International Journal of Forest, Animal and Fisheries Research (IJFAF)
ISSN: 2456-8791
[Vol-7, Issue-3, May-Jun, 2023]
Issue DOI: https://dx.doi.org/10.22161/ijfaf.7.3
Article DOI: https://dx.doi.org/10.22161/ijfaf.7.3.3

Resilience of riparian populations of the Agoua and Toui-Kilibo classified forests in Benin to the impacts of climate change

Etienne Akakpo[1], Sébastien Kouta[2], Romaric Ogouwale[1], Mama Sani Issa[1], Ibouraïma Yabi[1], Euloge Ogouwale[1], Brice Tente[3]

[1]Pierre PAGNEY Laboratory, Climate, Water, Ecosystem and Development (LACEEDE) /DGAT/FLASH/ University of Abomey-Calavi (UAC) 03BP:1122 Cotonou, Republic of Benin (West Africa)Capacity building
[2]Action for Ecological, Economic and Social Resilience (AREES NGO), Benin
[3]Laboratory of Biogeography and Environmental Expertise, UAC, Benin

Received: 27 Apr 2023; Received in revised form: 20 May 2023; Accepted: 28 May 2023; Available online: 04 Jun 2023

Abstract *— This research aims to strengthen the resilience of populations living along the Agoua and Toui-Kilibo protected forests. Its main aim is to analyze the adaptation measures used by the riparian populations and propose actions to strengthen their resilience. Data were collected from semi-structured individual interviews with each head of household or his/her sponsor in his/her household or field or plantation within and/or around the CF. Focus group interviews with key informants (between 05 and 13 participants representing the diversity of socio-professional or socio-cultural groups and gender-sensitive) were also conducted in riparian communities and within the CF. This data was collected through the QField application. The resulting database was transferred to the Excel spreadsheet for clearing and processing. For the processing of these data several parameters were calculated, in particular the importance value (IV), the response rate at the level of each respondent. In addition, the resilience of populations was assessed. To this end, the proposal for options to improve the resilience of communities bordering the Agoua and TK forests is based on the Multidimensional Resilience Index (MRI). For the calculation of resilience the basic variables are grouped into a set of actions which are themselves grouped into a set of seven (7) options. The various shares have been converted into indices called "core indices" and are calculated and obtained at the level of each option. Option-level indices are also calculated taking into account the indices previously calculated at the equity level. Finally, the Multidimensional Resilience Index is obtained by calculating the weighted arithmetic average of the indices calculated at the option level. The options that have attracted community attention are sustainable land management (4.1), and capacity building (3.89). These two options scored substantially 4, which shows that the communities are resilient. Improved social and cultural living conditions (3.33) can also strengthen the resilience of communities. Environmental protection, organizational level, institutional support and the creation of economic activities have a score ranging from 2 to 2.83. Actions to implement the priority options for adaptation to the adverse effects of climate change will reduce the vulnerability of the populations living near Agoua and Toui-Kilibo protected forests.*

Keywords *— **Resilience, impacts of climate change, Adaptation, priority options, Agoua and Toui-Kilib protected forest.***

I. INTRODUCTION

Climate change, according to the international scientific community, is a reality today whose impacts must be sought to limit. It has already manifested itself in the resurgence of extreme weather events that have caused significant human and material losses (heat waves, droughts, hurricanes and floods) [1]. Some authors see it as a major problem for the 21st century with all its implications that will only appear gradually [2]. According to [3; 4], and for many other scientists, the next few decades will be characterized by an increase in the average temperature at the Earth's surface of about 0.2 or 0.3°C every ten years, which will strain the adaptive capacity of species, including humans, and ecosystems. Like all environmental problems of global concern, climate change affects societies in extremely different situations. For these societies, where a large part of the population lives directly from agricultural production, seasonal disruptions will have a considerable impact [2]. Human-induced climate change, including the increased frequency and intensity of extreme events, has had widespread adverse effects and associated losses and damage to nature and people [5]. Its consequences are very dramatic in the developing countries [6].

In Benin, forest ecosystems are under increasing pressure due to changing environmental factors and intensifying disturbances related mainly to climate change and land use [7; 8]. These changes may cause ecosystems to move out of their historical range of variability [9], possibly causing unexpected and non-linear responses, such as abrupt transitions to other ecosystem states [10; 11]. In the current context of climate change, intensive exploitation of landscapes and ecosystems driven by unprecedented population and economic growth, as well as in the context of the sixth biodiversity crisis, knowledge of the capacity of ecosystems to absorb and respond to natural or anthropogenic disturbances is essential to predict their future evolution [12; 13]. These current disturbances are the source of the dynamics of forest landscapes and their spatial and temporal heterogeneity, making riparian populations vulnerable [14; 7].

The protected forests of Agoua and TK are part of the protected areas of central Benin that play a very important role in the lives of the local populations. They regulate the cycles of carbon, water and chemicals, which maintain a healthy climate and the cycles of nutrients needed for life. They are a powerful, sustainable, efficient and approved natural means of fiercely combating this phenomenon, the growing threat of which is becoming increasingly frightening.[15] They are fighting climate change [16]. Populations living near these protected areas, which are predominantly rural, are particularly vulnerable as they condition food, water and financial resources with direct and indirect impacts on public health. These changes have major adverse effects, especially on the livelihoods of rural communities, whose incomes are heavily dependent on farming activities and the exploitation of scarce and fragile natural resources [17; 18]. These poor and precarious conditions exacerbate the vulnerability of riparian villages and are the reason for their poor capacity to adapt to the phenomenon. Climate change imbalances have a negative impact on the local economy. Under these conditions, adapting populations to these impacts should be one of the priorities for promoting resilience [19].

As the world watches and experiences the impacts of climate change, a pragmatic way to adapt could be to look to nature.[20] The diversity of responses within and between interconnected populations supports population stability and resilience [21]. Some development and adaptation efforts have reduced the vulnerability of communities to these climatic disturbances, including income-generating activities. But the main areas of agricultural production suffer from the shifting seasons with late and short rains. This affects agricultural production and household food security in terms of low yields and insufficient food stocks [22]. The recurrence of these phenomena and their ever-changing intensity complicate and make the strategies to be advocated unpredictable. Non-climate constraints must therefore be relaxed to facilitate community and climate adaptation [23]. The aim of this research is to strengthen the resilience of populations living along the Agoua and Toui-Kilibo protected forests. Its main aim is to analyze the adaptation measures used by the riparian populations and propose actions to strengthen their resilience.

II. MATERIAL AND METHOD

2.1 Location of the study area

The research medium (FIG. 1) is located between 7°27' and 8°46' N latitude, and between 1°39' and 2°44' E longitude. It includes the municipalities of Bantè and Ouèssè and covers an area of approximately 13 899 km² or 12,35 % of the national territory [24].

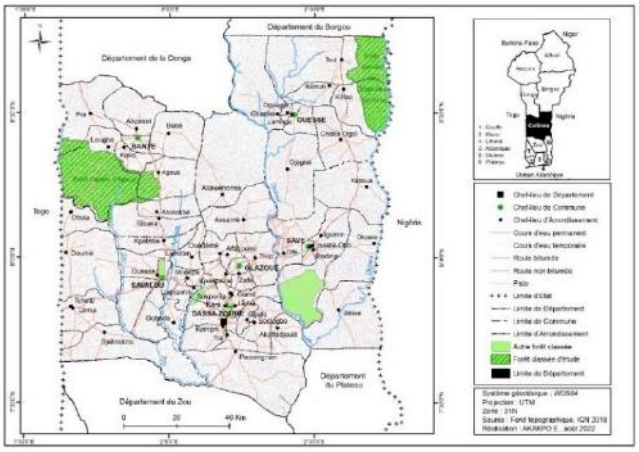


Fig.1: Geographical location of protected forests in the Collines department

2.2 Method of data collection

The main investigation unit is the head of household or farm holding occupying by his activity and/or dwelling, a portion of or around the CF. If the head of the household or holding is not available, his spouse or a member appointed by the household, who is at least 18 years old and capable of providing the required data, shall replace him as a guarantor.

Data were collected from semi-structured individual interviews with each head of household or his/her sponsor in his/her household or field or plantation within and/or around the CF. Focus group interviews with key informants (between 05 and 13 participants representing the diversity of socio-professional or socio-cultural groups and gender-sensitive) were also conducted in riparian communities and within the CF.

2.3 Data processing

The resulting database was transferred to the Excel spreadsheet for clearing and processing. For the processing of these data several parameters were calculated, in particular the importance value (IV), the response rate at the level of each respondent.

- ***Response rate***

The response rate at respondent level by modality was calculated using the formula of [25]:

$$T = S/N \times 100$$

Where, T: response rate at respondent level (%); S: number of respondents responding to a given modality and N: number of respondents

- ***Community Resilience Assessment***

Improving the resilience of communities to the impacts of climate change is possible through the participatory approach. It is promising and allows people to be the main actor in their development while clearly expressing their problems, needs, obstacles and opportunities [26]. In this short- and medium-term perspective, and in order to design, implement, monitor and evaluate more effectively the capacity-building of the populations and communities most exposed to the adverse effects of climate change, information on the resilience of communities and their households is essential. To this end, the proposal for options to improve the resilience of communities bordering the Agoua and TK forest massifs is based on the Multidimensional Resilience Index (MRI) established by [27]. This index meets scientific methodological requirements and has a relatively simple mathematical construction. According to these authors, it is measured by a weighted arithmetic mean of the basic indices that are calculated from the variables, which have been selected by considering the multidimensional aspect of resilience. For the calculation of resilience the basic variables are grouped into a set of actions which are themselves grouped into a set of seven (7) options. The MRI is being built gradually.

Table I: Scores for resilience assessment indices

Index	Score	Level of resilience	Result
[0,00 – 0,09]	0	Without resilience	Extremely bad result
[0,10 – 0,25]	1	Highly non-resilient	Very poor result
[0,26 – 0,45]	2	Moderate Resilience	Poor result but relatively acceptable
[0,46 – 0,59]	3	Mean resilience	Result considered acceptable
[0,60 – 0,89]	4	Good resilience	Good result
[0,90 – 1,00]	5	Very good resilience	Very good result

Source: CERED, 2015 adopted by [27]

First, because the variables are expressed in various units of measurement (meters, %, etc.), we transform the different shares into indices called "base indices" which are therefore calculated and obtained at the

level of each option. Option-level indices are also calculated taking into account the indices previously calculated at the equity level. Finally, the Multidimensional Resilience Index is obtained by calculating the weighted arithmetic average of the indices calculated at the option level. As shown in the table below, efforts have been made to facilitate the use of the RMI by practitioners and decision-makers, in particular the reading of the results obtained after its application through the change from the index to the scores and their significance.

The MRI used to assess a community's level of resilience following a given shock is based on two aspects: i) the community's level of resilience to a given shock; and ii) the ability to understand why the results achieved, good or bad, and to make improvements or corrective measures for better results in the future. Moreover, the design of the MRI already takes into account the time dimension, which is particularly important in terms of resilience. Indeed, without taking into account the time dimension, the results could easily be biased because the community or the households that make up the community would always be considered resilient regardless of the time they spend to rebound and regain the level of well-being, in this case after the passage of a shock.

III. RESULTS

3.1 Adaptation and enabling conditions

Climate-related criteria are essential to consider when choosing alternative options, as the purpose of the option transfer is to mitigate the impacts of climate change. The two main criteria include potential for adaptation and mitigation. This is precisely the potential capacity of each priority option to reduce vulnerability and build resilience within communities to climate impacts and any reduction in direct greenhouse gases.

3.2 Options for reducing the vulnerability of communities to climate impacts

The priority options for adaptation to the adverse effects of climate change stem from the adaptation needs expressed by local populations during village and municipal assemblies. Seven options have been identified. Figure 63 shows the average score recorded per priority option.

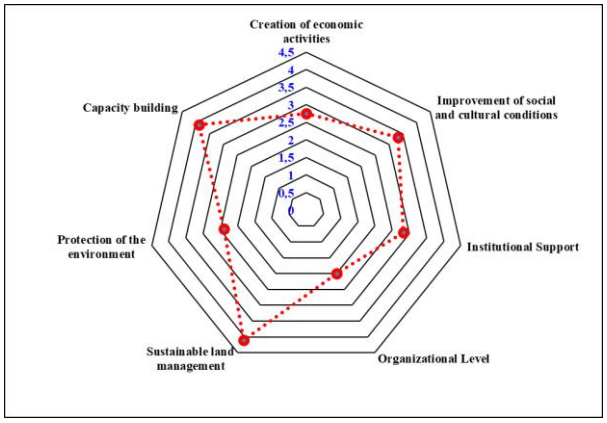


Fig.2: Priority adaptation options in the Bantè and Ouèssè municipalities

Source: Data processing, February 2022

Figure 2 presents the policy options identified by the riparian populations of Agoua and Toui-Kilibo protected forests to enhance their adaptive capacity. These options take into account not only the proposals of international and national institutions but also those of the local level. The options that have attracted community attention are sustainable land management (4.1), and capacity building (3.89). These two options scored substantially 4, which shows that the communities are resilient. Improved social and cultural living conditions (3.33) can also strengthen the resilience of communities. Environmental protection, organizational level, institutional support and the creation of economic activities have a score ranging from 2 to 2.83.

Actions to implement the priority options for adaptation to the adverse effects of climate change will reduce the vulnerability of the populations living near Agoua and Toui-Kilibo protected forests.

3.3 Urgent actions to implement priority options in the Bantè and Ouèssè municipalities

To implement the priority options, several actions are identified by the local population. These expressed adaptation needs take account of the different options. Table II shows the number of actions per option in the study area.

Table II: Number of actions per option in the study area

Summury	Number of priority options	Number of actions to be implemented
No. Iterations	0	0
Group Size	7	46
No.Indicator -ve	4	29
Borderline No. -ve	0	0
No. Misclassified -ve	0	0
No.Indicator +ve	3	17
No. Borderline +ve	0	0
No. Misclassified +ve	1	0

The hierarchical analysis showed forty-six (46) priority actions to be implemented to support the seven (07) priority options for reducing vulnerability and improving the resilience of communities along the Agoua and TTK protected forests. These options and urgent actions have been classified into two categories, one positive and the other negative. The number of negative options is 4 for 29 actions while the number of positive options is 3 for 17 actions. Positive actions are those to be implemented in the short term, while negative actions are to be implemented in the medium and long term. Figure 64 shows the two categories of options and actions to improve community resilience.

The two categories are distinguished by the colors in Figure 64a and b. The negative options (Figure 64a) and actions (Figure 64b) are in red and the positive ones are in blue. Negative priority options are Economic Activity Creation (EAC), Environmental Protection (ENP), Organizational Level (NO) and Institutional Support (IC). Positive options, however, include sustainable land management (SLM), capacity building (CB), and improved social and cultural conditions (CSCE).

3.4 Multidimensional resilience index of future adaptation options

The level of community resilience is assessed on the basis of the Multidimensional Resilience Index. Thus, for each priority option, whether positive or negative, a baseline resilience index has been calculated. Figure 3 presents the MRI in terms of adaptation options.

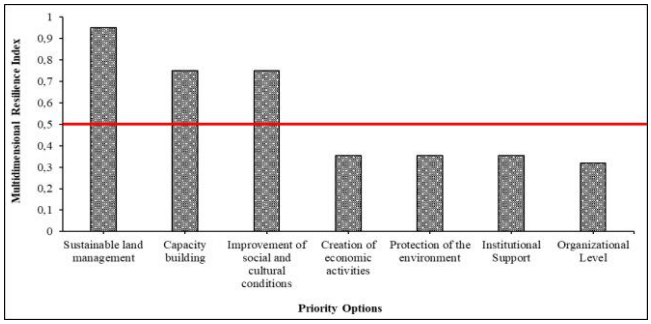


Fig.3: RMI by Adaptation Options

Source: Data processing, February 2022

The analysis of the Multidimensional Resilience Index shows that the option "Sustainable land management (0.95), capacity building (0.75) and improvement of social and cultural living conditions (0.75). The other options have an MRI less than 0.5.

3.4.1 Sustainable land management

This priority option brings together ten actions proposed by the local community. Table III shows actions for sustainable land management and their level of resilience.

Table III: Level of resilience of sustainable land management actions

Actions	Score	Subscript	Level of resilience
Increase in agricultural productivity	5	[0.90 - 1.00]	Very good resilience
Improved crop management	4	[0.60 - 0.89]	Good resilience
Modification of the date and techniques of cultivation operations	5	[0.90 - 1.00]	Very good resilience

Improved livestock management	2	[0.26 - 0.45]	Moderate Resilience
Practice of crop rotation	5	[0.90 - 1.00]	Very good resilience
Crop associations	5	[0.90 - 1.00]	Very good resilience
Agricultural diversification	5	[0.90 - 1.00]	Very good resilience
Improved grazing land management	2	[0.26 - 0.45]	Moderate Resilience
Integrated water management	3	[0.46 - 0.59]	Mean resilience
Reduction of grassland to cropland conversion	5	[0.90 - 1.00]	Very good resilience
Average	**4.10**	**[0.60 - 0.89]**	**Good resilience**
Standard Deviation	**1.29**		

An examination of Table III shows that more than half of the actions to be implemented to support the land management criterion have a basic resilience index between 0.90 and 1. This reflects very good household resilience as it achieved a maximum score of 5. These include increasing food productivity, changing the date and techniques of crop operations, practicing crop rotation and combination, agricultural diversification and reducing the conversion of grassland to cropland. Local populations gave an average score of 2 for improved livestock and grazing land management. Poor, but relatively acceptable, results in moderate community resilience.

Overall, the baseline index for land management in the study area is 0.75, which provides a basis for communities to be resilient to the impacts of climate change.

3.4.1.1. Changes in the dates and technique of sowing operations

Recurrent droughts since the 1970s and spatial and temporal variability in rainfall heights have made it difficult to use the traditional agricultural calendar. In the past, the peasant in the Bantè and Ouèssè communes rests from mid-December until January, periods of the end of the year festivities and great ritual ceremonies. There are two periods of intense activity, from February to April, reserved for field preparation and sowing, and from June to November, which is the period of field maintenance and harvesting. As indicated by the tendency to delay the onset of rainfall, farmers claim to be lagging in the establishment and harvesting of crops. Table XXIX shows the new agricultural calendar followed by the populations living near the Agoua and TTK massifs.

To overcome the problem of droughts at the beginning of the agricultural season and to adapt to the persistence of false starts of the growing season, farmers reseed in most cases in the first decade of May. Thus, the traditional agricultural calendar is in the middle of a phase of abandonment due to the high spatial and temporal variability of rainfall.

Indeed, 90% of the farmers surveyed sow from the second decade of April onwards (when it was at the end of March), while the remaining 10% sow from the last decade of March to the second decade of April. The farmers themselves call their seedlings "risky". The fact is that April seedlings would have a high probability of success compared to early seedlings. This perception is well justified because the risk of false rainfall departure is very high during the month of March over the last thirty years because this month is becoming drier and drier.

During the second rainy season, most of the surveyed producers (95 %) are already planting at the end of August and the beginning of September. This is only a good reading of the evolution of the climate, because the interseason represented by August becomes rainier and September has become the rainiest month of the small season. The other way farmers manage climate risks is by dispersing the dates when crops are sown. This practice is called staggered seeding. It consists in sowing the same crop on two different plots or even on a single plot on different dates; this in the hope that the pace will correspond to the growth phases of at least one of the crops in relation to their sowing date.

With a very good level of resilience, changing the dates and techniques of sowing operations is an action to improve the working conditions of farmers.

3.4.1.2 Crop rotation and combination practice

Table IV shows the types of rotation adopted by farmers in the municipalities of Bantè and Ouèssè.

Table IV: Types of crop rotation

Number of years	Types of rotation
1st year	Yam, cassava, cotton
2nd year	sesame, Sorghum, maize
3rd year	Cotton, Peanut, Cowpea
4th year	Rice, maize market gardening products
5th year	Cashew, set-aside

Source: Field survey, April 2020

Crop rotation improves yields over several seasons by using residues as fertilizers for new plants.

3.4.1.3 Crop Association

Crop combination is a system of growing several crops simultaneously on the same plot of land. In the municipalities of Bantè and Ouèssè, this system remains the most practiced by farmers. Agricultural assets combine two or three crops on the same plot. Thus, crops such as maize (*Zea mays*) and groundnut (*Arachis hyppogea*) on the one hand and yam (*Dioscorea spp*.) with cassava (*Manihot esculenta*) on the other hand may coexist on the same plot. Combinations of maize - cassava - cashew tree, soybean - cashew bean, etc. It should be noted that cashew tree is associated with other plants when the latter plants are still young. Figure 4 shows the most common types of crop associations in the municipalities of Bantè and Ouèssè.

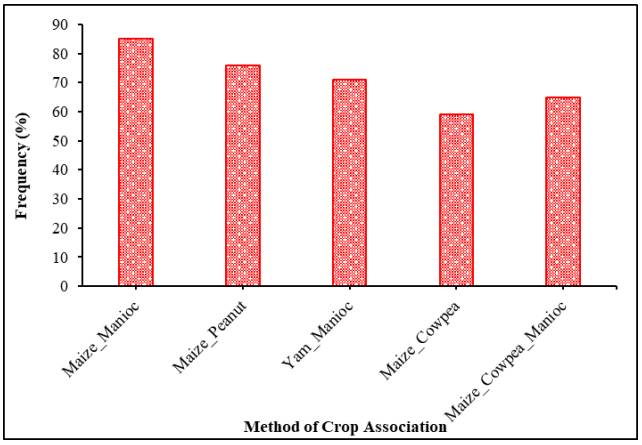


Fig.4: Most common types of crop associations in the Bantè and Ouèssè communes

The results of the study show that all households surveyed practice cultural association. The most common combinations are maize-cassava (85%), maize-peanut (76%), maize-cowpea (59%), maize-cowpea-cassava (65%). Although most respondents linked this practice to a lack of land for monoculture, more than 56% of producers linked it to a concern to preserve food and nutritional security in the household. Indeed, the farmers would be in a policy of multiplying the chances of guaranteeing a minimum harvest at the end of the season.

3.4.1.5 Increasing agricultural productivity

Ensuring food security, a healthy and balanced diet for a growing global population, remains a challenge. Indeed, experiences of food insecurity are an indicator that informs about the food insecurity of populations living near the Agoua and TTK forests. This indicator is based on the possibility of meal skipping, unavailability of the meal, limitation of food consumed, etc. Figure 5 shows the proportion of occupants on food insecurity experiences.

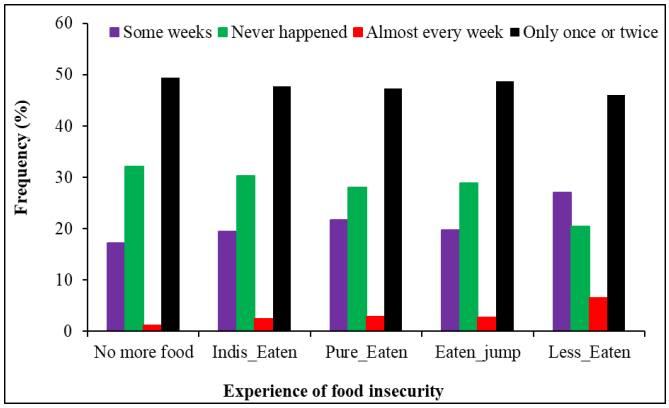


Fig.5: Food insecurity experiences

Source: Data processing, February 2022

An analysis of Figure 5 shows that communities living along the edge of the protected forest in Agoua have not eaten anything for only one or two times a year. It is also once or twice a year that they have no food, have eaten the same meal, eaten less or even skipped meals. Some have estimated that this happens on a few weeks or almost every week of the year. For others, these events never happened in their lives. This means that households are less food insecure. Despite this low threat of food insecurity, increasing agricultural productivity is critical to improving the resilience of coastal populations.

3.4.1.6 Description of household dwelling and equipment

In most localities bordering the protected forests of Agoua and TTK, dwellings are scattered. Most of these houses are built of precarious materials. FIG. 6 shows the characteristics of these dwellings.

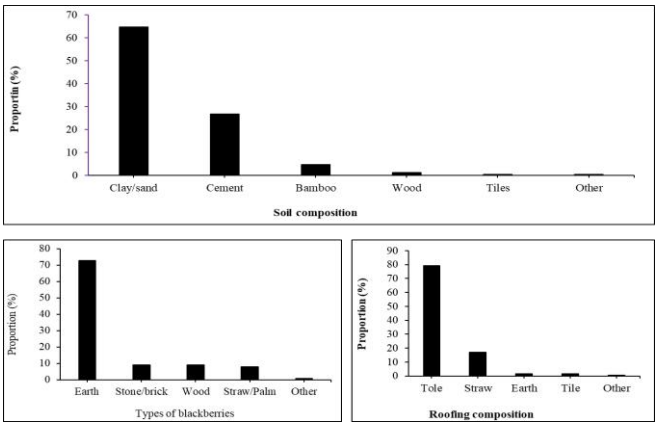


Fig.6: Characteristics of dwellings of households surveyed

Source: Data processing, February 2022

From an analysis of Figure 6, it can be seen that the majority of dwellings are clay (72.72%) for the wall, sheet metal (79.34%) for the roof and clay/sand (64.77%) for the soil composition. In addition, some houses are made of stone/brick, straw and cement for the composition of the soil. It should also be noted that other dwellings of the residents are made of wood, straw/palm for the wall, earth, tile for the roof and bamboo, wood for the composition of the floor. Plate 1 shows the types of dwellings found in the surrounding area and in the protected forests of Agoua and TK.

a: Traditional type habitat; c: Semi-modern type habitat

Plate 1: Type of dwelling in communities bordering the forest massifs

Shooting: E. Akakpo, 2021

3.4.2 Improvement of social and cultural conditions

In the social criterion, despite the maximum value of 5 obtained respectively by two variables, namely health and access to drinking water, the overall score of the criterion is only 3.67. The other two variables, namely the development of rural roads and employment, obtained only a value of 2. The score equal to 4 of the health variable means that in the rural communities of Bantè and Ouèssè, access to medicines, especially traditional medicines, is ensured by learning about their production from generation to generation, by word of mouth within the family or by consulting a practitioner of traditional medicines within the community. Access to such medicines is reinforced by the community when disasters occur in the study area, as the supply of modern chemical medicines is not necessarily guaranteed as a priority. Table V presents the score and values of the core resilience index of all the actions to be implemented to support this option.

Table V: Basic resilience index of actions to improve social and cultural conditions

Actions	Score	Subscript	Level of resilience
Use of medicinal plants (health)	4	[0.60 - 0.89]	Good resilience
Schooling of children (education)	5	[0.90 - 1.00]	Very good resilience
Employment	2	[0.26 - 0.45]	Moderate Resilience
Access to drinking water	5	[0.90 - 1.00]	Very good resilience
Development of rural trails	2	[0.26 - 0.45]	Moderate Resilience
Traditional knowledge and knowledge	4	[0.60 - 0.89]	Good resilience
Average	**3.67**	**[0.46 - 0.59]**	**Mean resilience**
Standard Deviation	**1.37**		

The basic resilience index of this option is between 0.46 and 0.59 explaining an average resilience of local populations. Table V shows that education takes

many forms, including formal schooling and technical or vocational training, mentoring of children and young people by communities. This education is the source of individual and social development. Thus, to be relevant and operational in the fight against climate change impacts, education must develop knowledge and skills among its users to manage and adapt to changes in their external environment. It must also be resilient to provide stability and protection in the event of a crisis.

Culturally, traditional knowledge and knowledge scored a maximum of 5. The community is rich in traditional knowledge about managing and mitigating the effects of climate change. The cultural characteristics of the community can greatly contribute to its resilience in the face of flood shocks, in particular, thus explaining this good level of resilience. By the same logic, populations belong to several social groups. Figure 7 presents the social organization of communities to deal with the impacts of climate change.

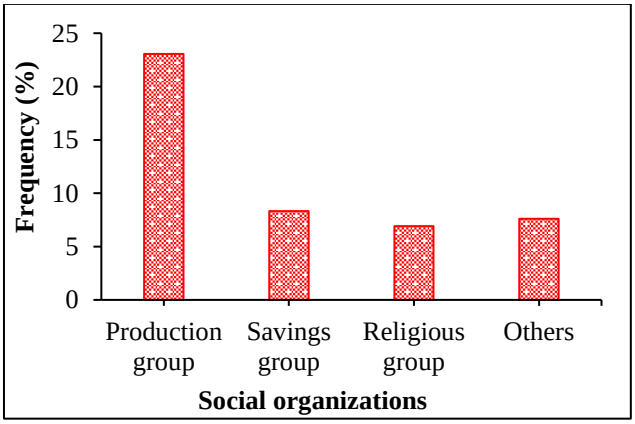


Fig.7: Social organization of riparian populations

Source: Data processing, February 2022

The analysis in Figure 7 shows that 23,07 % of the riparian populations in the Agoua and TTK protected forests belong to the production group, 8,32 % to the tontine group and 6,91 % to the religious group.

3.4.3 Capacity building

The capacity-building option, meanwhile, scored 3.89 ± 0.78, suggesting an average resilience of riparian populations. The actions, i.e. awareness-raising, outreach and simulation exercise (practice) have at least a score of 5 respectively, which is the basis for very good resilience. This situation is normal since some NGOs in the area are providing this reinforcement. Table VI presents the actions to be put in place for adequate capacity building.

Table VI: Capacity-building actions to be put in place

Actions	Score	Subscript	Level of resilience
Awareness Raising	5	[0.90 - 1.00]	Very good resilience
Popularizing adaptation strategies	5	[0.90 - 1.00]	Very good resilience
Simulation Exercise	4	[0.60 - 0.89]	Good resilience
Training on soil restoration and organic fertilizer manufacturing techniques	4	[0.60 - 0.89]	Good resilience
Training on the use of short-cycle varieties of maize, sorghum and rice seeds	4	[0.60 - 0.89]	Good resilience
Training on good practices for sustainable water resources management	3	[0.46 - 0.59]	Mean resilience
Veterinary support for poultry, sheep, goat and pig farmers	3	[0.46 - 0.59]	Mean resilience
Support for fodder production	4	[0.60 - 0.89]	Good resilience
Support for the acquisition of irrigation equipment	3	[0.46 - 0.59]	Mean resilience
Average	**3.89**	**[0.46 - 0.59]**	**Mean resilience**
Standard Deviation	**0.78**		

The various training courses on the use of short-cycle varieties of maize, sorghum and rice, good practices for sustainable water resources management, support for fodder production and veterinary support for poultry, sheep, goat and pig farmers will enable a

good adaptation to the impacts of climate change. In addition, the development of diverse agricultural systems, taking into account local knowledge of specific crop and livestock varieties, preserving crop diversity, diverse agricultural landscapes, can help ensure food security in changing local climatic conditions.

3.4.4 Creation of economic activities

In this option, the null value of the variable "Cereal bank", strongly influenced the low value of the score of the criterion. For example, the establishment of the Cereal Banks requires a large organization of the institutions in charge of agriculture. On the other hand, the creation of RMAs requires the capacity to work together among community members to raise awareness and use the available labor for rural agricultural activities.

Table VII: Actions to create economic activities

Actions	Score	Subscript	Level of resilience
Creation of AGRs	4	[0.60 - 0.89]	Good resilience
Access to credits	1	[0.10 - 0.25]	Highly non-resilient
Diversification of activities	5	[0.90 - 1.00]	Very good resilience
Management of income from agricultural work	3	[0.46 - 0.59]	Mean resilience
Labor Availability	4	[0.60 - 0.89]	Good resilience
Access to inputs	4	[0.60- 0.89]	Good resilience
Access to agricultural equipment	1	[0.10 - 0.25]	Highly non-resilient
Cereal Bank	0	[0.00 - 0.09]	Without resilience
Average	**2.75**	**[0.26- 0.45] 0.335**	**Moderate Resilience**
Standard Deviation	**1.83**		

The basic resilience index of the economic option is relatively low (2.75), reflecting moderate community resilience. Under this option, actions to be implemented include diversification of activities, creation of income generating activities (AGR), access to agricultural inputs and availability of labor. Moreover, mutual support among members of the rural community bordering the forest massifs is a real capacity and ability to respond to climate impacts.

3.4.5 Environmental protection

In environmental terms, forest ecosystems contribute to the reduction of CO2 from air, which is the most important for the concentration of greenhouse gases derived from human activities. Table VIII shows the different environmental protection actions to be implemented and their level of resilience.

Table VIII: Different environmental protection actions and their level of resilience

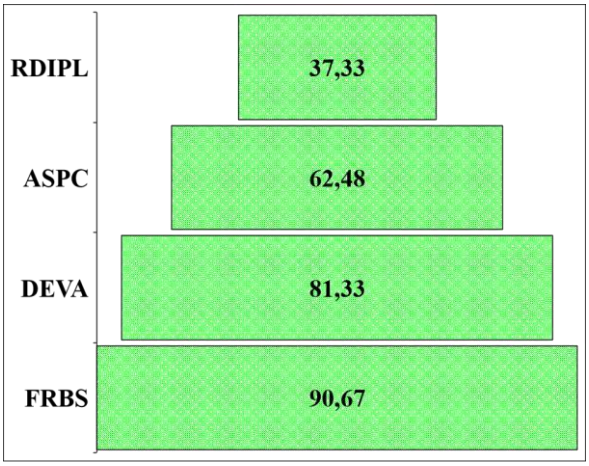
Actions	Score	Subscript	Level of resilience
Agroforestry	2	[0.26 - 0.45]	Moderate Resilience
Reforestation	2	[0.26 - 0.45]	Moderate Resilience
Stop illegal logging	1	[0.10 - 0.25]	Highly non-resilient
Planting of fruit plantations	5	[0.90 - 1.00]	Very good resilience
Reduction of area under protected forests	3	[0.46 - 0.59]	Mean resilience
Conservation and preservation of forest ecosystems	5	[0.90 - 1.00]	Very good resilience
Average	**3**	**[0,46 – 0,59] 0,52**	**Mean resilience**
Standard Deviation	**1.67**		

Table VIII shows that planting fruit plantations is the most important action to improve the resilience of communities. Its basic resilience index is substantially equal to 1, which shows that the fruit plantations in the two communes form a solid basis for the resilience of the communities. This action has a very good result and therefore a very good resilience. To protect these mountains from degradation, households should

practice agroforestry and reforestation. They should also reduce or stop illegal logging and planting in protected forests.

3.4.5.1 Conservation and preservation of forest ecosystems

The conservation and preservation of forests is an indicator that promotes their resilience. The practice of conservation is a long-term process which tends to limit the evolution of the degradation of existing forest ecosystems and/or to repair them (forest rehabilitation) so as to improve the living environment of local populations in a sustainable way. Figure 80 shows the effects of protected forest conservation on riparian populations.



IDPRD: Recognition of the inherent rights of local populations; **DEVA**: diversification of plant and animal species; **PHAC**: Improvement of carbon stocks and sinks; **FRBS**: Ease of searching for goods and services.

Fig.8 : Effects of protected forest conservation on riparian populations

Adaptation of natural forests includes conservation, protection and restoration measures. In the protected forests of Agoua and Toui-Kilibo, management policy, including participatory management, makes it possible to create management series, particularly the conservation and protection series. The analysis in Figure 70 shows that the conserved forest area facilitates community search for goods and services (90.67%) and promotes diversification of plant and animal species (81.33%). The conservation series strengthens forest resilience and limits forest degradation. Restoring natural forests and improving their sustainability also increases the resilience of stocks and carbon sinks (62.48%). Cooperation and inclusive decision-making with local communities and indigenous peoples, as well as recognition of the inherent rights of local populations (37.33%), are integral to successful adaptation of forests to climate change.

IV. DISCUSSION

This research has recognized the importance of prioritizing a variety of options to reduce the vulnerability of populations living along the Agoua and TK forests and to improve their resilience to the impacts of climate change. This study showed the need to prioritize seven (7) options and 46 actions. These are economic, environmental, land management, capacity building, organizational and social and cultural criteria. Options with significant scores were land management, capacity building and social and cultural options. Overall, the score is not satisfactory as it can still be improved to reach the maximum score of 5. Other options, including organizational, economic and environmental, scored relatively low, which explains the low level of resilience of the communities. The implementation of these measures will not be able to ensure the resilience of communities in the short and medium term. These results corroborate those of [27] for which scores expressing poor levels of resilience showing highly non-resilient community outcomes are recorded in economic, organizational and environmental criteria. Adaptation to climate change works towards reducing people's vulnerability to climate change and strengthening their resilience to impacts. This can be achieved by strengthening current living standards so that in the face of adversity, households can be able to cope with the climate shock. The development of social measures and other insurance mechanisms will help households to recover from the shock closely linked to social criteria, including poverty reduction. In creating the conditions for improving the resilience of the community, the participatory approach is considered a promising method, as it allows the population to be the main actor in its development by clearly expressing its problems, needs, obstacles and opportunities [26]. This process enables the population to identify, prioritize and plan local development actions and provides a context for creating pragmatic change in the management of the community's resources. In addition, the participatory

approach emphasizes the importance of the active participation and empowerment of people in all development actions concerning them.

4. 1 Increased agricultural production and food security

The very good level of resilience of this action is an indicator for the reduction of end and poverty in the municipalities of Bantè and Ouèssè. This is a short-term measure, because it will help to achieve the SDGs. These results are in line with FAO and OECD findings that agricultural predictions for 2021-2030 call for a transformation of global agri-food systems to achieve the Sustainable Development Goals (SDGs). With less than 10 years to go before the 2030 deadline to achieve the SDGs, governments must redouble their efforts on food security and the environment, the organizations said. [28] has shown that growing demographic trends, the substitution of poultry for red meat in countries should control future demand in order to sustainably feed a global population that is expected to reach 8.5 billion by 2030. According to the same source, among the increases in production to be achieved, 87% would come from the growth of agricultural yields, 7% from the increase in crop intensity, and 6% from the expansion of land use. In sub-Saharan Africa, per capita consumption of animal protein is expected to decline slightly as incomes tighten. This part of the continent will experience a decline in food security by 2030.

The research also showed that communities along the two forests have not eaten anything at all for only one or two times a year. It is also once or twice a year that they have no food, have eaten the same meal, eaten less or even skipped meals. Some have estimated that this happens on a few weeks or almost every week of the year. As a result, they are food insecure. Raising agricultural productivity is critical to improve the resilience of riparian populations. The results of [29] have shown that food security exists when all people at all times have physical or economic access to sufficient, safe and nutritious food to meet their energy needs and food preferences for a healthy and active life. Adopting an approach to food security that integrates vulnerability reduction will strengthen people's resilience to threats posed by the effects of climate change, while protecting and enhancing local ecosystems and strengthening the human resources needed to reduce vulnerability overall, they said.

4.2 Social and Cultural Options

The basic resilience index of the social and cultural criterion is between 0.46 and 0.59, indicating an average resilience of the local populations. Practical actions to be implemented in this option are the facilitation of drinking water, education through the schooling of children, and the health of households in the two communes. Social practices, which define a code of good conduct in society, can therefore play a role of community insurance against the effects of climate change and is therefore a way for the community to create solutions to its problems. This allows the community to rely on its own resources to anticipate, respond to, and withstand and recover from climate disruptions. In this way, a resilient community is organized in such a way as to be able not only to overcome the various possible disasters, but above all to improve its daily life and its environment by placing greater emphasis on solidarity. One of the key factors of collective resilience is therefore the existence of a capacity and ability to help each other among members of a community. These findings are in line with those of [30] which showed that access to social, cultural and economic capital are the factors that support building resilience. These authors then suggest distinguishing between resilience building processes (pre-impact) and resilience manifestations (post-impact). For them, resilience is more than management, in the sense of minimizing the consequences of adversity or managing vulnerability to ensure short-term survival. And they have shown that people can manage their resilience, but at the same time reduce it, consuming less food and spending less on education.

4.3 Environmental aspects

The results showed that, for the vulnerability of populations to climate risks, the establishment of fruit plantations is essential. The most popular fruit plantations are those in Anacardium Occidental. These plantations play a dual role, in particular the protection of the environment and their socio-economic benefits. The *Western Anacardium* plantations are found in all the classified forests of Agoua and TTK and each occupy given proportions. Their scale is due to the various socio-economic benefits they offer to the population, especially in times of welding. According to [26] resilience must emerge to protect communities and ecosystems.

Biodiversity conservation, including the restoration of degraded ecosystems, is essential, not only because it plays a key role in the global carbon cycle and in adapting to climate change, but also because it provides a wide range of ecosystem services that are essential to human well-being [29]. Forest protection and afforestation are difficult to envisage in the short term. Mixed agroforestry systems, on the other hand, contribute to cover. These systems benefit producers and contribute to biodiversity [31; 32]. Adaptation and resilience options offer multiple benefits, including risk and loss avoidance, economic growth, well-being, and social and environmental benefits [4]. According to scientific research, it is clear that trees/forest ecosystems associated with other components of the biosphere, through the mechanisms responsible for current net uptake, contribute to offsetting direct anthropogenic GHG emissions. However, if no action is taken to consolidate, preserve or even increase them, they will become completely ineffective [15]. Thus, increasing a population's resilience reduces its vulnerability to shocks. In addition, a better understanding of the climate, and the impacts of its variabilities, will help increase resilience [33]. Resilience is increasingly becoming a framework for addressing climate change adaptation [32]. Finally, for a community subject to frequent climatic hazards, environmental protection activities play important roles [27].

V. CONCLUSION

To deal with the effects of climate change, several seven (7) options are being considered. These measures should be based on around 46 actions to improve the resilience of the populations living along the Agoua and Toui-Kilibo protected forests. Of these identified options, three, namely: Sustainable Land Management, Capacity Building and Improvement of Socio-Cultural Living Conditions, have variables directly related to the social link and can positively contribute to community resilience. The influences of the other 4 options, in particular environmental protection, organizational level, institutional support and the creation of economic activities, also show modest results, which certainly helped to push down the AMI result (0.55).

ACKNOWLEDGEMENTS

The authors of this article sincerely thank the African Forestry Forum (AFF) for its financial support.

REFERENCES

[1] R. Ilmen et H. Benjelloun, “Les écosystèmes forestiers marocains à l’épreuve des changements climatiques”, *Forêt méditerranéenne*, 2013, t. XXXIV, n° 3, pp. 195-208
[2] V. Van Gameren, R. Weikmans and E. Zaccai, “L’adaptation au changement climatique,” Éditions La Découverte, Paris, 2014, pp. 1-128.
[3] GIEC, “Résumé à l’intention des décideurs, Changements climatiques, Les éléments scientifiques” Contribution du Groupe de travail I au cinquième Rapport d’évaluation du Groupe d’experts intergouvernemental sur l’évolution du climat, Cambridge University Press, Cambridge, Royaume-Uni et New York, 2013, 34 p.
[4] GIEC, "Climate Change 2022: Mitigation of Climate Change", consacré à l’atténuation du changement climatique, 2022, 1991 p.
[5] IPCC, “Impacts, Adaptation, and Vulnerability. Summary for Policymakers”, 2022, 3676 p.
[6] M. Massouangui-Kifouala, C. C. Moutakala Mounsounou, A. P. Batchi Mav et B. Michellon ‘’Vulnérabilité et résilience des quartiers précaires à brazzaville (république du congo) face au changement climatique: cas de Soukissa et Moukondzi-Ngouaka’’, Rev. Ivoir. Sci. Technol., 37, 2021, pp. 257-281. http://www.revist.ci
[7] S. KOUTA, I. TOKO IMOROU, E. S. SOGBOSSI, I. MAZO et G. MENSAH, “Résilience et résistance de la flore aux perturbations anthropiques dans le bassin cotonnier du nord-Benin”; *Cahiers de l’ENS-Bongor*, Vol. 1(2), 2020, pp. 167-179
[8] I. MAZO, S. KOUTA, E. S. SOGBOSSI et I. TOKO IMOROU, “Effets des facteurs anthropiques sur la biomasse ligneuse de la forêt classée de Goungoun et ses terroirs riverains dans la région soudanienne du Bénin”, *International Journal of Progressive Sciences and Tecnologies* (*IJPSAT*), 2020, Vol. 22(2), pp. 304-318
[9] J. Keane, S. Page, and J. Kennan, "Climate change and developing country agriculture: An overview of expected impacts, adaptation and mitigation challenges, and funding requirements." (2009).
[10] K. Albrich, W. Rammer, M. G. Turner, Z. Ratajczak, K. H. Braziunas, W. D. Hansen, & R. Seidl, « Simulating forest resilience: A review. » Global Ecology and Biogeography, 2020, *29*(12), pp. 2082-2096.
[11] Z. Ratajczak , S. R. Carpenter, A. R. Ives1 , C. J. Kucharik , T. Ramiadantsoa, M. A. Stegner , J. W. Williams, J. Zhang, M. G. Turner, “Abrupt change in ecological systems: inference and diagnosis”, Trends in Ecology & Evolution, *33*(7), 2018, pp. 513-526.
[12] IPCC, Climate Change and Land, 2019, 36 p.
[13] E. Gouriveau, “Résilience des écosystèmes: approche multiproxy de l’impact environnemental des activités humaines passées et récentes dans les Vosges du Nord (mines, verreries, activités militaires et agro-pastorales).

Sciences agricoles", Université Bourgogne Franche-Comté, 2020, Français. ffNNT : 2020UBFCD039ff. fftel-03134915f

[14] J. WILLIS, Kathy, JEFFERS S. Elizabeth et TOVAR Carolina, "What makes a terrestrial ecosystem resilient? A complex set of biotic and abiotic factors determines the resilience of an ecosystem", Science, 2018, 359 (6379), p. 988-989.

[15] SAFFACHE Pascal et JOSEPH Constantin, "L'importance des écosystèmes forestiers et les enjeux de la déforestation dans la lutte contre le changement climatique en Haïti: Cas des mangroves du Parc des Trois Baies, des forêts des massifs de la Selle et de la Hotte", Haiti Perspectives, 2018, 6(4), pp. 21 – 31.

[16] D. C. Gibbs, H. Yeung, et T. W. Blalock, "Incidence and trends of cutaneous adnexal tumors in the United States in 2000-2018: A population-based study" Journal of the American Academy of Dermatology, 2022, pp 1-12

[17] M. Fetoui, "Évaluer et suivre la désertification en zones arides tunisiennes pour accompagner l'aide à la décision : dynamiques interactives « Climat-Homme-Espace-Ressources naturelles » via les paysages". Thèse de doctorat en géographie. Université Paul-Valéry, Montpellier III. 441 pages. https:// ged.biu-montpellier.fr/florabium/jsp/win_main_biu. jsp?nnt=2011MON30007&success=%2Fjsp%2Fwin_main_biu.jsp&profile=anonymous.

[18] M. Fetoui, F. Aribi, F. Chouikhi, M. Sghaier, M. Sghaier, "Vulnérabilité des moyens d'existence des ménages ruraux au changement climatique: analyse comparative des territoires montagneux et littoraux des zones arides tunisiennes", Mediterranean Journal of Economics, Agriculture and Environment, 2021, pp 15-31.

[19] M.-M. Fleurant, ''Les changements climatiques à Haïti : Pour la résilience socio-écologique des populations par l'adaptation dans le domaine de l'agriculture. Possibilités et limites du droit interne et international'', 2020, 430 p.

[20] V. Lo, J. Qi, N. Jang, "Élucider les solutions climatiques basées sur la nature pour l'adaptation", International Institute for Sustainable Development (IISD), 2022, pp 1-25.

[21] M. Buoro, "Adaptation et persistance des populations de saumon face au changement climatique'', 2019 np.

[22] J. B. K. Vodounou et Y. O. Doubogan, "Agriculture paysanne et stratégies d'adaptation au changement climatique au Nord-Bénin", Cybergeo: European Journal of Geography [En ligne], Environnement, Nature, Paysage, document 794, mis en ligne le 15 novembre 2016, consulté le 29 décembre 2022. URL : http://journals.openedition.org/cybergeo/27836 ; DOI : https://doi.org/ 10.4000/cybergeo.27836.

[23] T. TABOU, "Contraintes climatiques et élevage pastoral bovin dans le département de l'Alibori (Bénin) : Vulnérabilité et stratégies d'adaptation", Thèse de Doctorat. DGAT/FASHS/UAC, 2020, 278 p.

[24] INSAE, RGPH4: que retenir des effectifs de population en 2013 ? Direction des études démographiques, Cotonou, 2013, 35 p.

[25] M. M., Seastrom, Taux de réponse comme outil de gestion de la qualité des données. Recueil du symposium 2001 de statistique Canada, 2001.

[26] J. Latour, Comment la gestion participative s'inscrit-elle dans la transition écologique et la résilience des communautés ? (Doctoral dissertation, Université de Sherbrooke), Centre universitaire de formation en environnement et développement durable, 2018, 84 p.

[27] J. Salava, H. Randriamanampisoa, T. Razanakoto, P. Lazamanana, A. Andrianjakatina Et M. Randrianalijaona " Évaluation de la résilience communautaire : L'Indice Multidimensionnel de Résilience", Communication, technologies et développement, pp. 1-12. DOI : https://doi.org/10.4000/ctd.3881

[28] R. B. K. Chabi, E. Dossou, B. F Yabi., I. Yabi, A. B. H. Tente, "Climate Changes and Dynamics of the Ecological Niche of Threatened Woody Species in the Dahomey Gap Corridor in Benin", International Journal of Agricultural and Environmental Sciences, Vol. 6, No. 1, 2021, pp. 1-14.

[29] M. Turnbull, C. Sterrett, & A. Hilleboe, "Toward resilience: A guide to disaster risk reduction and climate change adaptation", Practical Action Publishing, 2013, 194 p.

[30] B. Obrist, C. Pfeiffer, et R. Henley, "Multi-layered social resilience A new approach in mitigation research", Progress in Development Studies, 10, 2010, pp. 283–293. DOI: 10.1177/146499340901000402. disponible sur: http://pdj.sagepub.com/content/10/4/283.

[31] E. Boegh, H. Sogaard, N. Broge et coll., "Airborne multispectral data for quantifying leaf area index, nitrogen concentration, and photosynthetic efficiency in agriculture", RemoteSens, *Elsevier, Remote Sensing of Environment*, vol. 81, 2002, pp. 179-193.

[32] S. Weissenberger, "Haïti : vulnérabilité, résilience et changements climatiques", Cahier thématique – Gestion de l'environnement et développement durable Haïti Perspectives, 2018, (6)3 : pp 19-26.

[33] M-J. Fluet, Impacts des changements climatiques sur les agriculteurs de la province du Zondoma au Burkina Faso: adaptation, savoir et vulnérabilité, Thèse de doctorat. Université du Québec à Montréal, 2006, 140 p.