfall has caused overexploitation of the resources and severe depletion of soil and vegetation. Agriculture is predominantly rain-fed, and only a few percent of the land available for cultivation has access to irrigation. Competition between pastoral herders and settled farmers over local water resources are common.

The lack of income opportunities has led to extensive transmigration from the rural areas to the towns causing a concentration of water supply demand. Major urban centres are the cities of Ouagadougou (850 000 inhabitants in 2000 with a growth rate of more than 4%) and Bobo-Dioulasso (350 000 inhabitants in 2000 and with a growth rate of almost 3%). Some other cities have less than 100 000 inhabitants. The industrial development is limited to small-scale enterprises, with fairly limited water needs, except for some particular plants like the brewery in Ouagadougou.

Besides the transmigration from the rural areas to the towns inside one country, there is a migration towards the south, in particular along the coasts in the aim either to find more fertile lands or bigger cities. This movement of population is facilitated by the ECOWAS[10] regulations stipulating the free movement of persons from one member country to another. The result is that the Sahelian countries are moderating their population growth by emigration whereas coastal countries have an important foreign population e.g. more than 25% in Côte d'Ivoire.

Immediate causes of freshwater shortage in Volta Basin

The Causal Chain Analysis (CCA) was carried out according to the GIWA guidelines, by a team of regional experts based in Accra (Ghana) and Ouagadougou (Burkina Faso). The CCA has been validated during a workshop held in Ouagadougou, in February 2003.

The freshwater shortages in the Volta Basin are caused by two basic interventions in the hydrological cycle:

First and foremost, due to its location in the Sahel region, most of the Basin suffers from arid conditions. This disadvantage has been further aggravated as natural stream flow has been steadily decreasing during the last decades, due to the climatic precipitation changes occurring in the Sahel region. Decreases in annual rainfall have caused significant reductions in the total run-off, but also increased its variability and the drought and flood risks. Similarly, groundwater recharge has been

[10] *Economic Community Of West African States*

reduced due to lack of rain, and water tables have been lowered correspondingly.

This inevitable environmental cause of a serious water deficiency in the Basin has been further worsened by a strong increase in water demand. In particular increased diversions to satisfy water needs of the rapidly increasing population and – to a much less extent – the irrigation needs of agricultural crops, have caused shortages to the downstream users. In addition, unproductive evaporation losses from reservoirs constructed to save water for the dry season are responsible for huge losses of water (almost 85% of the total volume of most of the reservoirs in Burkina Faso according to the Volta Basin team, with the exception of the deep reservoir dams like Kompienga on the Red Volta or Bagré in the White Volta.

The groundwater aquifers of the region are not very productive, but they serve as a crucial reserve during droughts. A combination of reduced infiltration and increased pumping to replace the dwindling surface waters has caused severe lowerings of the groundwater table.

The activities behind these impacts are related to three economic sectors:

- Urbanisation and industrialisation create significant increases in water supply demands. The urban population is increasing very rapidly due to transmigration from the rural areas, where income opportunities in agriculture are extremely meagre, not least due to the drought. Towns are often located in water-limited areas, and they need extensive reservoirs to save water for the dry season. The land variation in topography is small and unfavourable for the construction of deep reservoirs, so significant amounts of water are lost by evaporation from water supply reservoirs. Furthermore, pipe systems are often old and leaking, and there are few significant attempts to introduce water saving activities and water recycling technology.
- The rural population needs water for basic water supply, but also for a safe crop production and for livestock. Direct rainfall, withdrawal from streams, combined with the productivity of shallow ground-water reservoirs is essential for subsistence agriculture, and even more so for cash cropping. In some cases, governments and donors have established irrigation systems, but the total command area is limited, due to lack of funds, but also due to the difficulty in achieving a reasonable economic cost-benefit ratio for the investments.
- Hydropower development has been exploited as a way to support the economic development of the region. But due to the unfavourable topography, the dams create huge lakes, vulnerable to excessive evaporation losses in the arid climate. Lake Volta is the largest artificial lake in Africa, and evaporation losses are substantial.

However, behind these developments in the economic sectors there are a number of root causes, which need to be addressed, if the issue of freshwater shortage is to be solved, or at least reduced.

Root causes of freshwater shortage in the Volta Basin

The immediate causes of the freshwater shortages were described above. However, these immediate causes are driven by underlying and basic *root causes* which also need to be identified to achieve a complete understanding of the combination of environmental and socio-economic dynamics that underlie the lack of water in the Volta Basin.

Impact of West African climatic evolution

The fundamental climatic constraint in the arid Sahel region is one of the most important root causes of water shortage, and it has to be accepted as a constraint given by nature. In desert and arid lands there will always be water shortage.

As mentioned above, the decline in rainfall in the Sahel has had a devastating impact on the water resources of the Volta Basin. Recent studies (e.g. Lebel et al. 2000), have shown that the main reason for the decline in the rainfall is the decrease in the number of rainfall events. Rainfall - and groundwater recharge - has been reduced by 30%, and stream flow reduced by up to 50%.

The reasons, and the future trends, for the climatic evolution are unclear as no natural climatic factors for these variations have been found. Long-term climatic variations are a common phenomenon in the region, and a similar dry period occurred in the beginning of the 20th century. It could even be argued that the 1950s were unusually wet. But no natural climatic factors for the variations, such as the El Niño phenomenon, have been identified.

The general increase in greenhouse gases and the associated global warming and climate change may also have an impact. But so far, no reliable documentation is available to demonstrate the precise impact of human induced climate change. Some researchers have proposed that the general destruction of vegetation has worsened the situation. It is unquestionable that the combination of drought and population pressure has significantly depleted the land and vegetation of the arid northern parts of the Basin. But a possible feedback on the precipitation

patterns has not been documented. As the climate conditions are a paramount factor in water resources, it appears most appropriate to address the lack of knowledge about the basic processes. Until this knowledge has improved, emphasis must be on robust and flexible water policies, accounting for the risks of climate related water shortages.

Rapidly growing population followed by increase in water supply

In the old days, 30-50 years ago and more, when the population pattern and the socio-economic systems were more or less adjusted to the basic climatic conditions through centuries of adaptation by the local people, it was possible to cope with the shortages. But when improved health policies and practices reduced the death rate, population grew to unexpected levels, beyond the carrying capacity of the traditional practices.

Thirty years ago, the population of the Basin was less than 10 million, which today has grown to approximately 20 million. With the present population growth of about 2.5% it is expected to increase to nearly 34 million by 2025. Accordingly, the fundamental per capita pressure on the water resources and the related shortages, will increase correspondingly, further aggravated by the general tendency for a higher water demand per capita, when economic conditions improve.

A complete picture of the causes of population growth and its relation to water resources depletion under such adverse conditions have not been well identified (Dasgupta 2000). The only certain conclusion is that the relationships are extremely complex and highly dependent on regional and local conditions. Some basic causes for high fertility rates are identified as:

- Lack of education and awareness of the, often very complex, consequences of high fertility and population growth;
- Social and cultural conditions favouring large families;
- Need for old-age economic security and support through a large extended family;
- Need for labour in labour-intensive subsistence agriculture;
- Lack of income alternatives.

Perhaps surprisingly, lack of knowledge of family planning is not seen as an important cause.

The population growth in the rural area with its very limited productivity has forced a significant number of the population to leave the farms and migrate to the cities in search of better living conditions and income opportunities. The population pattern is becoming more concentrated and may, if left uncontrolled, create critical hotspots, where it will be increasingly difficult to satisfy the water demand.

Accordingly, policies addressing the demographic root causes are essential for a successful solution to the problem of water shortages.

Inefficient water technologies and wasteful uses of the scarce water resources

Another root cause of freshwater shortage is the lack of efficient water use in the present agricultural and urban water supply technologies. The civil sector development not only causes increasing demands for water but also creates wastewater.

Given the adverse arid conditions in most of the Volta Basin, there is already a significant amount of indigenous technology for water saving in both the rural and the urban sectors. But these techniques were developed under conditions with much less population pressure, so they are often not appropriate and sufficiently efficient any more. There is an urgent need to address the potential of developing more water efficient technologies and user practices:

- Traditional farming techniques are not sufficiently intensive and productive (too little crop and livestock per drop of water), and in particular, improved water harvesting and in-field water management practices need to be developed. A key constraint in this context is the ability of the farmers to pay for introduction of such new technology. Already, it is very difficult to make agriculture economically feasible in the arid regions of the Basin, so any new technology must be low-cost and specifically targeted towards local conditions and practices. Also, the lack of alternative, drought-resistant crops (possibly developed through genetic modification) is an important reason for the technology gap in the agricultural sector.
- Concerning investment in the irrigation sector, the decision process is often based on opportunities for financial aid from donors. It takes into account neither the real costs, nor the recurrent costs (Titècat 1998). Apart from the cost of manpower, the factor costs (e.g. concrete, steel, energy) are very high in the region and result in investment costs which, reported per irrigated hectare, are commonly three times higher than in developed countries. The beneficiaries of irrigated parcels neither pay the investments nor the maintenance of the installations, nor do they pay for the water they consume. This implies that a part of the water resource is allocated to uses that at the end of the day are profitable to a few people but represent a loss to the community as a whole. Moreover, this situation is very inequitable since the farmers working the irrigated parcels benefit from these abnormally advantageous conditions compared to others.
- Urban water supply systems are most often inefficient, causing severe unproductive losses through evaporation in reservoirs and leakage losses in the distribution system. Up to 30% of a reservoir

volume may be lost by evaporation, and leakage losses of 20-30% are common, but not abnormal since the losses may reach 50% in some cities of industrialised countries.

- Heavy evaporation losses from reservoirs appear to be a problem without solution in the context of West Africa (hot climate and flat topography). There is a need to look into alternatives for reducing these losses. Some attempts to cover the surface of water with chemicals supposed to reduce evaporation have been made in the urban lakes in Ouagadougou (ONEA[11], pers. comm. 2001) but the results are not convincing.

Lack of appropriate governance and increasing water shortages

The Volta Basin is characterised by an unusual number of severe conflicts and mismatches between water supply and demand. Due to the upstream-downstream character of the issues, these conflicts are local, regional, as well as international, and non-optimal solutions - based on the power of special interest groups - often increase the already severe shortages. Specific causes are identified as deficiencies in:

- The enabling water management setting with an internationally and nationally binding policy framework setting the goals for water use in the economic sectors, including protection and conservation needs. Also, the international and national legal frameworks are inappropriate, without setting fair, transparent and equitable rules for water rights and water allocation to specific uses.
- The institutional framework at both national and international level which is insufficiently equipped to address the shortage issues, due to lack of institutional authority and capacity, as well as lack of efficient instruments to address these shortages, such as:
  - Lack of a comprehensive and decision-oriented water monitoring system, including data and indicators on both water supply and water demand, including monitoring of the important socio-economic links between supply and demand;
  - Lack of a realistic enforcement framework to make implementation of legal water initiatives realistic;
  - Lack of economic instruments to achieve a more optimal water allocation and demand management;
  - Lack of transparent and cost-efficient financing and cost-recovery of water projects;
  - Lack of credible fora for fair and transparent solution of water allocation conflicts between different stakeholder groups;
  - Insufficient facilities for awareness raising about water issues among the relevant stakeholder groups.

Summary of the causes of freshwater shortage in the Volta Basin

The immediate causes of the severe freshwater shortage in the Volta Basin were primarily associated with modification of the stream flow, due to three main impacts:

- Reduction in natural rainfall input to the river system over the last 40 years;
- Increased diversion - and water losses - to satisfy agricultural water needs in the rural development sector;
- Increased diversion – and associated water losses – to satisfy the water supply needs of the ongoing urbanisation and industrialisation.

The root causes behind these impacts were identified as:

1) Environmental conditions in the arid Sahel region, with decreasing precipitation;
2) The rapidly increasing population, creating increasing needs for basic water supply and for agricultural production;
3) The lack of appropriate technological responses to the water shortages, such as development of water efficient agricultural production systems and urban-industrial water supply systems;
4) The lack of an appropriate governance framework to address the water conflicts in the Volta Basin.

The links in the causal chains are schematically outlined in Figure 37.

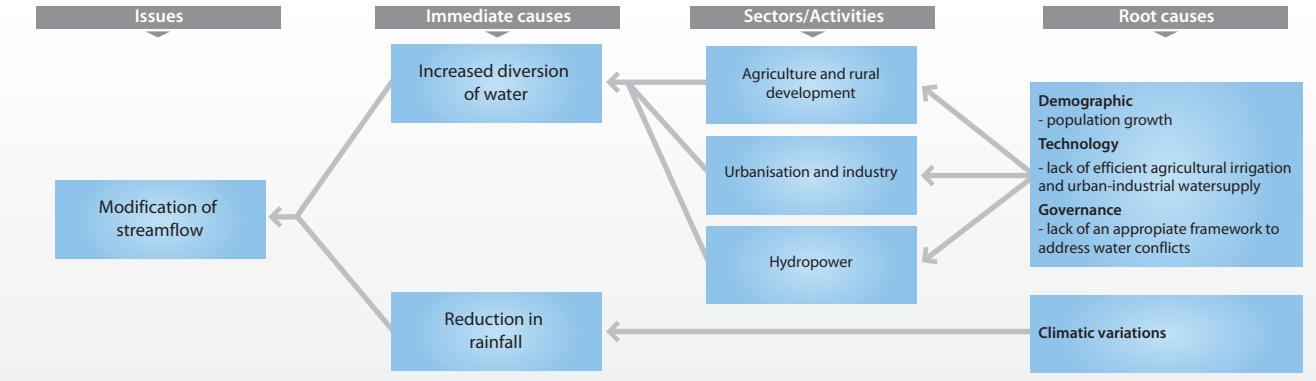

Figure 37 Causal chain diagram illustrating the causal links of freshwater shortage in the Volta Basin.

[11] *Office National de l'Eau et de l'Assainissement (Burkina Faso)*

Modification and loss of ecosystem: Case of the Niger Basin

Introduction

The Niger Basin has been selected as a typical example of an international river system in West Africa. It is characterised by significant changes in the aquatic ecosystems, partly due to the stream flow changes caused by the climatic evolution observed over the last 40 years in the Sahel region (Nicholson et al. 1988, Hubert & Carbonnel 1987), partly due to the land degradation caused by unsustainable land development practices of a rapidly growing population (ABN/GEF/UNDP/World Bank 2002). Three countries dominate the international basin: Mali and Niger in the upstream waters (54%), and Nigeria in the downstream catchment (28%). They constitute the key players in the international aspects of water management, but the other member countries of the Niger Basin Authority (NBA) i.e. Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire and Guinea also have important interests in the water resources management of the Niger Basin.

The Causal chain analysis has identified a complex pattern of causes behind ecosystem modification. The most important ones comprise changes in stream flow and increased sediment loads:

- Climatic variations have caused a reduction of average rainfall, and in the seasonal distribution, in the headwaters in the Sahel of about 30% within the last four decades. The associated change in stream flow pattern has significantly altered the fundamental balances of the aquatic ecosystems. Concurrently, the droughts have created severe desertification and land degradation, leading to soil erosion and increased sediment loads in the rivers.
- Population growth has led to significant increases in water diversions and depletion of the arid agricultural lands.
- Unsustainable agricultural techniques and practices have increased soil erosion and the sediment load and sedimentation of the ecosystems.
- Poverty limits the ability of the population to address the degradation by introducing and investing in more sustainable land practices.
- Lack of efficient governance has aggravated the situation by not being able to address the issues efficiently.

System description

The River Basin

The Niger Basin is described in detail in the first section of the report. It drains a catchment area of about 2.1 million km^2. At the outlet, the River has an average annual flow of around 5 000 m^3/s. Like the Volta Basin, this average figure hides the extreme annual variation from high waters in the rainy season to low waters in the dry season.

A main characteristic of the Niger River is the arid character of most of its catchment. Only the headwaters in Guinea and the Lower Niger have humid conditions with plenty of rainfall. This general lack of rainfall is further aggravated by the climatic evolution. For the past three decades the Sahel has been experiencing persistent drought resulting in drastically changed annual mean rainfall patterns and a southward shift of rainfall zones by 100 km (Figure 31). A significant decline in rainfall has been observed in the region since the late 1960s. Consequently, the Niger River and its tributaries have shown great variability over the last four decades because of the drought. It is known that since the run-off is the difference between rainfall (variable) and evaporation + infiltration (more or less constant), the reduction in rainfall is amplified in terms of reduction in the discharge of the River. Thus, a reduction of 30% in rainfall may cause a reduction of 60% in the run-off (Servat et al. 1998).

The aquatic ecosystems in the Niger Basin

Most aquatic ecosystems are associated to the floodplains of rivers and watercourses of the Basin. The strongly seasonal rains cause over-flowing of almost all the southern rivers and watercourses. The more important floodplains are spread out from the Gulf of Guinea border to Bamako, but they have to a great extent been converted into rice fields. There are also many secondary floodplains in Mali, Niger, Burkina Faso, Benin and Cameroon. In Nigeria, a wide floodplain is spread out from the entry of Niger River to Nigeria as far as Yelwa and another one upstream of the delta in Nigeria near Onitsha.

The Inner delta is a wetland of international importance and covers a land area of around 3.2 million ha (main delta and associated wetlands). The wetlands support 20% of the population in Mali economically and produce almost 100 000 tonnes of fish annually. They form a dense network of valleys lined with alluvial levies between which are low plains strewn with ponds. The system of valleys or creeks conveys water towards plains during the rainy season and conversely, ensures withdrawal of water towards rivers and waterways during dry season. There are several lakes; the most significant are Debo (the widest within the delta complex), Korienze and Faguibine. In an international waters context, the Inner delta is highly dependent on the condition of the humid forested headwaters in Guinea, and their impact on the inflow.

There are also a large number of natural lakes and artificial dammed reservoirs for generation of hydropower and for irrigation and water supply. These reservoirs are themselves important ecosystems and they are most sensitive to changes in inflow and sediment loads. Through

artisanal fishing, they provide a very important source of animal protein for the population in the Basin.

The Niger delta is an extensive wetland with an area of about 70 000 km^2 (Shell 1999). Its distinctive ecological attributes include sandy ridge barriers, brackish or saline mangroves, seasonal swamps and lowland rainforests. The delta comprises four major ecological zones: the barrier island complexes, the vegetated tidal flats, and the lower and upper flood plains. Influences of the flood region of the Niger River and tidal inversion of the Atlantic are the principal drivers of the hydrology. The coastal area of the Niger delta is generally low lying and interspersed with marshes, lagoons and mangrove swamps. The delta and associated wetlands of the Niger River are noted to be one of the largest wetlands in the world.

The people

The total population of the Niger Basin was approximately 106.5 million inhabitants in 2002 (GIS analysis based on ORNL 2003). The average annual growth rate is about 3% (UNDP 2002). Thus the population figure is expected to almost double by 2020. Population density varies significantly from a few inhabitants/km^2 in the arid lands in the north to more than 100 inhabitants/km^2 in the south.

Presently, about 75% are subsistence farmers and depend directly on the productivity of the natural resources in their direct neighbourhood. Poverty is the norm, and it has been estimated that more than 50% of the population live on about 1-2 USD per day. In the central regions, a combination of drought and population growth has caused severe overexploitation of resources and severe depletion of soil and vegetation. Agriculture is predominantly rain-fed, and only a few percent of the land used for cultivation has access to irrigation.

The lack of income opportunities has led to extensive transmigration from the rural areas to the towns, including the large cities outside the Basin (e.g. Abidjan, Accra, Lomé, Cotonou and Lagos). Urban areas in the catchment presently contain about 37 million inhabitants, but are expected to grow significantly by 2020.

The immediate causes of ecosystem modification in the Niger Basin

The Causal chains have been established by a local Task team, headed by a Niger Basin Authority expert. The CCA has been validated during a workshop held in Ouagadougou, February 2003. The modifications of the aquatic ecosystems are caused by two basic changes in the water supply to the ecosystems: water flow and water quality.

First and foremost, the fundamental ecological factor of water flow has been changed significantly by the climatic changes in the region. The annual flows have been reduced, droughts have been extensive and correspondingly, river plains, lakes and wetlands have been reduced and significantly depleted, with corresponding impacts on the fish and water bird populations. But stream flow has also been modified by human actions, in the form of increased diversions to satisfy water needs of the rapidly growing population and - to a much less extent - the irrigation needs of agricultural crops. The establishment of reservoirs has significantly increased evaporation losses.

A particular impact of reduced river flow may be found in the very productive brackish ecosystems in the coastal regions, in particular the estuaries, lagoons and mangroves. With reduced freshwater inflow, the salinity increases and destroy the sensitive environmental balances in fragile coastal ecosystems. Important species are unable to adjust to the new conditions and disappear. As many people depend on the productivity of coastal fisheries, socio-economic impacts may be severe in the affected regions.

Secondly, changes in the quality of the river waters have been changing the ecosystems. Most significant are the increases in sediments, impacting both water quality and sedimentation patterns in the riverbeds and flood plains. Deposition of the increased sediment loads reduces wetlands and lakes (in combination with the reduction in inflows), and coastal estuaries and lagoons become silted up (Niger Basin Authority 2002).

Another, so far much less important, cause is related to the losses from intensive mono-cropping farmlands. In some places, the increased use of mineral fertilisers and pesticides in monoculture production such as rice, sugar cane, cotton, and garden vegetables is the cause of increased salinisation of soils and eutrophication of the rivers manifested in the form of increased algal growth and invading floating aquatic weeds. Also, release of pesticides – very often so toxic that they are illegal in the industrialised countries – can cause severe disruptions locally. Moreover, some people use pesticides to catch fish in lakes and rivers, with severe consequences for both human health and aquatic life. The human activities behind these causes are primarily related to the rural, agricultural sector.

Human overexploitation of the fragile soil and water resources in the arid lands is the most important factor leading to soil degradation, intense erosion and desertification. When populations increase, the old sustainable farming practices become obsolete. Current agricultural practices have abandoned crop rotation, resulting in reduced fallow periods leading to the loss of soil fertility and less productivity of cultivated land. This vicious cycle leads to a need for further bush

clearing for land development, and further destruction and erosion of the fragile soils.

Also, livestock herds can grow beyond the carrying capacity of the rangelands, and over-grazing depletes the sparse natural vegetation cover and exposes the soils.

Hydro-agricultural developments through large-scale irrigation projects and semi-intensive irrigation, which are on the increase within the Basin, especially in Mali, Nigeria and to a lesser extent Niger, include a number of components such as mobilisation works, regulation works, transport works and network systems. The installation of these works, poor water supply and poor drainage systems can have negative influences on the biophysical environment and the flow regime of the fluviatile area.

It should be noted that water demand is not seen as a significant cause of the modification of the aquatic ecosystems, in relation to the climatic evolution and the land use impacts.

Root causes of ecosystem modification in the Niger Basin

The immediate causes of ecosystem modification were described above. However, the immediate causes are driven by underlying, basic root causes, which also need to be identified to achieve a full understanding of the combination of environmental and socio-economic processes behind the depletion of the biodiversity of the aquatic ecosystems in the Niger Basin (CILSS, n/d).

The root causes behind the changes in stream flow have been analysed for the Volta River in the previous section. These conclusions apply equally well to the Niger Basin. Also, salinity changes in coastal ecosystems belong to this category due to changes in flow. Accordingly, this analysis will not be repeated here, but the main root causes for quantitative shortage should be recalled:

- Natural root causes:
  - Arid climate, reduction in rainfall ⟶ Reduction of run-off and flow in rivers.
- Human root causes:
  - Population increase, urban transmigration, rising standards, economic sector development + Lack of appropriate water efficient technology + Lack of appropriate water governance ⟶ Increase in water demand and losses.
- Consequences:
  - Reduction of run-off and flow in rivers + increase in water demand and losses ⟶ water shortage.

The present analysis will focus on the root causes for important changes in water quality, in particular the increase in suspended solids. The issue of eutrophication will be treated in the case of Comoe Basin.

Climate change

Climatic evolution has further reduced the low productivity of the arid lands of Sahel (WCMC 1993, Awosika et al. 1992). As seen from the previous section, unsustainable land use is a key driving force behind the land degradation and the excessive sediment yields. Initially, it should be emphasised that the basic climatic conditions in the arid Sahel region put severe strains on the productivity of the land. In the past, the population had adjusted itself to these adverse conditions, and when the population density was low, it was possible to provide basic sustenance for everyone; settled agriculturalists, as well as migrating livestock herders.

Population growth

Population growth has significantly increased the pressure on the natural resources (WCMC 1993). The recent demographic trends have drastically impacted the delicate balance between man and his natural resource assets. During the last 30 years, the population in the Niger Basin has doubled. With the current population growth rate of 3% it is estimated to double again by the year 2020 (UNDP 2002). In the same time period, the fundamental per capita pressure on land and water resources will increase in relation to urbanisation and rising standards of living. Accordingly, the overall pressure on land and water resources will increase by more than 100%. Fortunately, from the point of view of the rural sector, many people migrate to the cities in search of better living conditions. But the rural population still grows; larger families need more food from their lands, and there is less and less productive land to support the new generations. The farmers will have to break new land through deforestation and bush clearance, and the herders will have to increase their herds. Concurrently, the water diversions for agriculture and water supply have increased.

Lack of technology

Lack of technological innovation has led to unsustainable land management practices (Moffat & Lindén 1995). The associated land degradation might have been alleviated, if farming and herding technologies and practices had been adjusted to the new conditions. Initially, indigenous practices were, through centuries of trial and error, sufficiently robust to negotiate the adverse conditions. But the increase in demand on land and water due to the population growth has rendered these techniques outdated. Lack of education, awareness and funds severely constrain the development of more appropriate agricultural practices.

Poverty constraints

Poverty limits the potential of the population to address the degradation efficiently. This leads to the fourth root cause, the abject poverty in the region. The links between poverty and environmental degradation are not so straightforward and simple as many are led to believe (Reardon & Vosti 1995). Many wealthy people in the region also participate in environmental degradation, and most poor people will, if properly informed and equipped, definitely understand that they have a crucial interest in maintaining the resource base they are living on. But it appears that investment in improved land management technologies involves resources (monetary, information and education) that are not readily available among poor farmers in the Sahel. When hunger threatens a poor family, it has no capacity to consider long-term conservation. Also, the potential for the farmers to raise their incomes is limited, in particular due to the inequalities and failures in the agricultural markets. As such, combined with the impossibility to achieve owner right to land property, it is very difficult, or simply impossible, for the farmers to invest in improving their land and water efficiencies.

Inefficient governance

Lack of efficient governance constrains the possibilities for governments and stakeholders to address the issues. The root causes outlined above are further aggravated due to a lack of efficient governance to address the causes and to overcome the problems in a comprehensive way. Well-intended, but unfocused and uncoordinated donor projects have not been able to seriously reverse the downward trend. The Niger Basin is characterised by severe conflicts and mismatches between economic development and protection of the productivity of the aquatic ecosystems. These conflicts are local, regional, as well as international. Under such conditions, the lack of an efficient governance system is critical, if sub-optimal or even damaging activities are to be controlled. In most countries of the Basin, the land is owned by the State, not by the farmers. There is an urgent need to reform and clarify this important issue of land tenure. Proper governance is particularly critical in the case of protection of the productivity of the aquatic ecosystems, but is low on the national and international agenda. If the land resources are mismanaged, there is very little potential for water resource managers to respond efficiently. Unfortunately, there is a lack of specific documentation and monitoring of the complex interactions between the socio-economic parameters and how they impact on the land and water resources. Also, the lack of involvement of all relevant stakeholders in a transparent co-operation makes it difficult to make effective policy implementation, not least at the local level, where the need for action is the greatest.

Summary of the causes of ecosystem depletion in the Niger Basin

The immediate causes of the ecosystem depletion in the Niger Basin were primarily associated with three main issues:

- Reduction in stream flow due to climatic change has had a significant impact on one of the basic parameters in the fragile aquatic ecosystems in the arid regions of the Basin. Also, reduction in flow at the outlet has had impacts on the coastal ecosystems and their productivity;
- Increased sediment loads have changed the water quality and the sedimentation patterns in flood plains, lakes and wetlands. Important species and sources for protein have been affected by this;
- To a minor extent, increased nutrient levels and the occasional occurrence of pesticides have caused impacts on the aquatic environment.

The root causes behind these sector causes were identified as:

- Adverse climate change has further reduced the already low productivity of the arid lands of Sahel;
- Population growth has significantly increased the per capita pressure on the natural resources;

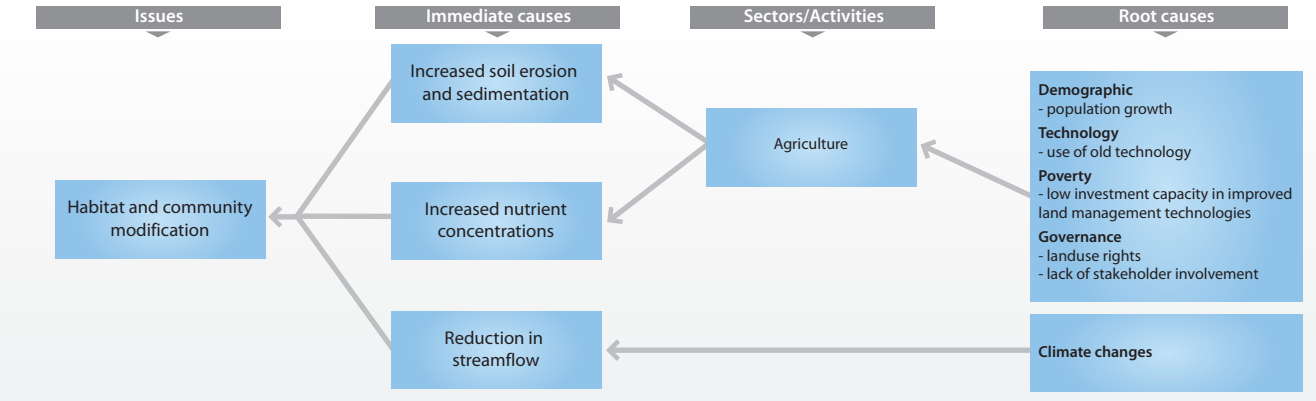

Figure 38 Causal chain diagram illustrating the causal links of ecosystems depletion in the Niger Basin.

- Lack of technological innovation has led to unsustainable land management practices;
- Poverty limits the populations potential to address the degradation efficiently;
- Lack of efficient governance constrains the possibilities for governments and stakeholders to address the issues.

It is apparent, that the root causes are primarily of a systems nature, and they are to a relatively limited extent related to any perceived lack of project investment and funding.

The links in the causal chains are schematically outlined in Figure 38.

Eutrophication: Case of the Comoe Basin

Introduction

The Comoe Basin has been selected as a typical example of an international river system in West Africa impacted by excessive enrichment of nutrients (i.e. phosphorus and nitrogen) in the water, giving rise to proliferation of aquatic plants and algal blooms in the lagoons and along the shoreline, near the outlets of eutrophicated rivers. This type of pollution, called eutrophication, was studied thoroughly within the frame of the GEF/UNDP biodiversity project "Control of exotic aquatic weeds invading the water bodies of Côte d'Ivoire to enhance/restore biodiversity".

It is an international problem since the algal blooms occurring in Ghana, are thought to be provoked by eutrophication of rivers from Côte d'Ivoire (Bia, Tano and Mé rivers) carried towards east by the coastal currents.

System description

The Comoe River Basin is described in detail the first section of the report. The total catchment is 78 000 km^2 and it is shared by four countries: Côte d'Ivoire (58 100 km^2), Burkina Faso (16 900 km^2), Ghana (2 300 km^2), and Mali (700 km^2). One of the special features of the Comoe River is the mobility and variability of its bifurcated mouth.

Since the opening of the man-made Vridi Canal in 1951, the natural outlet in Grand-Bassam became intermittent (it has been closed for many years now). The new outlet of the Comoe River is now the Vridi canal, which is located approximately 40 km west from the natural outlet of the River in Grand-Bassam. Another consequence of this change is that the Comoe river flow now receives the waters of four coastal rivers before arriving at the ocean shore: Mé River, Bété River, Djibi River and Agnéby (or Agbo) River.

The Mé River is now a right bank tributary of the Comoe River, into which it flows after having traversed the Potou Lagoon. The Mé Basin is a small agricultural basin in the proximity of Abidjan. The heavily eutrophicated waters of the Mé River are permanently invaded by water hyacinth (*Eichhornia crassipes*). The interest of this basin is that it has been the object of a computer model of exchanges between lands and waters in the framework of the aforementioned GEF/UNDP project.

Water quality assessments have been carried out, based on systematic measurements in the Basin, and compared to computer calculations with the DHI Mike Basin Model, using available information on point sources, population, livestock, use of fertilisers, rainfall and run-off in the Basin.

The model includes a description of the degradation of water quality in the River, as a function of BOD (Biochemical Oxygen Demand), ammonium, nitrate, time and temperature.

Immediate causes of eutrophication in the Comoe Basin

Running and calibrating the Mike Basin model of the Mé Basin has permitted the drawing of the following conclusions regarding the immediate causes of eutrophication.

The discharges of nutrients to the water include: load from people living in the Basin, load from livestock, and load from fertilisers. Additional short-term inputs are due to deforestation practices entailing burning of vegetation followed by intense erosion of arable land including its organic matter. Besides eutrophication, these practices are also responsible for turbidity.

The specific quantities released by each category are well known and used as calibration factors in the model. But the quantities arriving into the rivers are a function of drainage systems, agricultural practises, nature of the soil in the given area and of the distance (i.e. the time) the nutrients have to travel from their source to the water way. Table 39 and Table 40 respectively show the factors of emission of nutrients from human beings and animals, and the total loads of nitrogen and phosphorus calculated in the Mé catchment.

No point source (such as an agro-food plant or sewage discharge from a city) is present in the Mé catchment. However, these types of sources

Table 39 Conversion factors used in the DHI Mike Basin model: specific nutrient loads released by humans and animals by year in the Mé catchment.

	N (kg/unit)	**P** (kg/unit)	**BOD** (kg/unit)
Humans	5	0.5	14
Cattle	51	20	-
Pigs	20	7.4	-
Sheep/goats	33	7.4	-
Poultry	0.43	0.23	-

(Source: DHI Water & Environment 2002)

Table 40 Computed total loads in nitrogen and phosphorus in the Mé catchment using the DHI Mike Basin model.

		Fertilisers	**Animals**	**Domestic sources**
N (kg)	Abidjan	455 471	7 165 751	981 211
	Adzopé	129 279	17 978 928	336 767
	Alépé	499 338	20 421 778	693 049
P (kg)	Abidjan	1 269	2 189 072	112 138
	Adzopé	101 023	5 421 627	38 488
	Alépé	294	6 152 015	79 206

(Source: DHI Water & Environment 2002)

are present in the Banadama River catchment (to the west of Abidjan) and their relations to eutrophication have been studied through the same computer model (DHI Water & Environment 2002).

The fertilisers only represent a small fraction of the nutrients in the Basin compared to animal and domestic sources. The majority of nutrients are used in the growth of annual crops that fix the nutrients quite well, as long as the fertilisers are not added in too large quantities and are not washed out just after spreading.

The model indicates that the input of nutrients increases with the population density. This is particularly significant when comparing the northern with the southern parts of the Mé Basin.

The model calculations seem to indicate that the input of nutrients coming from non-point sources is presently limited. The transport coefficients are not elevated. Nevertheless the discharges resulting from human settlements and animal excreta seem to be the main source of observed nutrient concentrations in the River. It is thought to be most likely that a significant part of that source is caused by direct inflow that could be avoided by placing water holes away from the riverbanks and by ensuring that human excreta cannot enter the water directly.

It is however possible that the significant nutrient load has rocketed along with the deforestation (very intense in the late 1970s and early 1980s) because of erosion of formerly vegetated soils having high contents of nutrients and ashes originating from burning. Per hectare of deforested land, the additional discharges of nitrogen and phosphorus due to erosion are of the same order of magnitude as all other sources combined. The discharge of phosphorus from newly cleared land is 6 to 7 times higher than the actual average discharge of phosphorous.

Another conclusion of the modelling study is that for sites having the highest concentrations of suspended solids, the content of chlorophyll a is low. This relation indicates that the phytoplankton growth is limited by the dimming of light because of the suspended solids at many stations. The suspended solids increase the turbidity and limit the penetration of light into the water. Without light, the phytoplankton cannot fix the nutrients and this thus enables invasion by waterweeds, the growth of which is not limited by turbidity since they absorb light directly from their aerial leaves.

Root causes

The immediate causes of eutrophication in the Mé Basin (applicable to most basins in the region) are thus the following:

- Non-point sources:
  - Human excreta and lack or failure of sanitation systems;
  - Animal excreta in proximity to river courses;
  - There is still weak (permanent) erosion on cultivated fields, but inputs due to erosion are significantly higher in the periods of intense deforestation or just after bush fires;
  - Misused fertilisers yielding higher inputs to the water system, combined with miscalculated compositions and incorrect spreading periods. However, the overall use of fertilisers in the Guinea Current region is low since financial constraints impede regular use as seen in the developed countries.
- Point sources:
  - These are not observed in the Mé Basin but their effects have been assessed in the neighbouring Bandama Basin. Here agro-industrial units and dense human settlements use the natural water system as sewers.

The root causes can be subdivided into the following categories.

Demographic

The eutrophication is proportional to the density of population in the catchment. Moreover according to the Comoe Basin team the impact of human excreta is aggravated by the lack (or failure) of sanitation systems.

Knowledge

Inadequate knowledge about the use of fertilisers contributes to increasing the nutrient loads in the waters. Failures in sewage systems have the same effects. Many awareness-raising campaigns have been

organised in West Africa to combat bush fires. But, until now, the rural populations have inadequate understanding of the causal chain starting with their agricultural practices leading to the invasion of water bodies by the aquatic weeds.

Poverty

The method used to clear the vegetation before cultivation (bush fires) is typical among poor farmers applying the most economic method they can find. The effects are generally that: (1) the surface cleared is larger than necessary, and (2) the discharges of organic matter to the rivers provide nutrients that cause eutrophication of the waters.

Socio-cultural

Clearing the vegetation by using bushfires occurs not only for economic reasons. It is also a general practise in the region and it comes with other traditional (but illegal) activities such as poaching of animals fleeing the fire. The presence of aquatic weeds is considered to have supernatural causes, while the scientific explanations are difficult to understand/ believe for rural populations.

Legal

Generally farmers in the region are not the owners of land. The consequence is that they do not bother about the sustainability of their practices. The discharges from agro-industrial plants are not estimated in the context of Environmental Impact Assessments (EIAs) and are not controlled by environmental audits.

Governance

This is a key root cause since it has been assessed by the GEF/UNDP Aquatic Weeds project that the best way to reduce eutrophication (and to limit aquatic weeds proliferation) is to have sound environmental management of the catchment, following IWRM (Integrated Water Resources Management) principles. Land and water have to be managed together, using a participatory approach associating all stakeholders in the catchment: e.g. farmers, herdsmen, fishermen, heads of villages, elected representatives and industrialists. This is not the case in most of the basins of the region where IWRM is still an objective, not a reality. The statutes of the catchment management bodies must be embodied in the institutional framework and the opportunity for their establishment must be accommodated by law. The way the catchments have to be managed must be part of the water policy.

Summary of the causes of eutrophication in the Comoe Basin

Figure 39 summarises the Causal chain analysis for eutrophication in the Comoe Basin, linking eutrophication with immediate causes, and immediate causes with root causes, as presented here above.

Chemical pollution: Case of the Guinea Current LME

Introduction

The Guinea Current Large Marine Ecosystem (GCLME) is a typical example of an international marine area impacted by land-based pollution.

While most impacts are localised, the problems are common to all the 16 countries bordering the LME and require collective action to address

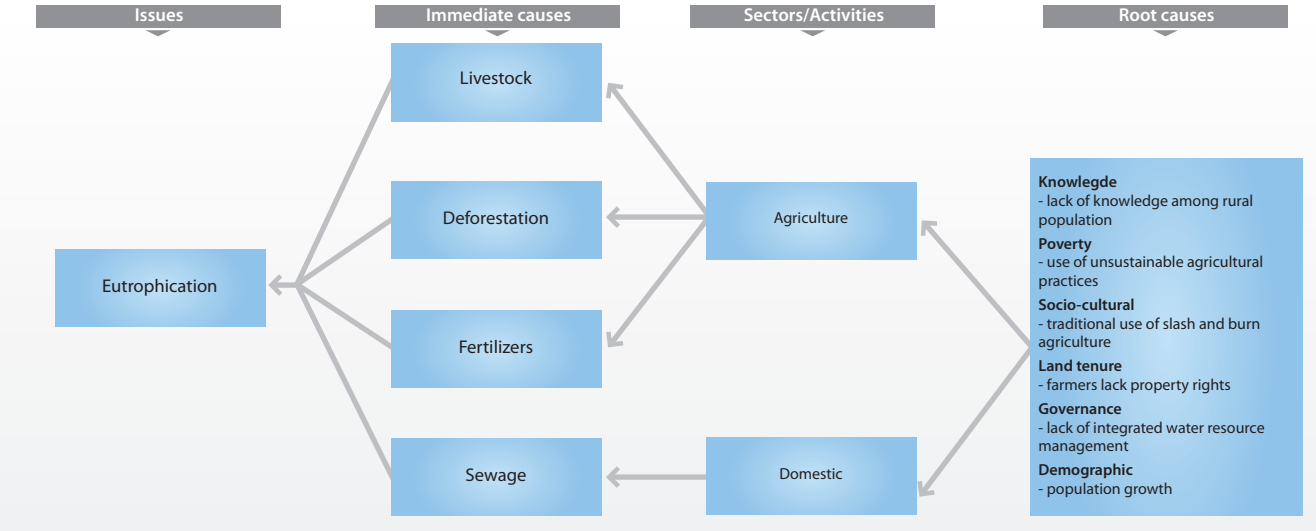

Figure 39 Causal chain diagram illustrating the causal links of eutrophication in the Comoe Basin.

the pollution from municipal, industrial and agricultural sources. For example, eutrophication and algal blooms are a common problem in most of the countries (see previous sections) and require collective (or at least co-ordinated) action.

Heavy metals originate mainly from mining and other land-based industrial activities. The rivers transport them to the Ocean, either directly or via the coastal lagoons. When arriving in the Ocean, the pollutants drift to the east with the Guinea current and spread throughout the entire LME thereby contributing significantly to the global pollution loading in international waters.

This is the reason why, among the different types of pollution inventoried in the region, chemical pollution is considered to be one of the most critical international issues, due to its long-distance and long-term impacts.

System description

The studies conducted on the Guinea Current LME show significant levels of pollution regarding pathogens and microorganisms in sewage, industrial effluents with high organic loading and hazardous chemicals, heavy metals, oils and hydrocarbons and tarballs on beaches. Among these issues, that of chemical pollution by heavy metals is considered to be particularly critical as an international issue for various reasons:

- Heavy metals concentrate along the food chain until the final link i.e. human beings. The corresponding health hazards are important and the consequences, in socio-economic terms, are severe.
- Heavy metal pollution has long-term and long distance impacts. Therefore, it is typically an international issue contrary to organic pollution or microbiological pollution, which remain confined.
- Heavy metal pollution is typically a land-based pollution, contrary to hydrocarbon pollution that, to a great extent, has its origin in tankers emptying ballast water and from exploitation mainly at the mouth of the Niger River.

Generally, environmental stress from land-based sources and activities is globally considered to contribute about 70% of the coastal and marine pollution, while maritime transport and dumping-at-sea activities contribute about 10% each. The stresses arising as a result of interactive human developments and consequential increases in harmful impacts on the environment and natural resources of the Guinea Current LME were identified in the GCLME Transboundary Diagnostic Analysis (TDA) (GEF/UNIDO-GCLME Project 2003).

Immediate causes of chemical pollution in the Guinea Current LME

The immediate causes of chemical pollution by heavy metals in the Guinea Current LME were identified as follows:

- Discharge of effluent from industrial or craft activities (mainly surface treatment in urban areas, using silver, copper, chromium and cadmium);
- Release from mining (e.g. mercury used by artisanal gold miners);
- Discharge of solids (e.g. batteries containing mercury or lithium from domestic waste);
- Run-off and stormwaters causing leaching of landfills;
- Leachates from landfills, containing the solids quoted above, conveying the pollutants to surface waters and/or to groundwater aquifers. The pollutants originating from the solid waste are mobilised in the aquatic phase and enter the bio-geochemical cycle.

A study carried out on land-based polluting industries situated within the 30 to 50 km strip of the shoreline in Côte d'Ivoire, Ghana, Benin, Nigeria and Cameroon (GEF/UNIDO-GCLME Project 2003) focused on the following categories of industrial plants: food manufacturing and beverages, textiles, chemicals, petroleum and petroleum products, pulp and paper, the metal industry and mining, wood processing and pharmaceuticals.

This study revealed the following as contributing factors to pollution in the coastal areas:

- Absence of pollution abatement infrastructure in the region thus leading to uncontrolled discharge of untreated effluents and wastes;
- Absence of common effluent discharge standards;
- Absence of Environmental Impact Assessments (EIAs);
- Insufficient human and material resources assigned to monitoring of the environment;
- Inadequate financial resources for implementation and compliance enforcement of regulations where they exist;
- Insufficient public awareness and concern about pollution issues due to poverty and its related hardship.

Root causes of chemical pollution in the Guinea Current LME

The origin of immediate causes mentioned above is a matter of a number of various root causes that, combined together, lead to the actual situation.

Technological

Often the processes used by industry and mining in Africa are not up to date. They utilise polluting methods and machinery. Financial constraints

do not allow replacement of old installations with modern more efficient ones. These technological causes are encouraged due to the absence of environmental controls at all levels of industry and mining (this root cause is also combined with some of the following root causes).

Knowledge

Industry technicians are not trained in clean technologies and they are generally incapable of relating their professional activities to the proximal or more distal environmental degradation. They have not been trained in the understanding of the sanitary threats posed to aquatic life or its dependants while on the other hand the population are not aware of the dangers they face. Environmental monitoring is weak and systematic measurements of pollution levels in water, sediments, fish and crustaceans are not practised.

In Côte d'Ivoire, where the larger part of the Comoe Basin is situated, the National Observation Network (RNO-CI), financed by Danida[12] from 1990 to 1995 to establish permanent monitoring of the water quality, is not well functioning since 2000. The international programme GEMS/Water (Global Environmental Monitoring System) is no longer operational in the region. Although analyses exist, there is no intercalibration between different laboratories allowing direct comparison of the results, within one country or from one country to another. Under these conditions, it is difficult to judge where the situation is the most severe and to prioritise actions.

The existing data is not brought forward to the decision makers, and the politicians themselves are not surrounded by technical advisers who could be capable of: (i) interpreting the data; (ii) understanding the situation; (iii) forwarding the conclusions to the level of the policy makers; and (iv) proposing how to include this important information in the decision making. At this point, root causes associated with lack of knowledge among the decision makers are closely linked with root causes related to poor governance.

Governance

The governments of the region only devote very limited budgets to monitoring of the environment. The taxes imposed on polluting installations are merged into the (often in deficit) national budget. The corresponding incomes are not fully allocated towards environmental restoration. Examples of misappropriation of funds have been reported; payments for fraudulent invoices for lab furniture, payments for monitoring missions that never took place, and procurements by institutions dealing with environmental protection of equipment or material that does not serve its core function.

Knowing the shortcomings of the controlling administration, industry managers realise that it would be difficult to make their installations compliant with the law. They often prefer to avoid the controls by paying small sums to the controllers instead of investing large sums in new environmentally friendly installations.

Environmental impact assessment studies and environmental audits are not systematic, even though they are inferred by law. Special procedures for delivering "priority agreements" to key investors, as they are generally seen in most of the countries of the region, have been designed to improve and facilitate foreign investment. These sometimes have the effect of increasing the pressures on the environment by authorising the operation of installations that would be prohibited in the developed world.

The population is not associated to the EIAs and is not consulted with respect to what nuisance they may be exposed to. The only way unsatisfied people can make their voice heard is to use physical measures like blocking the entrance of a factory or a mine. This was the case when the Maféré gold mine in Côte d'Ivoire caused massive fish-kills in the nearby river. The artisanal gold miners deploying large quantities of mercury for the fixation of gold often manage to stay out of reach of the authorities. Their number is unknown as is the quantity of mercury they disperse into the environment.

Efforts of one country are seldom co-ordinated with the neighbouring countries. Improvements gained with difficulty in country-A can be annihilated by the transboundary pollution resulting from the degradation of the situation in neighbouring country-B.

Chemical pollution issues have by the way been outlined and analysed in the National Environmental Action Plans (NEAP) that all countries made during the 1990s. Measures have been proposed to suppress, mitigate or compensate the identified environmental damages (through action programmes, projects, budgets). One is forced to realise that in the countries of the region, most of the projects suggested in the NEAPs have not been implemented and most of the projects that have been implemented over more than 10 years are not the ones proposed by the NEAPs.

It is also well known that a number of projects aimed at protecting the environment have not had the expected outcomes. Despite the lack of results, some of them were positively evaluated. It is often the practise to distribute significant daily allowances to participants in project-funded meetings. In this way meetings have often been positively appreciated by the attendants, even though results are insignificant.

[12] *The Danish international development assistance*

Environmental laws are in place in most countries of the region, but they are rarely applied for reasons generally related to the absence or the imperfection of the implementation texts (e.g. regulations), which can present various errors:

- The regulations have not been approved (many countries do not have application decrees of the environment law/code);
- The regulations are not precise (for instance by not saying who is in charge of filing offences);
- The regulations are contradictory (for instance those dealing with EIAs and those dealing with investments);
- The regulations are incomplete, by leaving behind legislative voids;
- The regulations create overlapping responsibilities (for instance the responsibility of monitoring industrial plants is given both to the Department of Industry and the Department of Environment);
- The regulations are in contradiction with cultural traditions (see below).

The pressure groups that could change the situations (e.g. political parties, media and NGOs) are close to the sphere of power. The affected people (who are the first concerned) are not informed by the authorities about the risks that they face and have no idea of what to do to change things to the better.

Socio-cultural

The rules of modern societies addressing technical issues are often in conflict with traditions, religions and African life-style. Scientific facts are often in conflict with ancestral beliefs, which make the process of moving away from environmentally unhealthy practises very difficult. Socio-cultural constraints generally rarely constitute the root cause of pollution but can easily create a gap in its understanding (and therefore its remediation) by those who are responsible for the situation.

Poverty/Economy

Besides the societal handicaps, poverty is also an aggravating factor to pollution, since people or enterprises do not have the financial means to change their practises. They do not want to give up practises that are harmful to the environment but less costly for them, by adopting less harmful but more costly techniques (Reardon & Vosti 1995). Furthermore there are no dissuasive financial mechanisms (taxes) nor financial incentives (subsidies) that will make them change their practises. Adding to this, the prices of local products are often too low to permit sufficient revenue to be reinvested in pollution reduction. For example the illegal gold-washers in the southwest of Côte d'Ivoire sell their gold at less than half of the international market prices. Furthermore the buyers are often local authorities that in principal ought to respect the ban on black market mining. This clearly shows how linkages are direct between socio-economic and governance root causes.

Finally, as stipulated in all environmental laws, the laws do not apply to activities related to national security or war operations. Conflicts are thus doubly dangerous for the environment: first, environmental regulations do not apply to military activities and, second, they create areas that are beyond the law.

Summary of the causes of chemical pollution in the Guinea Current LME

The root causes of most of the environmental problems in the Guinea Current LME have principally to do with inadequate governance, non-compliance, ineffective monitoring and enforcement, inadequate technologies, lack of community support, and lack of legislation/regulation (Figure 40).

Moreover, addressing these root causes is made difficult by the paucity of reliable, detailed and historic scientific data on coastal, marine and freshwater environment in the Guinea Current LME.

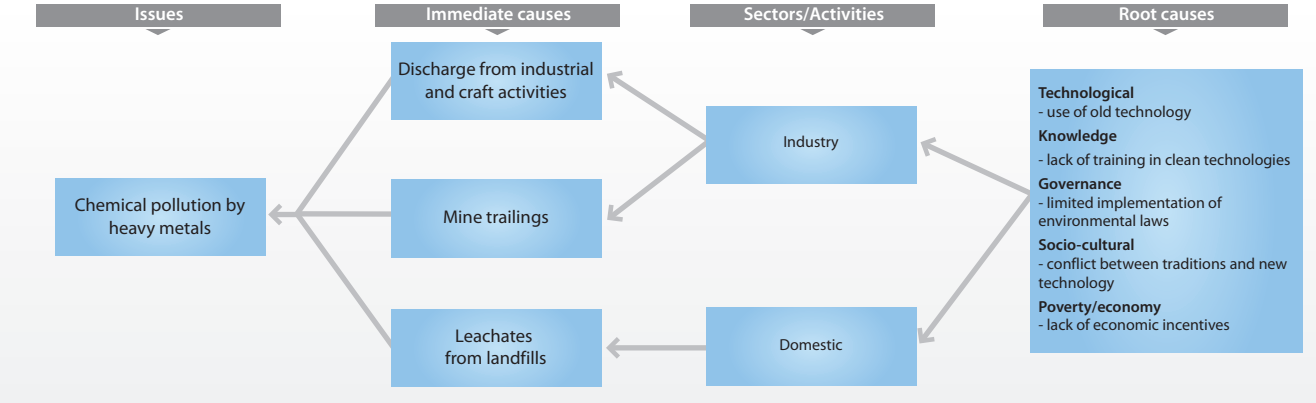

Figure 40 Causal chain diagram illustrating the causal links of heavy metal pollution in Guinea Current LME.

Overexploitation of fish: Case of the Guinea Current LME

Introduction

The rich fishery resources of the region are both locally important by having resident stocks supporting artisanal fisheries, and international important by having migratory stocks that have attracted large commercial offshore foreign fishing fleets from the European Union, Eastern Europe, Korea and Japan.

The Guinea Current Large Marine Ecosystem (GCLME) has been selected as a typical example of an international marine area where the depletion of fish stocks is becoming critical, first for people living around the LME, in terms of loss of income, and second for the international community, in terms of loss of biodiversity.

The major transboundary/international elements of the problem can be summarised as follows:

- Loss of income from regional and global trade of marine products;
- Region-wide decrease in biodiversity of the marine living resources, including the disappearance of critical natural resources;
- Region-wide destructive fishing techniques degrading habitats (including mangroves);
- Increasing catch effort on pelagic species such as tuna and sardinella;
- Non-compliance with the FAO Code of Conduct for Responsible Fisheries.

System description

The GCLME region, of high ethno-cultural and social diversity, is endowed with abundant renewable and non-renewable resources. The considerable natural resources of this region have not been optimally utilised for the enhancement of the quality of life of the people. Poverty, paucity of social infrastructure, disease and social instability are the major characteristics of this richly endowed region. Approximately 40% of the population in the region lives in the coastal areas and depend on the ocean and the lagoons, estuaries, creeks and associated wetlands and inshore waters surrounding them (GEF/UNIDO-GCLME Project 2003).

Several physical factors have an impact on the Guinea Current LME. These include: hydrography, especially temperature; salinity and other water quality parameters; tidal ranges; upwelling and thermocline regimes; topography, nature of bottom and trawlability; primary and secondary productivity; associated wetlands, lagoons and their estuarine products and services; terrigenous flush; climate evolution and variabilities; Inter Tropical Convergence Zone (ITCZ) movements, and wind forcing; as well as rainfall and drought cycles. Oil spillage and other marine pollution, marine debris in addition to nutrient enrichment and eutrophication are the major anthropogenic factors.

The various studies that have been conducted in the coastal and marine environment of the GCLME, within the framework of the UNIDO-GEF GCLME PDF-B project, indicate alarming rates of decline of fisheries resources i.e. the State of Coastal and Marine Environment of the Gulf of Guinea report, the Coastal Areas Profiles of the six Gulf of Guinea coastal states, the National Reports of the 16 countries bordering the GCLME, and the Regional Synthesis report summarising some of these studies.

Similarly, studies have also been conducted on marine fisheries resources of the Guinea Current region by CECAF[13], FAO and ORSTOM[14]. Marine environmental and pollution monitoring programmes have also been carried out by WACAF[15] in collaboration with UNEP, FAO and WHO. A review of the status of marine fisheries resources in 1994 indicates that apart from offshore demersal resources, all other fisheries in the region are near to full or fully exploited (Ajayi 1994). This has resulted in loss of food security and increased conflicts between commercial (industrial) and artisanal (community-based) fisheries.

In summary, it is recognised that the coastal and the marine ecosystem of the GCLME and its resources have witnessed various environmental stresses as a result of the increasing socio-economic and unsustainable developmental activities. All the above studies and assessments have identified three broad coastal and marine environmental problems and issues in the GCLME region namely:

1) Fishery resources depletion and loss of marine biodiversity, treated in this section;
2) The decline of water quality due to land-based and sea-based human activities;
3) Physical degradation, alteration and modification of habitats/ecosystems and coastal erosion. This is not treated in this synthesis report but constitutes significant issues in the GCLME.

Immediate causes of overexploitation of fish in the Guinea Current LME

The immediate causes of overexploitation of fish in the Guinea Current LME were identified as follows:

Increased fishing effort.

CECAF[13] assessed the biomass of the small pelagic species in the western and central Gulf of Guinea as 392 000 tonnes. The current level of exploitation in the area is about 257 000 tonnes annually clearly

[13] Fishery Committee for the Eastern Central Atlantic. [14] Ex-Office de Recherche Scientifique et Technique por le Développment (now IRD). [15] West and Central Africa

showing overexploitation. Significant changes in species composition have occurred over time as a result of overexploitation of several demersal and pelagic fish species, especially by foreign trawlers in the offshore areas. Recent trawl surveys conducted in Ghana showed that significant changes were occurring in the demersal fish biomass in terms of distribution, abundance and reproductive strategy (Koranteng 2001a and b). The exploitation rate applied to cuttlefish stocks has been increasing since 1984, and by 1990 was considered to be equal to, or slightly above, the optimal fishing effort. The rate of growth of these organisms appears faster than previously estimated (FAO 1997). Such changes in fishery patterns appear, in part, to be related to overfishing, as evidenced by a decline of Catch per Unit Effort (CPUE), and the catching of young immature fish.

The demand for high quality fishery products and ornamental species has also contributed to the overexploitation of lagoon and coastal resources.

Shift in biomass distribution.

Environmental changes manifested a periodic variability in water temperatures and coastal upwelling intensities play a role in coastal pelagic fish abundance fluctuations. Shifts in biomass appear to be connected to a shift in the boundary of the Guinea Current. These alterations have been linked to oceanographic changes including the southward displacement of the ITCZ during Atlantic El Niño events.

Root causes of overexploitation of fish in the Guinea Current LME

The causal chain of the decline of commercial fish stocks and the non-optimal harvesting of living resources in the GCLME were analysed in the frame of the TDA of the GCLME project (GEF/UNIDO/GCLME 2003).

The main root causes were identified as follows:

Knowledge

Inadequate knowledge of the complexity of ecosystem and high degree of variability, and insufficient capacity development (human and infrastructure and training) contribute to overexploitation of fish.

Governance/Legal

Lack of efficient governance and legislation is mainly caused by: poor legal framework at the regional and national levels; inadequate implementation/enforcement of available regulatory instruments; inadequate financial mechanisms and support; insufficient public/stakeholder involvement, and lack of co-management.

Figure 41 summarises the causal chain analysis of the decline of commercial fish stocks and the non-optimal harvesting of living resources in the Guinea Current LME.

Summary of the causes of overexploitation of fish in the Guinea Current LME

The Guinea Current LME supports significant international fisheries of importance for food security, and as a source of export income, for the countries bordering this region. The fisheries sector is very significant in the GCLME in the context of domestic food. Fish consumption is quite high in the region and contributes significantly to the protein intakes of its citizens especially in coastal communities. Pelagic and demersal fisheries within the region are fully exploited evidenced by declining landings of many species. The drop in fish availability in the subsistence sector has led to the adoption of destructive fishing practices e.g. use of undersize meshes and blast fishing. Despite nutritional requirements and current population growth rates, the industrial (commercial) fisheries sector in the countries bordering the GCLME generally exports the trawl fishery products exacerbating the food security situation in the region.

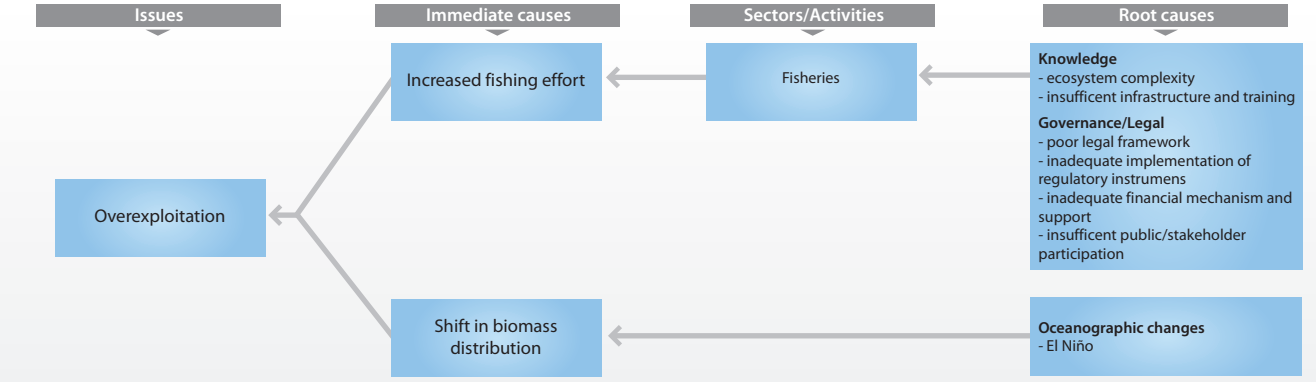

Figure 41 Causal chain diagram illustrating the causal links of overexploitation in Guinea Current LME.

Overexploitation of fishery resources may have impacts on the status of the coastal communities in a number of ways similar to those of modification/loss of ecosystems and destructive fishing practices.

The main root causes of this situation relate to the complexity of the marine ecosystem, to the lack of knowledge, the lack of (or the non enforcement of) legislation and regulation, and the economic conditions.

But all these root causes lead back to lack of governance, which is recognised as *the* key factor to be addressed to reverse the actual trends of degradation. Moreover, pressure on the coastal resources is likely to increase significantly in the immediate future since - on the basis of present consumption patterns and population growth rates - most of the countries (and especially large coastal cities such as Abidjan, Accra, Lagos, Douala) will need significantly more fish to sustain domestic demands.