Annex 14 - Risk assessment and sectoral vulnerability analysis

The below summary provides an overview of key findings of the sectoral vulnerability studies undertaken under the Scientific Support Project for the National Adaptation Plan Process (PAS-PNA) in support to the development of the National Adaptation Plan (NAP) in Benin (2021). These studies (full reports are also enclosed to the funding proposal - French versions), were used as one of the key resources to develop the climate rationale of the LoCAL programme and its localized interventions in target departments, aligning national adaptation priorities and supporting their localization into local development plans to respond to specific local needs.

Executive Summary - Sectoral Vulnerability Analysis Agriculture

Benin, like other West African countries, is suffering the adverse effects of climate variability and change, the manifestations of which are reflected in the accentuation of variability and the recurrence of extreme weather events (devastating floods, long droughts, heat waves, torrential rains etc.). Some pessimistic projections announce a continuous drop of 10 to 20% in rainfall by 2025 and a drop in agricultural production of around 23% by 2020 in certain regions of the country. The objective of the study is to assess the vulnerability of agriculture to climate change, in particular current and future vulnerability (horizon 2050) in Benin. The work was carried out by an interdisciplinary team of Beninese researchers with the technical and scientific support of Climate Analytics and the Pôle de Développement Agricole IV (PDA IV), which encompasses a large part of the Agroecological Zone N°5 and part of the Agroecological zones N°3 and N°4. The study is based on the defined impact chain approach in which vulnerability is seen as a function of exposure, sensitivity and adaptive capacity. The data analysis consisted in estimating the different parameters of the impact chain and evaluating the degree of current and future vulnerability of the different systems. To this end, several methodological approaches were combined from the climatic, agronomic and socio-economic angle.

The results of the study show a significant interannual variability of precipitation with a slightly decreasing trend. As for rainfall, the results also show interannual variability in average temperatures (from 27 to 29°C) with a clear upward trend in the study area. The analyses underline when the exposure, sensitivity and adaptive capacity indices are aggregated for the sample communes and areas analysed under this report, the Communes of Savalou, Tchaourou, Dassa-Zoumè, Glazoué and Copargo are the most vulnerable to climate change. Compared to the assessment of the future vulnerability to climate change in the agriculture sector, the results of the simulations show a significant inter-annual variability of the simulated precipitation by 2050. The number of years with deficit precipitation will increase in the future, with the municipalities of Copargo, Djougou and Ouaké which will be the most affected regardless of the model considered.

The simulation results indicate an increase in the average temperature by 2050 over the entire study area regardless of the model considered. The results of the simulations show that climate change by 2050 will not have a major impact on the sown areas of crops such as corn, cotton, and soybeans. Under the effect of climate change, maize and cotton yields could decrease significantly, by up to 30% for maize and 20% for cotton. Faced with the consequences of climate change on the means and livelihoods of rural populations, communities have often initiated endogenous strategies including staggered sowing, the use of short-cycle varieties, the development of lowlands, the use of fertilizers, diversification of sources of income, etc. But in practice, these adaptation strategies still remain fragmented with small-scale impacts (generally at the

household level) due to the limited resources of the communities. The avenues identified in this report could help build resilience capacity at scale, at the level of rural communities.

Executive Summary - Sectoral Vulnerability Analysis Forestry

The forest cover of Benin according to the FAO in 2010, is estimated at 4,625,000 ha, or about 42% of the national territory. The State's forest domain is structured into a classified domain and a protected domain. The classified area includes three national parks (Pendjari National Park, W National Park and Mono Delta), wildlife reserves (420,000 ha) and 58 classified forests and reforestation perimeters (1,436,500 ha). In terms of current vulnerability, forest resources have for several decades been subject to severe degradation under the effect of anthropogenic pressures (anarchic extension of agricultural and pastoral areas, soil impoverishment and change of land use, extension of cities and countryside, anarchic exploitation of service wood and wood energy, desacralization of classified forests). The major climate hazards with the greatest impact on forest ecosystems and riparian communities are floods, heavy rains and drought. The livelihoods most exposed to these risks include smallholder foresters and farmers. At the socio-economic level, urban and rural wood craftsmen, transporters, hunters, traders in wood energy and lumber and traders in non-timber forest products are more vulnerable in relation to access to basic resources. But in terms of access to social services, nurserymen are more vulnerable.

The assessment of future vulnerability in this sector was made on the basis of expert judgment. Among the potential impacts likely to affect the forest ecosystems of Benin, it is necessary to retain the decline of the gallery forests, the physiological and ecological dysfunction of certain forest ecosystems, the regression of the populations of characteristic ligneous species (Dialium guineense, Sclerocarya birrea , Afzelia africana, Diospyros mespiliformis, Daniellia oliveri, Gardenia erubescens, Vitellaria paradoxa, Berlinia grandiflora, etc.) of the country's major plant communities (forests and savannas), the reduction in the size of animal populations in national parks and the modification of the stand structure of certain plant and animal species.

It follows from the vulnerability analysis of this sector, four (4) adaptation options:

- Strengthening forest monitoring
- Improving forest governance
- Promotion of sustainable management of forests and protected areas
- Promotion of large-scale state and communal plantations based on
- native or local commercial species.

Executive Summary - Sectoral Vulnerability Analysis Water

This report thus aims to assess the vulnerability of the water sector to climate change in the Ouémé basin, which is home to about 40% of the population of Benin. The Ouémé River rises in the Atakora Mountains and is about 510 kilometres (320 mi) long. It is indeed the largest river in Benin and it crosses several agro-ecological zones and feeds downstream, the lagoon system ''Lake Nokoué-lagoon of Porto-Novo'' through a Delta zone.

This study focused on two (02) main axes, namely: (i) the assessment of the level of current and future vulnerability, faced with the risks of flooding in the Ouémé basin at the Bonou outlet; and (ii) assessment of the level of current and future vulnerability to water shortages in the Ouémé basin at the Savè outlet (essential for proper application of IWRM). The periods of 1970-2015 and 2016-2050 were retained for current and future vulnerabilities respectively.

The methodology developed consisted of (i) the definition of the chain of impacts (which revolves around the conceptual framework for the study of vulnerability to climate change), (ii) the identification and determination of indicators, and (iii) determining the level of vulnerability of exposure units. Various data were used, including historical climate data from the Benin Weather Agency (1970-2016), data from four regional climate models (ECEARTH, HADGEM2, IPLS and MPIESN, scenario RCP4.5), flow data from the DGEau, geospatial data (digital terrain model, vegetation map, soil map, etc.) and socio-economic data (poverty index, access to household information, etc.).

The results indicate that the Ouémé basin is very vulnerable to the adverse impacts of climate change both in relation to water scarcity and in relation to flooding. By 2050, a large part of the basin would be very vulnerable both to pluvial flooding and to probable water shortages. The communes most potentially vulnerable to pluvial flooding in the future would be those of Djougou, N'Dali, Pèrèrè and Ouaké in the north of the basin; the municipalities of Glazoué, Ouèssè, Savalou and Djidja in the center of the basin; Bohicon, Zakpota, Zagnanado, Zogbodomey south of the watershed. The municipalities in the deltaic zone, in particular Adjohoun and Bonou, will continue to suffer the horrors of river flooding in the absence of adequate infrastructure.

With regard to the shortage of water resources, the most affected localities will be the north of the commune of Djougou, Ouèssè and its surroundings. This vulnerability stems in particular from the low adaptive capacity of the populations in these regions of the study. Not having much leeway with regard to potential impacts, the effort must be concentrated on building the adaptive capacities of the populations through realistic adaptation options that would contribute to strengthening their resilience.

Possible adaptation measures to the probable increase in flooding in the future can be considered on several scales. These include adaptation options at the individual level (family or household), infrastructure and development, institutional (Langis, 2013). At the individual level, this will involve promoting adaptation options such as:

- the choice of construction techniques aimed at reducing damage by installing the buildings on stilts and ensuring the elevation of the dwellings which are particularly at risk of being flooded and the moving of houses, even agglomerations, most at risk of flooding on higher ground (with a possible public financial support);
- a judicious choice of agricultural and livestock practices favoring the maintenance of a plant cover on the ground, integrating anti-erosion practices and infiltration of water as well as water conservation and water management practices, etc.;
- the availability of climate information (weather forecasts).

With regard to infrastructure, it is necessary:

- Improve the rainwater management system so as to be able to manage floods water during floods;
- Develop and expand rainwater and waste water evacuation systems in order to increase the drainage capacity;
- Prioritize areas vulnerable to climate change identified in this study for urgent adaptation actions;
- Assess the resistance of infrastructures to extreme phenomena;
- Incorporate adaptation into the planning, maintenance and replacement of new or existing infrastructure;
- Define and popularize new sizing and construction standards that incorporate the impacts of climate change;

- Map the areas most at risk based on the places where floods have already occurred and determine the causes of these floods (poor maintenance, lack of drainage capacity...).

At the institutional level, the following actions will contribute to strengthening the resilience of populations to floods:

- The development of emergency management plans and local mitigation policies then training programs on how to prepare for emergencies;
- Government financial support for research on the management cycle of disasters;
- The strengthening of the early warning system in the event of extreme events by the provision of both financial and human resources;
- The revision of standards and criteria for the design of sanitation structures;
- Prohibition of new construction works in flood plains for reduce flood damage;
- The establishment of a permanent committee composed of the municipal council and representatives of Civil Society Organizations (CSOs) citizens to deal with climate change adaptation issues.

The sustainable management or development of water resources requires the implementation of actions concrete steps in the direction of developing documents or strategic orientation guides or areas of intervention, as well as the implementation of policies aimed at safeguarding and protecting water resources. For the water sector to best adapt to meet the challenges of climate change, vulnerable populations must be helped to increase their resilience to the climate risks and guidance on the main elements to take into account for the planning and implementation of actions in the sector, are among the main concerns about coping strategies. Added to this is the question of the valorisation of water, the most important role of which is in the management of demand and better allocation between uses.

Executive Summary - Sectoral Vulnerability Analysis Energy

The analysis of future vulnerability in the power generation segment focused on the exposure units that are the sites planned to house the power plants and production facilities. In the context of this study, this analysis has not been extended to the future availability of exploitable renewable energy resources (hydro, wind, biomass potential)

a) Site of Maria Gléta – Some is located in an area that experiences annual flooding during the rainy seasons.
b) Ouémé and Mono watersheds will be affected by the probable decrease in precipitation that could lead to a decrease in the hydropower potential exploitable at the level of these basins. However, we must not rule out seasonal increases in precipitation causing strong temporary increases in flow rates at the level of the Ouémé and Mono watersheds with the corollary of the rise in water levels at hydroelectric dams.
c) Sites to house solar power plants could be exposed to risks of strong winds, particularly in the northern region of the country.

Climatic risks can have an impact on the transport and distribution of electricity, as well as on the transport of liquid petroleum products, gas and firewood, charcoal and certain agro-food processing residues. The development of electricity transport and distribution networks depends on the evolution of demand and the effective implementation of means of production to meet this demand. The increase in demand is the result of the socio-economic evolution of the country which leads to an increase in consumer needs. High winds, lightning, conductor vibrations, avalanches, and flooding could cause power transmission and distribution lines to fail. Extreme temperatures could create overheating within the transformers causing failures in their operation. Strong winds could cause trees to fall into electrical networks. Floods could weaken the

foundation structures of electric poles and cause them to fall. Intense heat could disturb the conductivity of the lines and negatively affect their performance. Extreme events would be likely to increase the risk of failure of power transmission and distribution lines, preventing electricity from reaching its users.

At the communal level, adaptation measures that can support adaptation are identified in terms of (northern departments mainly):

- Promotion of mini solar power plants and promotion overall of renewables,
- Rehabilitation of existing power plants,
- Provision of individual solar kits (through subsidized vehicles/with partners support),
- Promotion of biogas in households,
- Develop micro hydroelectric dams,
- Realization and popularization of improved stoves,

Executive Summary - Sectoral Vulnerability Analysis Costal Areas (Mono-Couffo)

Benin's coastline is limited to the coastal marine domain and the coastal plain, including their intracontinental extensions. It extends over a length of 125 km. The littoral zone is confined to the departments of Atlantique and Littoral, departments of Ouémé and Plateau, and the departments of Mono and Couffo. It is a sensitive area in which many economic activities have developed (fishing, agriculture, commercial activities, leisure, tourism, etc.) allowing the population to derive most of its subsistence. It is full of socio-economic and administrative infrastructure such as schools, health centers, shopping and hotel centers, ministries, etc. This area is today weakened and threatened by natural hazards (coastal and marine risks), rising sea levels, increasing urbanization, etc.

The littoral zone is characterized by a dynamic that is very sensitive to disturbances, whether of natural or human origin. It has one of the highest rates of coastal erosion recorded in the countries of the Gulf of Guinea, with a decline in the coastline of up to 12 to 30 meters per year at the most critical points. Alongside these current risks, the coastal zone is also threatened by the rise in sea level. The most exposed economic activities are fishing, agriculture and tourism. According to the impact indicators, two major risks, namely floods (rain and overflows) most affect livelihoods (fishermen, market gardeners, breeders, farmers, in particular). Among the impacts attributable to these current climatic risks, it is necessary to note the destruction of habitats and property, the degradation or even the destruction of road infrastructures/structures, the decline in tourist and leisure activity, the development of disease vectors and deterioration of the quality of drinking water. The indirect consequences include the decline in income-generating activities, loss of employment and the proliferation of diseases (malaria, cholera in particular).

In the Beninese coast, the most relevant climatic risks identified are: drought, floods due to intense rains and due to the overflow of water courses), sea level rise, late and/or heavy rains, excessive heats. In Mono-Couffo impacts on livelihoods are mostly driven by floods (either by heavy rains or overflows) and affecting socio-professionals in general and farmers, breeders and market gardeners in particular.

More specifically, from the analysis of sensitivity to climate risks, it can be said that:

- Ecosystem services are most exposed to climate risks is terrestrial biodiversity. This sensitivity is lethal for mineral resources and hot springs;

- Other social services (in terms of provision) are not so very sensitive to climate risks;
- The livelihoods most sensitive to climate risks are agriculture, livestock, fishing/fish trading and market gardening;
- Groups most sensitive to climate risks are farmers, breeders, market gardeners and fishermen/fishmongers. These have great difficulty in accessing social basic services, making them even more vulnerable.

In terms of future vulnerability, potential impacts include:

- Exacerbation of the phenomenon of coastal erosion.
- Submersion of beaches (Cotonou, Ouidah, Grand-Popo in particular).
- Degradation or even disappearance of mangroves and associated ecosystems (central sector and western sector of the coast).
- Salinization of land, groundwater and surface water.
- Sedimentary deposits that can induce the raising (loss of depth) of the beds of watercourses (Ouemé River, Mono River).

These effects on the biophysical system could lead to very significant socio-economic impacts since they would notably affect a large population in both urban and rural areas, areas of agricultural land and would jeopardize economic activities, infrastructures and human settlements. These effects are, among others, the migration of the population, the accentuation of poverty, the drop in agricultural yields, the displacement of tourist attraction areas, the death of livestock and the impact on the country's economic growth.

Adaptation choices in the coastal sector will be conditioned by current policies and development objectives. Faced with major current and future climate risks that pose a threat to the coastal zone, it should be noted that adaptation strategies must take into account the nature and degree of persistence of each risk. Due to the cross-border nature of the risk associated with sea level rise, cooperation with neighboring States is an imperative.

The dynamics of the coastal environment requires an integrative management approach to this coastal ecosystem at all scales and components of the public authorities. An appropriate adaptation strategy will make it possible to minimize the negative impacts of climate change on the ecosystem. However, the adoption of a new management approach is necessary to best curb the degradation of land and marine resources. Also, it will be necessary to consider the need to establish an emergency plan comprising response measures to respond spontaneously to extreme events or dangerous phenomena in order to reduce the vulnerability of populations and minimize losses. This plan must be constantly updated in the light of scientific and technical progress.

Five (5) adaptation options arise from these considerations, namely: Option 1: Protection of the littoral zone Option 2: Integrated management of coastal ecosystems Option 3: Emergency measures plan Option 4: Retirement Option 5: Flood management.