Vulnerability and adaptation of communities to climate change: a Benin case study
Lower Ouémé Valley, Adjohoun District, Benin

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1.0 Introduction

The physical and socio-economic characteristics of the Adjohoun District in southern Benin mean it is disproportionately affected by variations in climate and is vulnerable to climate change[3]. This study identifies how both the biodiversity[4] within swamp forests and the communities living nearby are vulnerable to the effects of climate change. We also discuss adaptations measures at different levels of decision making.

The study methodology is based on:

- a literature review (document review, analysis of geographic and forest maps);
- climate data from ASECNA[5] and analyses;
- community perceptions collected via individual and focus group discussions (including farmers, fishermen, agricultural traders);
- analysis of past and present land occupation in the Adjohoun District;
- discussions with forest protection services (local and ministerial) and municipal authorities.
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Direct observations and photos complete the study.

In Benin, generations of farmers were managing biological diversity long before international institutions understood its value. But today, communities living near swamp forests in the Ouémé Valley in southern Benin are witnessing the loss of biodiversity as a result of climate change. We chose the Adjohoun District as the site for this study because the impact of climate change on biodiversity is particularly relevant here; the Ouémé River runs through the district and the area has many swamp forests. The local people are also easily reached.

[3] The concept of climate change and variability is defined here as *significant climate modification or variation, of natural or anthropogenic origin.*
[4] 'Biodiversity' means all types of life (animal and plant) in an environment.
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1.1 Local context and ecology

Located in the lower Ouémé valley, in the middle of the Ouémé department in south-eastern Benin, the Adjohoun District (between 6°36'–6°47'N latitude and 2°24'–2°34'E longitude) has an area of 308 square kilometres. It is bordered in the north by the Bonou District, in the south by Dangbo, in the east by Sakété, and in the west by Zè and Abomey-Calavi. The Ouémé River[6] crosses the district from the north to the south.

At the last population census in 2002, the total population was 56,455 with 48.14% men and 51.86% women (Institut National de la Statistique et de l'Analyse Economique), distributed in eight districts, or 'arrondissements' (see Table 1 and Map 1).

Table 1: Evolution of population in Adjohoun District

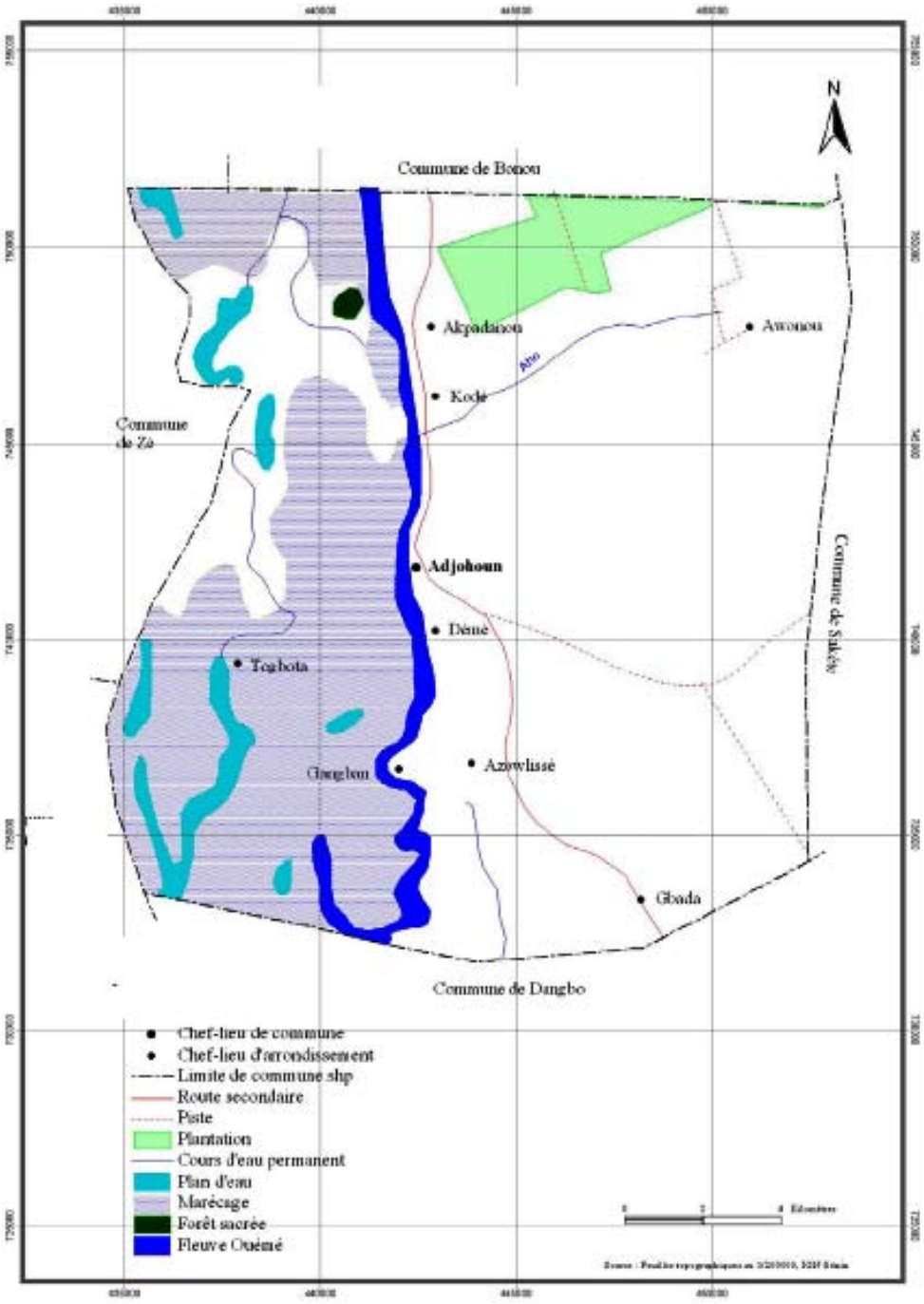
	Population			
Arrondissements	1979	1992	2002	2006*
Adjohoun	7620	7647	7623	8726
Akpodanou	4046	5793	6158	7649
Awonou	1378	3556	4173	4776
Azowlissè	12889	15173	16883	19324
Demé	1780	1719	1785	2043
gangban	8141	10261	11755	13454
Kodé	3700	4701	5289	6053
Togbota	2010	2363	2789	3192
Adjohoun District (Total)	**41564**	**51301**	**56455**	**64616**

*projection

Total human density (2002) is estimated at 198 inhabitants per square kilometre. Table 1 shows that the population is increasing; between1992–2002 the growth rate was less than 1%.

[6] Ouémé is the longest river in Benin (510 kilometres) and has the largest surface basin (45,000 square kilometres) (Pelissier 1963).

Map 1: Location of study area in Benin (in red)



Map 2: Adjohoun District, showing forest swamps ('marécage') and the Ouémé River

The district belongs to an area (agro-ecological zone VIII) designated as a "fisheries zone". It has a sub-equatorial climate, with approximately 250 days of rain distributed across two wet seasons. The first wet season runs from March to the end of July, and the second from September to mid-November. They are separated by two dry seasons.

The district has several types of soil: alluvial soils (made up of both small and large particles) which are fertile but liable to flooding, and sandy soils which are less fertile

but favourable for growing coconut and other tropical trees. Natural vegetation is composed of grassy savannah and swampy mangrove forest. The mangrove species include *Raphia, Rizophora racemosa* and *Avicenia africana.*

The local communities primarily engage in fishing along the Ouémé River and in agriculture. The farming population represents about 80% of the total population. Farmers grow corn, cassava, cowpeas, peanuts, leafy vegetables, palm and coconut trees, and also raise pigs. Village cooperatives process cassava and women smoke fish.

Despite the fertility of the lower Ouémé Valley, the region suffers from ineffective management of its natural resources, especially with regards to climate change. Development of the region is further stunted by locals migrating to the country's urban centres (Porto-Novo, Cotonou, Abomey) and to countries like Nigeria and Gabon in search of better jobs.

Group discussions identified the main environmental problems in agriculture and forestry as:

- the disappearance of certain plant and animal species (fish and mammals);
- the decrease of soil fertility;
- the destruction of trees (this happens for various reasons, for example when farmers claim new land for agriculture. Palm trees in particular are destroyed to produce palm wine).

These problems constitute a real challenge to the development of the Adjohoun District.

2.0 Changes in the local climate

Widespread ecological impacts of climate change are visible in most African ecosystems, especially those dependent on rainfall. People, plants and animals, as well as non-living components of the environment, are vulnerable. The people living in the lower Ouémé Valley, especially those from the Adjohoun District, have noticed some impacts on their natural and man-made systems.

2.1 Perceptions about climate change effects

We collected the following statements about evidence of climate change from locals during public discussions in the Adjohoun District.

> *Kossou Assogba, 76, a farmer who has lived in the Adjohoun District since he was born: 'Climate change appeared twenty years ago, when the rains came later compared with the thirty previous years. Some years, the rains begin and we start cleaning the fields and planting seeds, but then the rains suddenly stop for more than two weeks. The seeds are unearthed by rats, and consumed by bugs. Some years, seeds germinate but with the irregular rains small plants can't grow.'*

> *Kangni Bojrènou, 39, farmer and crop trader: 'In 1999, the flooding of the Ouémé River arrived early and flooded the maize fields.'*
>
> *Jean Houéssou, 56, fisherman: 'We have less and less fish in the stream in the valley. In the 40 years that I have been fishing, I have never seen it like this. We are obliged to fish for small fish, and to spend more time fishing.'*
>
> *Houédanou Bossa, fisherman and carpenter in Adjohoun city: 'Old trees and non timber products found in forest, which were used by our grandfathers and hold therapeutic properties and other values, nowadays don't exist or are disappearing. Some of these trees possess very woody trunks, but now we don't find them in our District.'*

Other statements confirm these perceptions, including the following collected from local Adjohoun people during a National Adaptation Programme of Action session[7].

> *Dah Gbèhouinnon, local leader: 'For some years, the rain hasn't fallen during ploughing. It falls when the plants are already dead. This rain is heavy and erodes the soil, which fills up the Ouémé River. Then the fish move away, into deeper waters. Farmers and the fishermen have all problems at the moment.'*
>
> *M. Sevrin Gnonlonfoun, district adviser: 'The two seasons of rain have a tendency to come closer, disrupting the natural cycle of living organisms. Animals and plants have disappeared as a result of a shorter humid and unsettled weather season.'*

2.2 Climate variability in the Adjohoun District and its effects

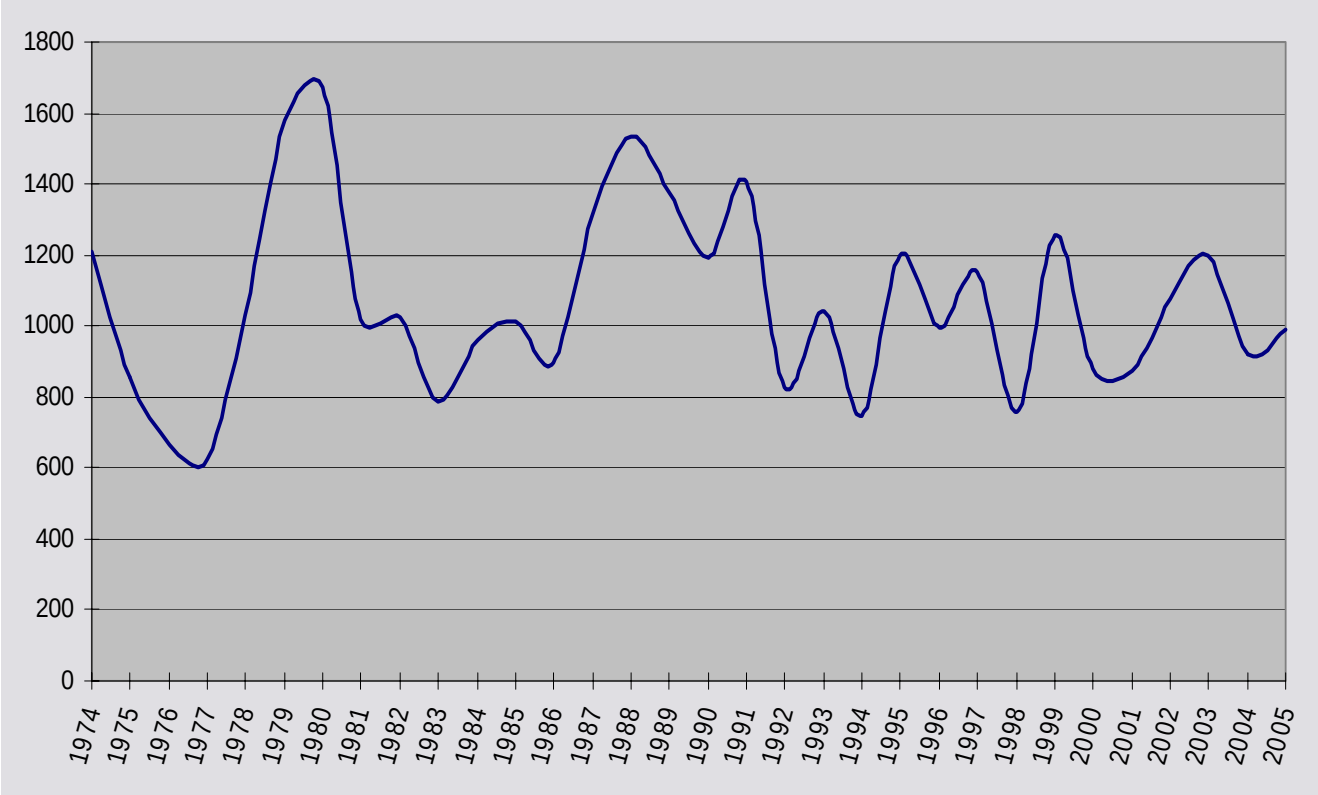
Rainfall analysis

We were able to access rainfall data for the period 1974–2005 (see Chart 1). Data analysis shows that annual rainfall has decreased in the Adjohoun District over the past 30 years, from 1674.2 millimetres in 1980, to 989.5 millimetres in 2005.

Since 1990, the region has suffered from insufficient rain; average annual rainfall is 993 millimetres (with a standard deviation of 167 millimetres) compared with 1100 millimetres (with a standard deviation of 321 millimetres) for 1974–1990. This situation is confirmed by the statements quoted above.

[7] The objective of this working session was to help populations in the Adjohoun district participate in an assessment of their resources and their vulnerability to climate change, and to identify adaptation strategies. Adjohoun's local authorities, religious chiefs and various farmer's associations attended.

Chart 1: Annual rainfall from 1974 to 2005 (in millimetres)

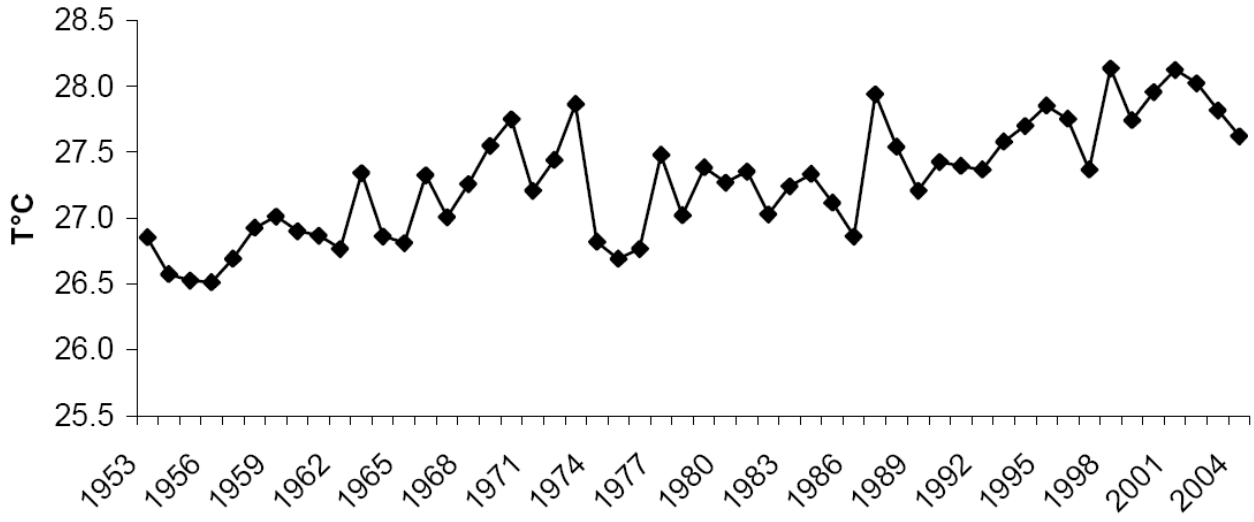


Source: ASECNA

Temperature analysis

Temperature data for our case study site were not available; we used data (see Chart 2) from a nearby site (Cotonou meteorological station) located in the same climatic zone.

Chart 2: Evolution of annual average temperature from 1953 to 2004



Source: ASECNA (Cotonou)

Average annual temperature varies between 26.1–28.1° Celsius. Data analysis shows a clear rise in temperature over the past 50 years. The progressive warming of the ambient air could be an effect of global warming.

The average daily temperature is 31.5°C during the day and 23°C during the night. The minimum daytime temperature is 22°C (August) and the maximum is 34°C (February). From December to February, there is a small drought; the Ouémé River dries and crops suffer from lack of water. Table 1 shows the drought period and rainfall deficit during November–April, compiled from data from 1974–1993.

Table 1: Estimated rainfall deficit (R–PET) in the Adjohoun District, with average monthly rainfall (R) and potential evapotranspiration (PET) (in millimetres) during the period 1974–1993

	Nov	Dec	Jan	Feb	Mar	Apr
R	38,29	16,12	6,2	22,74	60,67	116,15
PET	131,5	125	128,3	136,8	158,3	152,5
R–PET	-93,21	-108,88	-122,1	-114,06	-97,63	-36,35

According to the local water resources sector, water evaporation from the Ouémé River is higher today than 10 years ago. This has resulted in a decrease in the quality of available drinking water. Several districts, such as Akpodanou, have installed wells with the help of Benin's National Society of Water, but have had little success in improving water quality.

Health experts report that the increase in daytime temperatures has adversely affected children and old people in the Adjohoun District. They report that there has been an increase over the past 20 years of diseases such as Buruli ulcer and malaria. Diseases such as chickenpox, tuberculosis and skin diseases have decreased.

2.3 Sensitivity of livelihoods to climate risks in Adjohoun

By building a sensitivity matrix[8], the vulnerability of resources and human groups to climate change can be described. This exercise highlighted the following points:

- People agreed that the drought has the most significant impact on livelihoods (72%). Early flooding (68%) is next, followed by delayed and violent rains (60%), and violent winds and excessive heat (52%).
- The vulnerable resources and livelihoods, listed in order of importance, are:
  - Subsistence agriculture (76%);
  - Biodiversity and industrial agriculture (72%);
  - Land and water resources, cattle farming and human health (68%);

[8] The method compares vulnerable livelihoods and climatic risks. The horizontal lines of the sensitivity matrix are made up of livelihoods in the region, elements linked with productive activities, economic sectors, infrastructure and services linked to ecosystems. Columns of the matrix present the climatic threats (or opportunities) which influence vulnerable livelihoods. One of the objectives of the matrix is to show how thresholds of vulnerability vary from one livelihood to another.

- Human settlements, and roads and other infrastructures (55%).

- The livelihoods most exposed to climate risks are:
  - Small farmers and fishermen (72%);
  - Emergent farmers (64%);
  - Cattle breeders (60%).
- The livelihoods least exposed to climate risks are:
  - Traders and transporter (36%)

Because small-scale farmers and fishermen, the groups most vulnerable to climate change, make up more than half of the district's population, the need to support affected communities to adapt is urgent.

3.0 Changes in resources

There is evidence of major changes in livelihoods in many sectors in Adjohoun. These effects and changes, mentioned briefly in the previous section, are discussed here in more depth.

3.1 Resilience of ecosystems and loss of animal forest resources

In the Adjohoun District, forest biodiversity provides a large variety of food, medicinal plants, animals, wood for fuel, and construction materials. In turn, loss of biological diversity could mean a decrease in the productivity of the ecosystem, and a reduction in services and natural goods for locals who use the forest.

There is increasing proof that individual forest species of the Adjohoun fauna[9] are already being affected by climate change.

Five species of monkeys used to be common in the Adjohoun District. Two species still exist, resisting recent climate variations and forest degradation. Photo 1 shows one of these species, the red-bellied monkey, which is endemic to West Africa. This species is threatened with extinction.

Photo 1: *Zinkaka (Cercopithecus erythrogaster erythrogaster)* in Togbota forests (Adjohoun District)

[9] An evaluation of fauna richness in the lower Ouémé Valley is ongoing and will provide a basic inventory of wild species. Comparison with other available data will hopefully reveal the specific diversity of the region.

The following factors could contribute to the extinction of the red-bellied monkey:

- demographic pressure that creates the need for new space for extensive agriculture;
- a lack of understanding of the importance of the forests, especially the sacred forest in Togbota, which shelters this species.

According to fishermen, there is a general and continuing impoverishment of aquatic resources and fish diversity in the lower Ouémé Valley. This has affected households dependent on fishing activity, reducing their incomes by at least 40%. A direct consequence of the lack of fish has been a change in fishing techniques, many of which harm the valley's ecosystems. One technique, "Mèdokpokonou", in which fishermen use nets with small stitches so they can capture even the smallest fish, didn't exist twenty years ago when there was an abundance of fish.

Local fishermen have listed the following fish species as hard to find in the Ouémé River in the Adjohoun District: *Heterobranchus, Citharinus, Hydrocynus.* They list the following as disappeared: *Heterosotis*, *Sardinella*, *Lates* (barramundi), mullet.

Other factors could be contributing to the loss of fish in the lower Ouémé Valley, including the filling up of the Ouémé River with eroded and degraded soil, and the use of chemicals in agriculture in the north of the country[10].

3.2 Disappearance of plant diversity

Because the local people depend on many resources from the forest, the disappearance of plant biodiversity in swamp forests is particularly deplorable.

Table 2: Useful plants that are disappearing or have disappeared

Local name	Utility for populations	State in the district	Scientific name
Afintin	Construction material	Disappeared	*Rothmania longiflora (Rubiaceae)*
Botin	Construction material	Disappearing	*Cynometra megalophylla (Cesaelipiniaceae)*
Lètin	Medicinal (fevers)	Disappearing	*Rauvolfia vomitoria (Apocynaceae)*
Hètin	Medicinal (rheumatism)	Disappearing	*Fagara zanthoxyloides (Rutaceae)*
Djètin	Medicinal (psychic unrest)	Disappearing	*Diospyros mespiliformis (Ebenaceae)*
lokotin	Wood used for carving, medicinal (anti-asthmatic)	Disappeared	*Milicia excelsa (Moraceae)*
Gbègbètin	Medicinal (haemorrhoid and tiredness)	Disappeared	*Pterocarpus santalinoides (Papillonaceae)*

[10] The source of the Ouémé River is in the Donga Department, located at least 300 kilometres north of the Adjohoun District.

The biodiversity of this region has both cultural and aesthetic value to the local people. Add the role of particular plant species in traditional pharmacopoeia and in food security for the communities in the lower Ouémé Valley, and it becomes difficult to determine its financial value.

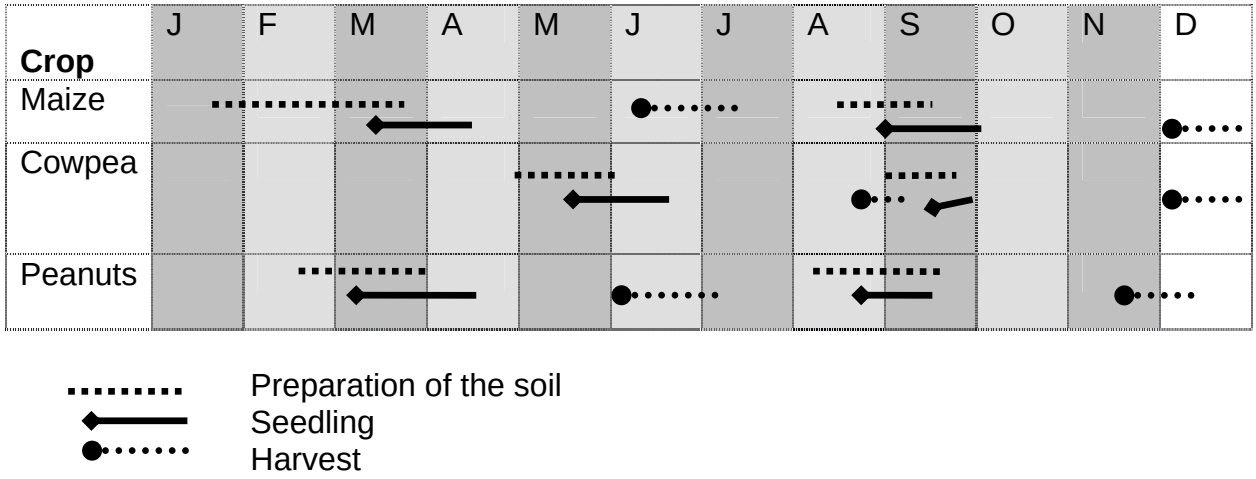
3.3 Recent changes in livelihoods

According to farmers and local authorities working in agriculture sector, for the past 20 years the delay of rains and unpredictable dry periods have meant a decrease in crop yields for crops such as maize, cassava, yams, peanuts and cowpeas. They report that the short rainy season (September–October) is often disrupted or may even be disappearing. Most of the peasants in the Adjohoun District agree that during this time, the households of the valley have been unable to satisfy their food needs. Nowadays, maize harvested on two Kantins[11] remains insufficient to feed a family. The problem is particularly acute for poorer farmers who don't use fertilisers.

To improve crop production and benefit from higher water content of the soil, farmers are now planting near the Ouémé River or directly in the swamp zones. However, these swamps are progressively drying with global warming.

Some farmers, with assistance from agricultural services, have begun to use early-growing cultivars which combine good yield potential or drought tolerance. Another change in farming techniques noted by farmers in the group discussions is the continuous planting of seeds from the beginning of the first rains until the end of the rainy season. This is done to maximize the chances of their crops benefiting from the rain, and is a deviation from the standard agricultural calendar. Traditionally, farmers planted maize seedlings on March 15th as shown (see Table 3).

Table 3: Agricultural calendar of several crops established in the 1960's in Ouémé Department



Rural extension services set this and other dates for seedling, manure and soil preparation several years ago by. But farmers reported to us that for the past 15

[11] The Kantin is a local unit of measure of agricultural land in the south and in the middle of Benin. One Kantin equals 400 square metres.

years, they have been unable to use these dates because of the early or delay in onset of the rain. They report that they are unable to predict when the rainy season will start and need assistance. Unfortunately there is no institution in Benin responsible for either analysing risks to agriculture from climate unpredictability or alerting farmers to early rains.

Because maize is the district's most important crop (annual production for Ouémé department is about 120 000 tons), agricultural researchers have been working on an improved variety which produces better yields (with manure), is tolerant to drought and is pest resistant. This variety has a short cycle of less than 3 months. A short cycle rice variety (called "New Rice for Africa") has also been developed which requires less water than traditional varieties.

The main energy sources used by locals are also vulnerable to climate change. Most households don't have access to mains electricity. 95% of the population depend on traditional sources of energy such as wood, woody charcoal, sawdust and dry palm leaves.

Since 1990, some rural households in Adjohoun have also produced charcoal, but most of this is sold in the nearby cities of Porto-Novo (37 kilometres away) and Cotonou (73 kilometres away). Professional charcoal sellers source raw materials (wood) from forests in the Adjohoun District, and as a result, some households have found it difficult to find wood for fuel and have adopted economic stoves to save energy. Petrol to run motors and paraffin oil for lamps is available on the black market from Nigeria.

The increase in subsistence farming is placing pressure on the forestry sector as forests are cut down and replaced with farmland. These farmers often grow palm trees; the palm nuts and oil are a source of income. There are two types of palm trees:

- old palm trees with heterogeneous distribution and weak production;
- palm trees specifically bred to produce better quality palm nuts. These are often planted by farmer cooperatives and supported by Ministry of Agriculture.

Rice and leafy vegetables are also grown on the farm.

3.4 Changes in soil occupation

A diachronic analysis comparing two maps showing soil occupation in 1998 and 2006 has been done. Although the two maps (maps 3 & 4) come from different sources, it is still possible to observe the following:

- A drying of the left side of the Ouémé River and disappearance of wetlands. In the south west, near Togbota, wetlands have been transformed into cultivated land (see Photo 2).

Photo 2: Aerial view of the Ouémé Valley taken on Gangban village showing a forest islet and a mosaic of farms

- On the right side of the Ouémé river, in the Adjohoun District, the following changes between 1998 and 2006 can be observed (see also Table 4 and Maps 3 & 4):
    - Swamp forests are degraded and have lost more than 10% surface area
    - An extension of farms and fallows with palm trees (the area they cover is approximately three times greater in 2006)
    - Farms and simple fallows regressed 26%
    - Reforestation efforts by local authorities have improved with plantations of *Tectona grandis, Eucalyptus* and *Acacia*.

It is clear that human activity, as well as climate change, is responsible for these changes. The following table (Table 4) shows details on changes in land use from 1998 to 2006.

Table 4: Changes in land use in the Adjohoun District

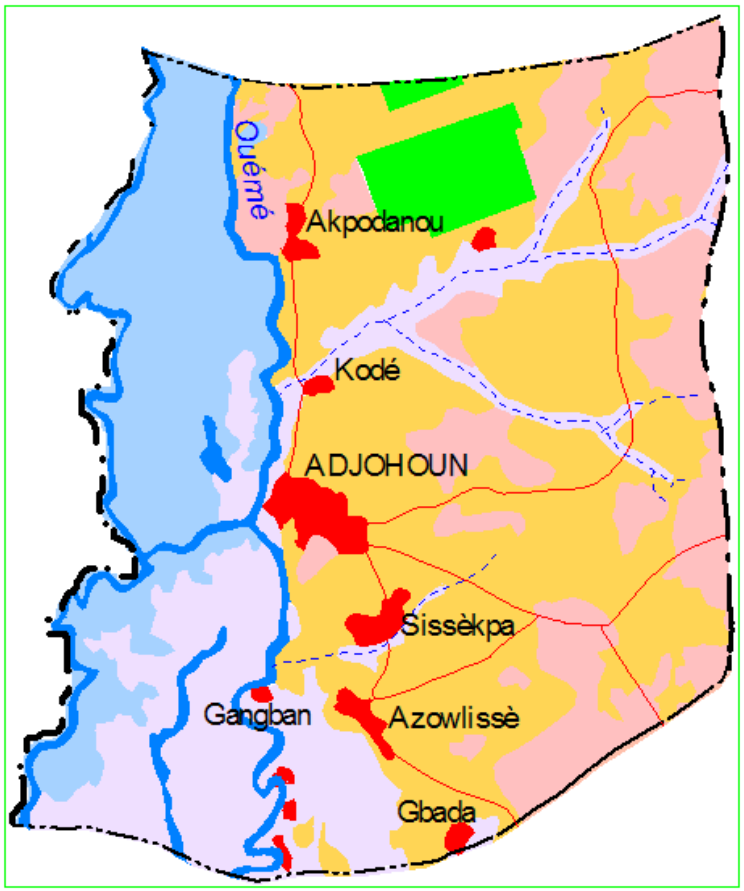
	State in 1998		**State in 2006**		**Evolution in relation to 1998 (%)**
	Surface (hectare)	**%**	**Surface (hectare)**	**%**	
Swamp forest	13 315	36.81	9 563	26.44	-10.37
Mosaic of farms and fallows	13 203	36.51	3 669	10.15	-26.36
Mosaic of farms and fallows with palm trees	5 656	15.64	17 954	49.65	34.01
Plantations	1 660	4.59	3 268	9.04	4.45
Urban area	777	2.14	762	2.10	-0.04
Stretch of water	1 551	4.28	946	2.62	-1.66

Since 1998 there has been a significant increase (34%) in the amount of land covered by palm trees. Palm oil production is an important income-generating activity across

the entire Ouémé department; palm oil and palmist oil are raw ingredients for many industries and artisan enterprises (soap, butter, food production). Farmers have been exporting palm oil since 1930 to places such as Nigeria and Gabon. The Benin Ministry of Agriculture supports the production and commercialisation of palm oil by assisting farmers to organise into cooperatives, and funding a national research centre to improve national palm oil production.

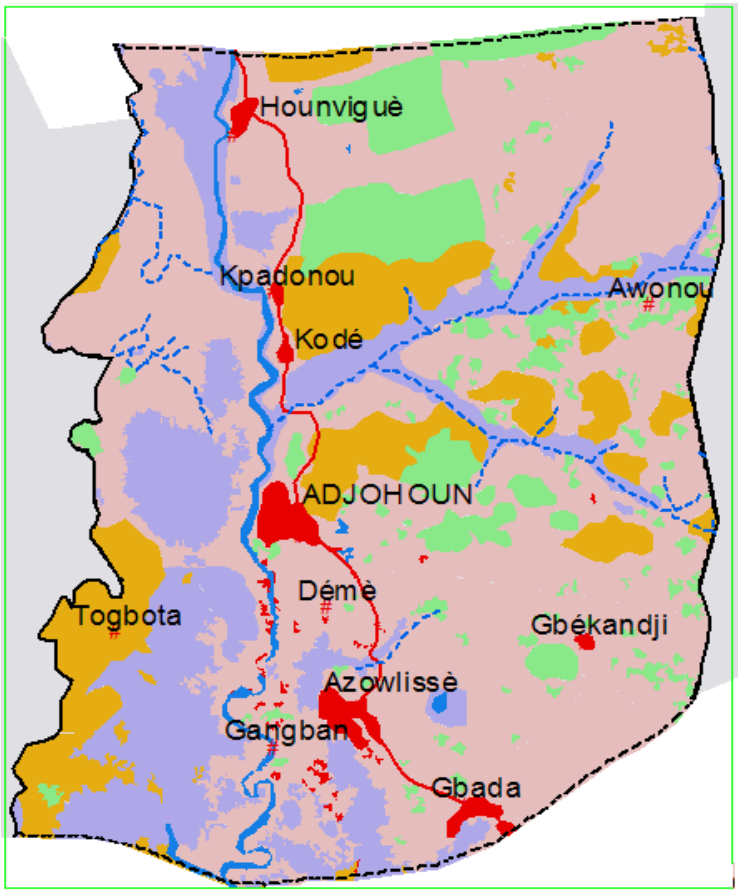
Source: Vegetation map of Benin, 1998

Map 3: Soil occupation in 1998



Source: Landstat, 2006

Map 4: Soil occupation in 2006



4.0 Adaptations in resource management and resource dependence

In the face of socioeconomic and ecological consequences of climate change, people in Adjohoun have implemented the following adaptation measures:

- adoption of short cycle crops (maize, rice, palm, etc.) that are better adapted to shorter periods of rain;
- planting crops in swamp ecosystems;
- acknowledgment of the need for reforestation;
- promotion of traditional pharmacopoeia;
- planting trees to attract rain and regulate the water cycle;
- development of techniques to provide drinkable water;
- promotion of agro-forestry to farmers.

Farmers plant trees for various reasons:

- trees regulate the water cycle and can reduce heat and create shade;
- trees produce fruits, and other food products;
- trees produce wood that can be sold;
- trees limit the boundaries of their farmland.

Locals plant indigenous, fruit-bearing trees near houses and on farmlands. Unfortunately there is little evidence that locals know how to regenerate useful indigenous timbers (for example, the disappearing or disappeared plants in Table 2). Farmers prefer quick growing species (*Acacia, Tectona, Eucalyptus*, etc.) to produce wood for fuel or for crafting.

Many projects run by NGOs (such as OFEDI, l'Organisation des Femmes pour la gestion de l'Energie, de l'Environnement et la promotion du Développement Intégré) educate the district's young people to promote best environmental practice by planting and protecting trees. Between 1998 and 2006, approximately 600 hectares of land was reforested in a combination of private and communal plantations. The training programmes teach simple forestry techniques and how to create seed nurseries.

As a result of the disappearance of swamp forest species, like "Afintin" (see Table 1), useful in house construction because it resists floods and putrefaction during raining season for many years, people have begun using other, non-forest materials, such as reinforced concrete pylons (see Photos 3, 4, 5, 6).

Photo 3: Traditional houses built on stilts in Agonlin village in the lower Ouémé Valley (Adjohoun) near the Ouémé River

Photo 4: The main stilts are made from the trunk of Afintin trees (*Rothmania longiflora)*

Photo 5: Reinforced concrete pylons made with cement and sand now take the place of stilts (Afintin trunks)

Photo 6: This new form of house is becoming more and more common as natural materials become less available.

Photo 7: A group of fishermen and farmers are holding the trunk of an Afintin tree (*Rothmania longiflora*) in Agonlin village. These trees have disappeared from Adjohoun and this trunk was imported from a forest in the Bonou District.

5.0 Roles of local institutions

The role of local public institutions and NGOs has so far been to assist the local population with natural resource management. In particular, they can help with bringing in measures to adapt to changes in the environment and the climate, particularly with regard to providing drinkable water, protecting the Togbota forest and its population of red-belied monkeys, and sustainable economic utilisation of the Ouémé Valley.

The effects of this assistance can already be seen: reforestation projects, initiated by locals and supported by public institutions and other organisations like OFEDI, have increased plantations surface area by 4.5% from 1998 to 2006 (see maps 3 and 4).

OFEDI has also been involved with a project to produce energy-saving stoves, made by locals with local materials. The organisation has been involved with environmental education and energy extension in the Adjohoun District since 1998. They have adopted the local practice of using traditional songs, proverbs and riddles to transfer knowledge in spreading the word about the deterioration of the environment and sustainable management of agro-biodiversity.

For example, the following proverb, translated from the “Wémè” language – “The one who planted trees before dying, did not uselessly live” – encourages people to plant trees. New songs and proverbs are created with the following goals:

- to raise awareness of the value of and threats to biodiversity in the Adjohoun District;
- identify ways of managing and conserving agro-biodiversity;
- encourage knowledge exchange about agro-biodiversity between communities;
- reinforce the effectiveness of these traditional modes of knowledge diffusion.

6.0 Conclusion

During the National Adaptation Programme of Action process in Adjohoun, local people, decentralized authorities in charge of environment and energy, administrative chiefs and religious authorities identified the following urgent adaptation needs:

- Providing drinkable water
- Protecting Togbota forest and red-bellied monkeys
- Sustainable economic utilisation of the Ouémé Valley

We emphasise that these needs must be taken into account by the district development programme and the council authorities. We believe that a local development programme would provide a good basis from which adaptation measures could be defined. The Adjohoun council should develop partnerships with relevant organisations to promote adaptation to the climate change.