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Climate Variations and Implementation of Climate Planning in The Municipalities of Zio1 (Togo) And Zou (Benin)

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Abstract

Climate variations negatively impact municipalities in West Africa. In the municipalities of Zio1 and Zou, climate variations have consequences on the local economy. However, these municipalities are unable to implement climate actions defined at the local level. This research is based on the following hypothesis : in Zio1 as in Zou, the same difficulties in implementing climate planning are explained by choices of carrying out socio-economic development projects to the detriment of implementing climate actions. This article aims to examine the explanatory factors for the difficulties in implementing climate planning in the municipalities of Zio1 and Zou. In this research, climate variables from gridded observed data for the years 1981 to 2022 were used to analyze current climate conditions. For the analysis of future climate conditions, namely from 2021 to 2050, nine general circulation models were used. For socio-demographic data, a survey was conducted among 449 people aged 18 and over, spread across the territories of Zio1 and Zou. The results show that the implementation of climate actions is not a priority in the municipalities of Zoi1 and Zou. Several projects carried out at the local level are not sized to take into account climate variations.

Keywords: *Climate Variations, Climate Planning, Municipalities, Local Actions.*

Introduction

Climate change is one of the major challenges facing the world in the 21st century (Abidoye & al., 2015). Today, climate change has become a major international concern. Several studies have addressed the phenomenon (Hansen & al., 2000). According to the Intergovernmental Panel on Climate Change (IPCC, 2022), a number of pressures and a lack of adaptive capacity make Africa one of the most sensitive continents to climate variation. As a result, climate change is causing changes in rainfall patterns, temperature rises and natural disasters in Africa in general and West Africa in particular. Thywissen (2006) has shown that vulnerability evolves over time and across geographical areas. This means that vulnerability to climate change is location-specific and spatially variable (Torresan, 2008), as some areas are more vulnerable than others. Climate change is therefore one of the major challenges facing West Africa in the 21st century. A case in point is the flood along the Gulf of Guinea coastline, affecting countries such as Senegal, Côte d'Ivoire, Ghana, Togo and Benin. This coastline is one of the three most vulnerable coastal zones in the world (ECOWAS-SWAC/OECD, 2008). West Africa is therefore considered one of the regions which are most vulnerable to climate change and is affected by extreme climatic hazards (Niang & al, 2014). West African countries face more difficult climatic conditions (Diarra & al., 2013). For example, agricultural production is particularly affected by climate variation in this zone (Heinrigs, 2010).

Climate change is defined by several parameters. In the context of this research, these are mainly parameters linked to variations in temperature and precipitation. In general, studies show that global warming leads to an increase in temperature, a change in precipitation patterns and an increase in the intensity of extreme weather events (O'Gorman, 2015). According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), a further increase in the risk of extreme weather events, namely heavy rainfall, extreme temperatures, heat waves and the like, is likely to occur worldwide throughout the 21st century as a result of climate change (IPCC, 2014). In the recent public presentation of the IPCC Working Group II Sixth Assessment Report (IPCC, 2022), it is stated that human-induced climate change is causing

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major disruptions in nature and affecting the lives of billions of people worldwide. For the IPCC (IPCC, 2014), each of the last three decades has become warmer than any period before 1980. Climate change is having a significant impact on many developing countries, whose main economic activities rely heavily on climate-sensitive sectors (Mesfin, 2020). The low capacity of municipalities to adapt to climate change is worsening the lives and livelihoods of vulnerable populations, especially at the local level (Houndjo & Kpotchou, 2024). These vulnerable populations play an important role in land-use planning, so it is necessary to integrate climate change issues into land-use planning with a focus on greenhouse gases reduction (Stoeglehner, 2020). The low-carbon development strategy was incorporated into the Paris Agreement, with obligations for all countries to keep global warming levels below 2 degrees Celsius (Duyck, 2015). This is because climate variation affects, among other things, the socio-economic development of municipalities. Climate variation threatens the food security of especially vulnerable populations, as agricultural production is sensitive to this phenomenon (Heinrigs, 2010).

According to the Intergovernmental Panel on Climate Change, climate variability refers to variations in the mean state and other statistics, such as standard deviation and extremes, of climate at all temporal and spatial scales beyond that of individual weather events (IPCC, 2014). In simple terms, climate variation describes how climatic elements, such as temperature and precipitation, deviate from their mean values over given months, seasons, years, decades or centuries. The complex mechanisms behind climate variation are influenced by a variety of factors (Malherbe & al., 2016). The IPCC predicts that the effects of climate variation will intensify as greenhouse gas concentrations in the atmosphere increase (IPCC, 2018). Thus, socio-economic activities including among others agriculture, human health and biodiversity are affected by climate variation and extreme events (Muluneh, 2021). Climatic parameters, especially precipitation and temperature (De-Graft & al., 2012), affect for example crops and infrastructure. Among the various parameters of climate variation, rainfall and temperature play a more decisive role. Indeed, climate variation has a direct impact on socio-collective infrastructures. This is borne out by the destruction of social and community infrastructures caused by flood and violent winds. These destructions are partly due to the fact that municipalities do not integrate climate change risks into the construction of socio-collective infrastructures such as roads, schools, market infrastructures, retention basins, gutters, etc. Altamimi (2023) reveals that projection models have a lasting influence on assessing the sustainability of socio-economic structures. Climate variation also affects various sectors such as agriculture, health, water and energy (IPCC, 2007).

Global warming, a global phenomenon with local signatures, does not spare the municipalities of Zio1 (Togo) and Zou (Benin). The economies of the municipalities of Zio1 and Zou are essentially based on agriculture and trade. The agricultural system is dominated by food crops. The bulk of commercial activity is rightly concentrated on food products. The quantity of foodstuffs produced fluctuates. This is largely due to the implications of climatic variability. In the municipalities of Zio1 and Zou, maize cultivation predominates (PDC Zio1, 2023 and EIES Zou, 2024). One of the main characteristics of the climate in Togo and Benin is the rainfall regime (Ramel, 2005). Climate variation therefore has consequences for the local economy, particularly for agriculture. Climate trends are marked by a variation in rainfall on the one hand, and an increase in temperature on the other. Developing countries like Benin and Togo, remain highly vulnerable to climate risks due to their high dependence on natural resources and low adaptive capacity. For Hounkponou (2015), populations unanimously recognize that climate risks have become highly perceptible and essentially disrupt agricultural activities. The climate risks identified in the municipalities of Zio1 in Togo and Zou in Benin are : drought, flood, high temperatures, seasonal shifts and poor rainfall distribution. Analysis of the manifestations of climate change showed a rising trend in temperature and a gradual decline in rainfall levels in the study areas. There has been a change in the onset of the rainy season, the frequency and impact of floods and droughts. The impact of climate change on crops and ecosystems, livestock and fishing is overall negative (MERF Togo, 2009).

With regard to climate planning, the municipalities of Zio1 (Togo) and Zou (Benin) are experiencing difficulties in implementing projects related to climate change. In 2019, with the support of external experts, the municipalities of Zio1 and Zou drew up their action plans for Sustainable Energy Access and Climate Action Plan (SEACAP) within the framework of the Covenant of Mayors for Sub-Saharan Africa (CoM

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SSA). The SEACAP is a territorial sustainable development project whose primary aim is to combat climate change. Despite the impacts of climate change on agriculture and infrastructure, among other things, in the municipalities of Zio1 and Zou, it has been observed that action plans for sustainable energy and climate access are not being implemented. The municipalities attach very little importance to the climate projects contained in the SEACAP. To date, the number of projects carried out in connection with climate change remains very low. Thus, we note that the climate planning drawn up by the municipalities of Zio1 and Zou (SEACAP Zio1, 2019 and SEACAP Zou, 2019) is not being implemented by municipal actors.

In view of the low rate of implementation of climate planning despite the impacts of climate variation, the aim of this research is to show the factors that explain the difficulties in implementing climate planning in Zio1 and Zou. To clearly define the scope of this research, a central question is formulated : what explains the difficulties in implementing climate planning in Zio1 and Zou despite the impacts of climate variation ? The following heuristic proposition is put forward : in Zio1 as in Zou, the same difficulties in implementing climate planning can be explained by choices to carry out socio-economic development projects to the detriment of implementing climate actions.

The testing of the hypothesis is in line with the decision-theoretic perspective of S.O. Hansson (2005). Decision theory is a theory about decisions. This theory evokes two aspects of decision-making : normative decision theory and descriptive decision theory. Normative decision theory refers to the way in which decisions should be made. Referring to the municipalities of Zio1 and Zou, municipal actors should give priority to implementing projects selected and planned in local planning documents such as communal development plans (PDC) and Sustainable Energy Access and Climate Action Plan (SEACAP). This is not the case in the municipalities of Zio1 and Zou, as the implementation of climate planning is not effective in the aforementioned municipalities. Descriptive decision theory deals with how decisions are actually made. In the municipalities of Zio1 and Zou, the decisions that are actually taken with regard to project implementation do not take climate action planning into account.

Materials and Methods

Study Area

Togo is located in West Africa and is a state on the Gulf of Guinea. With a surface area of 56,600 km2, Togo is bordered by Ghana to the west, Benin to the east, Burkina Faso to the north and the Atlantic Ocean to the south. Since September 1965, Togo has been subdivided into five administrative regions : Maritime, Plateaux, Central, Savanes and Kara. Each region is subdivided into prefectures. Togo currently has 39 prefectures. Each prefecture is made up of municipalities. After the June 2019 municipal elections, Togo will have a total of 117 municipalities. The prefecture of Zio has 4 municipalities, including Zio1 (figure 1). It is located in the southern part of Togo, less than 20 kilometers from the Atlantic Ocean. The town of Tsévié is the capital of the Zio1 municipality, the Zio prefecture and the Maritime region. Tsévié is located 35 km from Lomé, the capital of Togo. The municipality of Zio1 is made up of 8 cantons : Abobo, Dalavé, Davié, Djagblé, Gbatopé, Gblainvié, Kpomé and Tsévié. The municipality of Zio1 lies between 1°10' and 1°22' East longitude and between 6°11' and 6°37' North latitude. It covers an area of 889 km². The municipality of Zio1 is in the northern extension of Lomé. Oriented south-north, the municipality's southern flank is a logical gateway to the capital city, less than twenty kilometers from Lomé. Figure 1 below shows the municipality of Zio 1, one of the two research sites.

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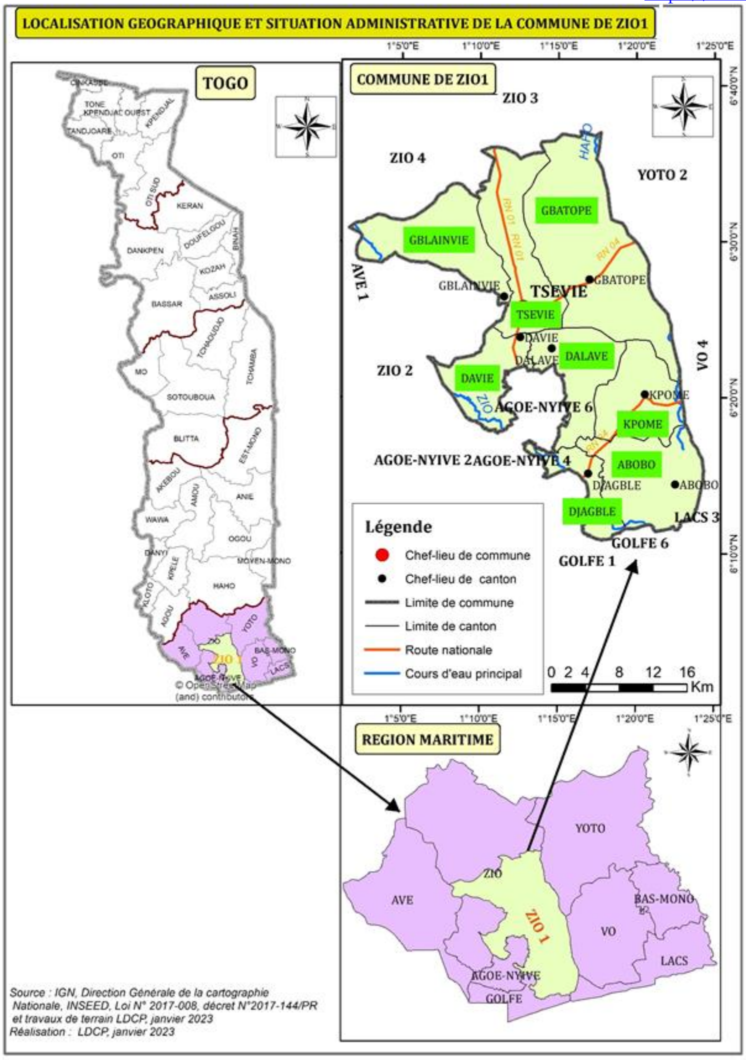

Figure 1 : Location of the municipality of Zio1

The municipality of Zio1 borders several municipalities in the Maritime region. It is bordered to the south by the municipalities of Golfe 1 and Golfe 6 ; to the southeast by the municipality of Lacs 3 ; to the southwest by the municipalities of Agoé-Nyivé 4 and Agoé-Nyivé 6 ; to the north by the municipalities of Zio 3 and Zio 4 ; to the east by the municipalities of Yoto 2 and Vo 4 ; and to the west by the municipalities of Avé 1 and Zio 2. According to the latest general population and housing census carried out in November 2022, the Zio 1 municipality have a population of 307,292 inhabitants (RGPH-5, 2022).

The second research site is the Zou department in Benin (figure 2). Togo and Benin border each other. Benin is located in West Africa between latitudes 6°30' and 12°30' North and longitudes 1° and 3°40' East. According to the results of the general population and housing census carried out in Benin in May 2013 (RGPH-4, 2013), Benin has a population of 10,008,749 inhabitants and a surface area of 114,763 km². Since January 1999, Benin has had twelve (12) departments : Atacora, Donga, Bogou, Alibori, Atlantique, Littoral, Mono, Couffo, Ouémé, Plateau, Collines and Zou. The departments are subdivided into 77 municipalities. The Zou department is the focus of our study in Benin. With a surface area of 5,243 km² and a population of 851,623 inhabitants (RGPH4, 2013), the Zou department is located in central Benin. Zou is made up of nine municipalities, namely : Abomey, Agbangnizoun, Bohicon, Covè, Djidja, Ouinhi, Za-kpota, Zagnanado and Zogbodomey.

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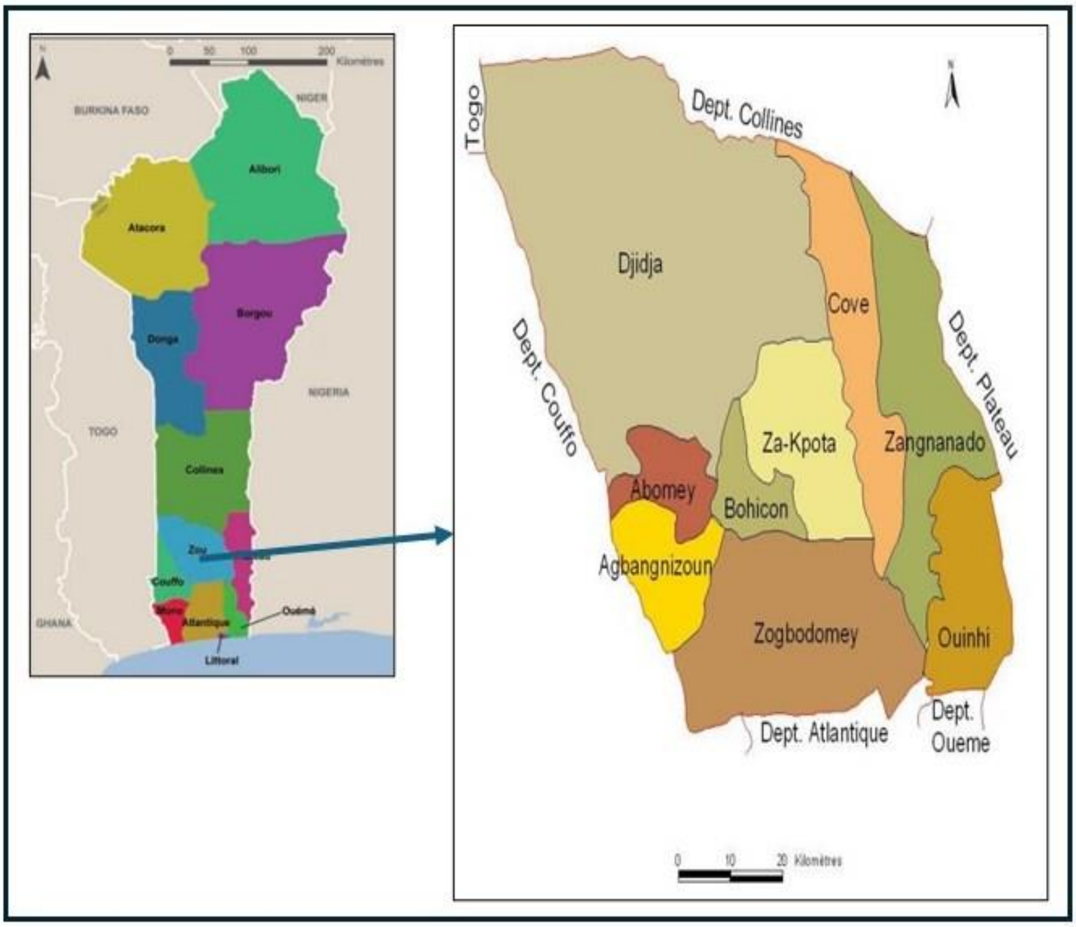

Figure 2 : Location of Zou department

Climate data collection and processing

Climate data

In this study, climate variables from observed gridded data (precipitation, mean temperature at 2m) for the years 1981 to 2022 were used to analyze current climate conditions. These observed data are obtained from the Climate Research Unit (CRU, Harris et al., 2020). CRU data are station data interpolated to a spatial resolution of 0.5°x0.5° on global grid points. These gridded data are used in this study as they fill in gaps where weather station observations are not available. In addition, data from the ECMWF v5 reanalysis (ERA5) were used. Using both types of data allows us to assess the biases and uncertainties of both datasets. If the two sources agree, confidence in the results increases. Discrepancies highlight areas requiring further research or model improvements.

For the analysis of future climate conditions, nine (09) NEX-GDDP-CMIP6 (NASA Earth Exchange - Global Daily Downscaled Projections) general circulation models (GCMs) with bias correction at 0.25° spatial resolution were used (table 1). NEX-GDDP-CMIP6 consists of downscaled global climate scenarios derived from general circulation model (GCM) simulations carried out as part of phase 6 of the Coupled Model Intercomparison Project (CMIP6) (Eyring et al. 2016). In addition, all these models have data for the historical period. SSP 2 (SSP2-4.5) and SSP 5 (SSP5-8.5) are used to reflect a central path and an energy-intensive fossil fuel-dependent economy, respectively. In this research, the overall average of the models (9 models) was used.

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Table n°1 : Details of the NEX-GDDP-CMIP6 models used in this research.

N°	Model	Institute	References
1	ACCESS-CM2	Commonwealth Scientific and Industrial Research Organisation—Australia Bureau of Meteorology (BoM), Australia	Bi et al., 2012
2	ACCESS-ESM1-5	Commonwealth Scientific and Industrial Research Organisation,	Law et al., 2017
3	CanESM5	Canadian center for Climate Analysis and Modelling	Swart et al., 2019
4	CNRM-CM6-1	Centre National de Recherches Météorologiques	Voldoire et al., 2019
5	CNRM-ESM2-1	Centre National de Recherches Météorologiques	Séférian et al., 2019
6	FGOALS-g3	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences and CESS, Tsinghua University, China	Pu et al., 2020
7	INM-CM4-8	Institute for Numerical Mathematics, Russia	Volodin et al., 2018
8	MPI-ESM1-2-LR	Max Planck Institute for Meteorology	Mauritsen et al., 2019
9	UKESM1-0-LL	UK Met Office and Hadley centre	Mulcahy et al., 2020

Method of analysis of climate data

The analysis of climate conditions in this research consisted of analyzing current climate conditions (1981-2022) and future climate conditions (2021-2050) relative to a reference period (1985-2014).

For current climate conditions, the spatial distribution of rainfall and 2m temperature for the months from December to February (DJF), March to May (MAM), June to August (JJA), and September to November (SON) was analyzed in both study areas. This spatial analysis identifies wet (dry) and hot (cold) areas within the study area. Gridded observation data from CRU and ERA5 reanalysis were used for this spatial analysis.

To study future climate conditions (2021-2050), the spatial distribution of projected changes in rainfall and 2m temperature was analyzed. The projected change corresponds to the difference between the future climate condition (2021-2050) and the reference climate condition (1985-2014). Whenever current and future climate conditions are compared, a Student's t-test taking into account unequal variance at the significant level of 0.05 is performed to determine whether the mean values are significantly different between the two climate conditions. In addition, the projected changes in the climate extreme indices that characterize the climatic hazards floods and heat waves were analyzed for the future period 2021-2050 with the period 1985-2014 as a reference, taking into account the two socio-economic scenarios (SSP2-4.5 and SSP5-8.5). These extreme indices (Table 2) were selected from the list established by the Expert Team on Sectoral Climate Indices (ET-SCI) established by the Commission for Climatology of the World Meteorological Organization (WMO-CCL). ET-SCI indices were calculated using ClimPACTv2 software (Alexander and Herold, 2016).

Table n° 2 : Climate extreme indices used in this analysis.

Index	Name of indices	Definition	Unit
Prcptot	Total precipitation on wet days	Daily precipitation sum PR >= 1mm	mm

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R95ptot	Fraction of annual precipitation from very heavy rain days	100* (annual sum of daily precipitation PR > 99th percentile)/Prcptot	%
Rx5day	Max. PR 5 days	Max. Total PR 5 days	mm
WSDI	Duration of consecutive hot days indicator	Annual number of days contributing to events in which 6 or more consecutive days have a Tmax > 90th percentile	days
HWF	Heat wave frequency	Number of days contributing to the heat wave	days
HWD	Duration of heat waves	Longest heatwave on record	days
TXX	Max TN	Highest daily temperature TN	°C
R10mm	Number of days with PR >= 10 mm	Number of days with PR >= 10 mm	days

Socio-demographic data collection and processing

The methodological approach used in this research combines a structured questionnaire, semi-directive interview guides, an observation grid and documentary research. To measure the indicators and identify the difficulties involved in implementing climate planning in Zio1 and Zou, a quantitative survey was carried out in the two study areas using a structured questionnaire from September to November 2023. Information was gathered from municipal administrations, leaders of civil society organizations, traditional chiefs, heads of neighborhood development committees, heads of village development committees, and also from technical executives of decentralized state services.

Sampling and questionnaire administration

In November 2022, Togo carried out its fifth general population and housing census (RGPG-5). According to the results of this census, the Zio1 municipality has a population of 307,292 inhabitants. In Benin, the fourth general population and housing census (RGPG-4) was carried out in May 2013. According to the census results, the municipalities of Abomey, Bohicon, Djidja and Za-Kpota have a population of 92,266, 171,781, 123,542 and 132,818 inhabitants respectively. The municipalities of Bohicon, Djidja and Za-Kpota have the highest populations in Zou. The municipality of Abomey is the capital of the Zou department. Taking into account both the number of inhabitants in each municipality and the administrative status of the municipality of Abomey, the four above-mentioned municipalities were selected and a sub-sample of interviewees determined.

For the purposes of this research, we used purposive sampling. The proportion of people to be surveyed in each municipality was screened using quota sampling. For Camille Javeau and Cathérine Vigneron (1989), the complexity of the operations involved in constructing sampling rates explains why it's not surprising to see rates of 0.1%, 1.21 ‰, or 10% considered significant when contexts allow. For Henri Mendras (1967), quota sampling aims to constitute a reduced model of the population to be studied. Bearing in mind the objectives of the study, which requires the use of the same measuring instrument in each of the municipalities, we applied a sampling rate of 1/3,000th as for all municipalities. To determine the sub-sample of people surveyed in each municipality, we use the following formula :

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$$n = N \times T$$

N = Base

T = sampling rate

n = sample size to be surveyed.

In the field, the survey was carried out with 279 people from civil society organizations, community leaders and other citizens. Community leaders included representatives of development organizations and traditional chiefs. The diversity of respondents in the sample made it possible to measure indicators and identify difficulties linked to the implementation of climate planning in the municipalities of Zio1 and Zou. The table below shows the number of people surveyed in each municipality.

Table n° 3 : Sample size for the quantitative survey

Municipalities	Abomey	Bohicon	Djidja	Za-Kpota	Zio1	Total
Population of municipalities	92 266	171 781	123 542	132 818	307 292	**827 699**
Sample size	31	58	42	45	103	**279**
Total	**31**	**58**	**42**	**45**	**103**	**279**

Source : Field survey, November 2023.

Focus groups with key local players

Two (2) focus groups were held in each municipality. The first focus group involved grassroots community organizations, civil society organizations, traditional chiefs and private operators. The second focus group was made up of other categories of citizens from the municipalities. Ten (10) people took part in each focus group session. Thus, the two (2) focus group sessions reached 20 people per municipality. Overall, 100 people were reached in the 5 municipalities selected for this research.

Individual interviews with target players

The interview guides were sent to the municipal administrations, including the members of the steering committee responsible for developing the SEACAP for Zio1 and Zou, and to the technical executives of the deconcentrated state services. The formal individual interviews involved fourteen (14) people in each municipality, including ten (10) people from the municipal administration and four (4) people from local government departments.

Field observation

During awareness-raising and information campaigns on the theme on climate change and other field activities, simple observations were made in order to ascertain the difficulties involved in implementing climate planning despite the impacts of climate variation in the study areas.

A summary table of all survey types and the number of respondents is provided.

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Table n° 4 : Sample size by survey type

Type of survey	Municipalities					Total
	Abomey	Bohicon	Djidja	Za-Kpota	Zio1	
Quantitative questionnaire	31	58	42	45	103	**279**
Formal individual interview	14	14	14	14	14	**70**
Focus group	20	20	20	20	20	**100**
Total	**65**	**92**	**76**	**79**	**137**	**449**

Source : Field survey, November 2023.

In total, the field survey reached 65 people in the municipality of Abomey, 92 people in the municipality of Bohicon, 76 people in Djidja, 79 people in Za-Kpota, and 137 people in the municipality of Zio1, making a total of 449 people.

Data processing and analysis

To measure the indicators and identify the difficulties involved in implementing climate planning in the municipalities of Zio1 and Zou, the data collected via KoboCollect were cleaned and processed with R software version 4.4.0. Analyses involved cross-tabulation of the variables of interest and statistical tests. Potential relationships between variables were examined using the chi-square (chi2) test, supplemented in some cases by analyses of associated residuals. Results were visualized using various packages to represent relationships between variables and modalities.

Results

Climatic characteristics in the municipality of Zio 1

Climatic characteristics over the historical period

Figures 3 and 4 respectively show the spatial distribution of rainfall and temperature at 2m, for the DJF, MAM, JJA and SON seasons in the municipality of Zio 1 for the period 1981-2022. This spatial distribution shows similarities between the CRU and ERA5 data. For example, for rainfall, both types of data, the MAM, JJA and SON seasons are the wettest (> 110 mm/month) where the northern part of Zio 1 municipality is the wettest. Also, the analysis shows that the DJF season records very low rainfall, particularly for the CRU data set. In terms of temperature at 2m (Figure 4), the DJF and MAM seasons are the hottest, as shown by both types of data, with temperatures reaching 28.5°C in the MAM season. The JJA season, which is the wettest, is the warmest in the municipality.

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Seasonal rainfall (1981-2022)

Figure 3 : Spatial distribution of seasonal average rainfall over the period 1981-2022 in the municipality of Zio 1; DJF (first column), MAM (second column), JJA (third column) and SON (fourth column) from CRU (top row) and ERA5 (bottom row) data.

Average temperature (1981-2022)

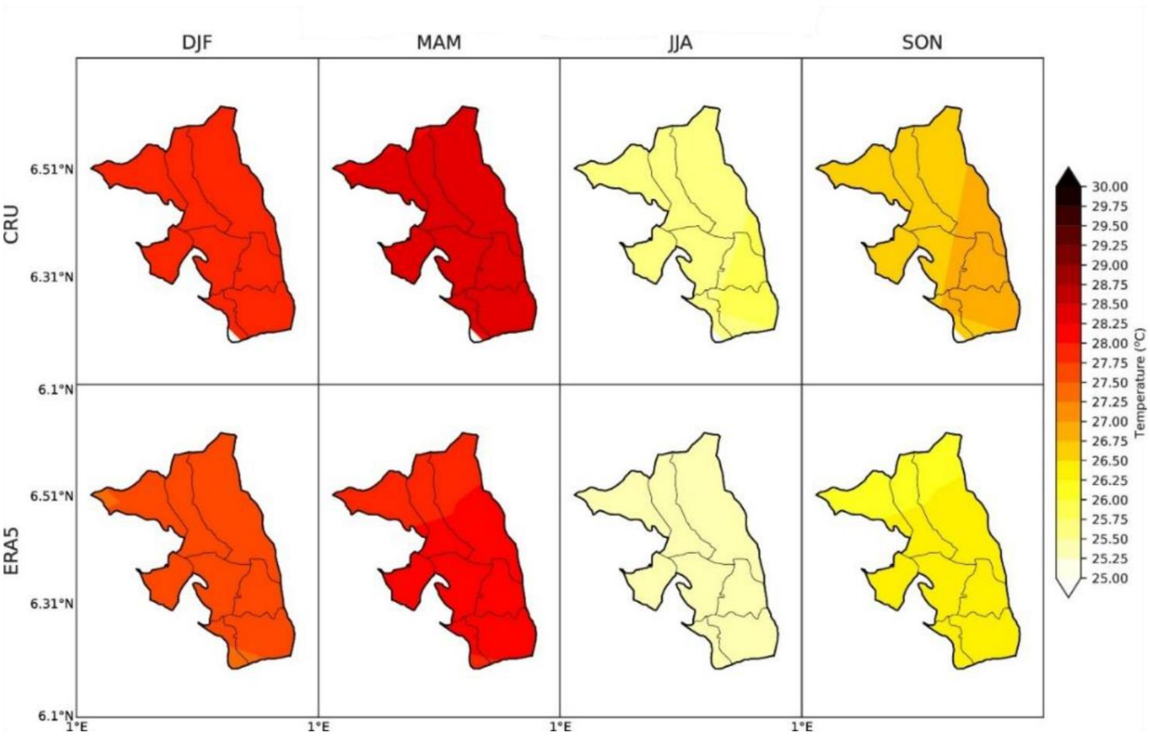

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Figure 4 : Spatial distribution of the seasonal average over the period 1981-2022 of the 2m temperature in the municipality of Zio 1; DJF (first column), MAM (second column), JJA (third column) and SON (fourth column) from CRU (top row) and ERA5 (bottom row) data.

Projected change in climate characteristics over the period 2021–2050

Projected change in rainfall and 2m temperature

The spatial distribution of changes in rainfall and 2m temperature over the future period 2021-2050 compared to the reference period 1985-2014 are presented in figures 5 and 6. The spatial distribution of future changes in climate variables is used to determine how these parameters are likely to evolve spatially in the future compared to their spatial distribution in the past.

The results show that for the SSP2-4.5 scenario, rainfall could decrease during the MAM and JJA rainy seasons (figure 5). This decrease in rainfall could be around 12 mm in the north and northwest of the municipality during the MAM and JJA seasons respectively. As for the SSP5-8.5 scenario, the results show a slight increase in rainfall in the municipality during the JJA season and a decrease during the MAM season.

For the temperature at 2m, the analyses show a possible increase over the period 2021-2050 in the municipality of Zio 1, regardless of the scenario (Figure 6). However, this increase is higher in the case of the SSP5-8.5 scenario. For example, while the increase is less than 1 °C during all seasons for the SSP2-4.5, it is greater than 1.5 °C for the SSP5-8.5 scenario. This increase in the temperature at 2m could increase evapotranspiration in this municipality and thus impact several socio-economic activities.

Projected change in rainfall (2021-2050)

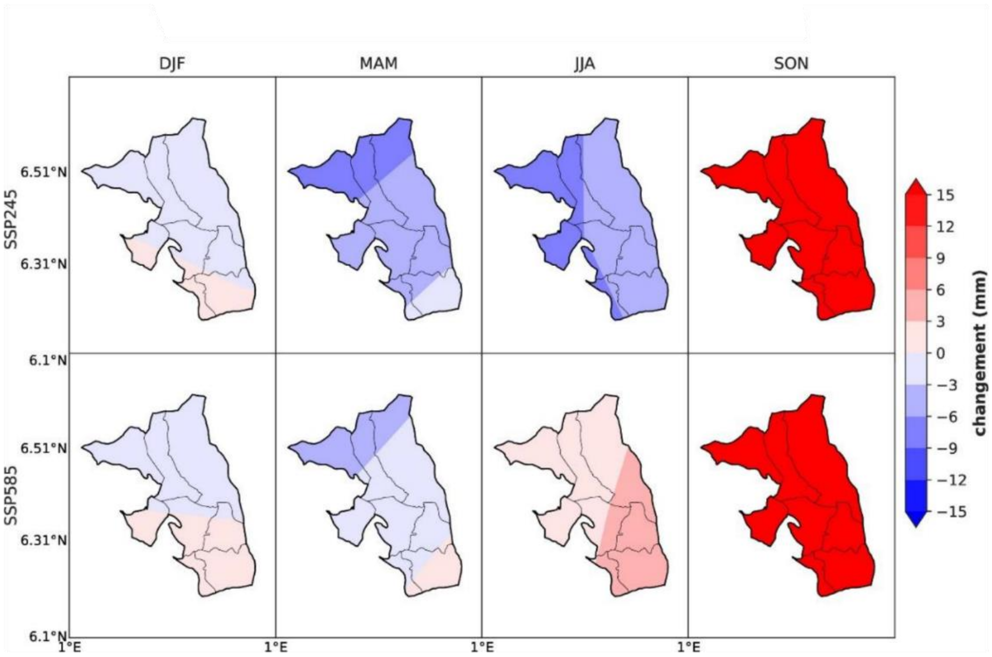

Figure 5 : Projected change in seasonal rainfall (mm) for the period 2021-2050 relative to the 1985-2014 baseline for DJF (first column), MAM (second column), JJA (third column) and SON (fourth column) from the mean of downscaled CMIP6 climate models (SSP2-4.5 top row ; SSP5-8.5 bottom row).

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Projected change in average temperature (2021-2050)

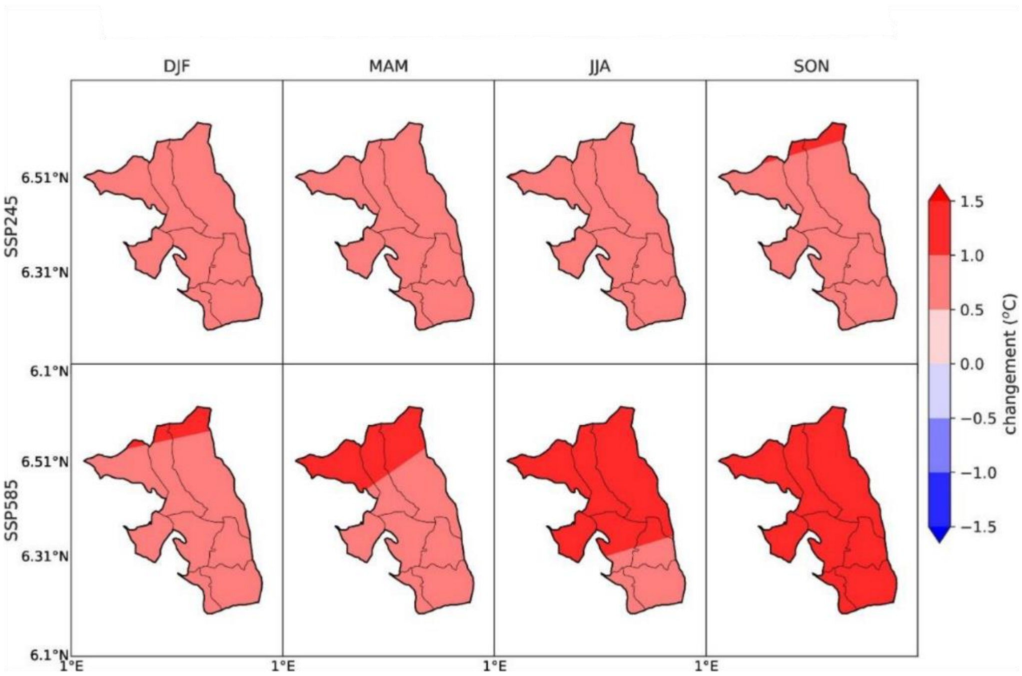

Figure 6 : Projected 2m temperature change (°C) for the period 2021–2050 relative to the 1985–2014 baseline for DJF (first column), MAM (second column), JJA (third column), and SON (fourth column) from the mean of downscaled CMIP6 climate models (SSP2-4.5 top row ; SSP5-8.5 bottom row).

Projected change in heavy rain and heat stress indices

The spatial distribution of future changes in four heavy rainfall indicators for the two scenarios (SSP2-4.5 and SSP5-8.5) over the period 2021-2050 is presented in figure 7. The analysis shows a general increase in three indicators (PRCPTOT, R99PTOT and R10mm) across the entire Zio 1 municipality for both SSPs. However, this increase in R99PTOT and R99PTOT is higher when considering the SSP5-8.5 scenario. With the increase in PRCPTOT associated with the increase in heavy rainfall (R99PTOT) and the number of days with rainfall above 10 mm, the Zio 1 municipality may experience more flood events over the future period (2021-2050) compared to the past situation. This situation could have negative impacts on the socio-economic activities of the municipality. Immediate impacts include the destruction of infrastructure, both buildings and transportation networks. These impacts could also lead to crop destruction, loss of livestock, and deterioration of health due to waterborne diseases.

Figure 8 presents the spatial distribution of future changes in simulated heat stress indicators for the future period (2021 - 2050) compared to the baseline period (1985 - 2014) for the SSP2.4-5 and SSP5.8-5 scenarios. Compared to the baseline period, the analysis shows an increase in TXX indicators in the municipality of Zio 1 over the future period. For the period 2021-2050, the increase in TXX across the municipality is almost uniform (~ 0.9 °C) for both SSPs scenarios. The Warm Spell Duration Index (WSDI) could increase by 100 days under the SSP2.4-5 and SSP5.8-5 scenarios compared to the historical period. Similar to the WSDI, the average of all models predicts an increase in heat wave frequency (HWF) and heat wave duration (HWD) indicators in Zio 1 municipality for both SSP scenarios. These future characteristics of heat stress indicators could have negative impacts on the municipality's socio-economic activities. For example, heat waves could increase water demand for irrigation, which can put a strain on water resources in affected areas. In addition, these future characteristics could cause building deterioration : concrete cracking, plaster cracking, corrosion of plumbing systems, etc.

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Projected change in heavy rainfall indices (2021-2050)

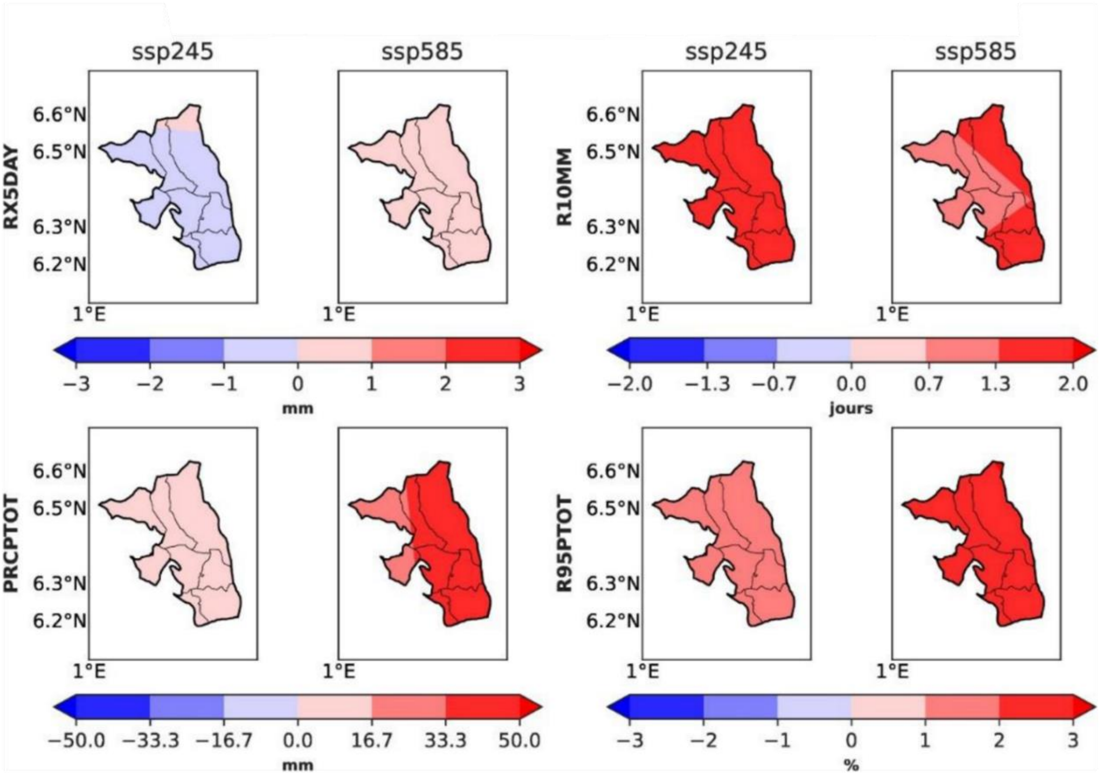

Figure 7 : Spatial distribution of projected changes in flood indicators under the SSP2-4.5 and SSP5-8.5 scenarios in the municipality of Zio 1, for the future period 2021 - 2050 compared to the 1985-2014 reference.

Projected change in heat stress indices (2021-2050)

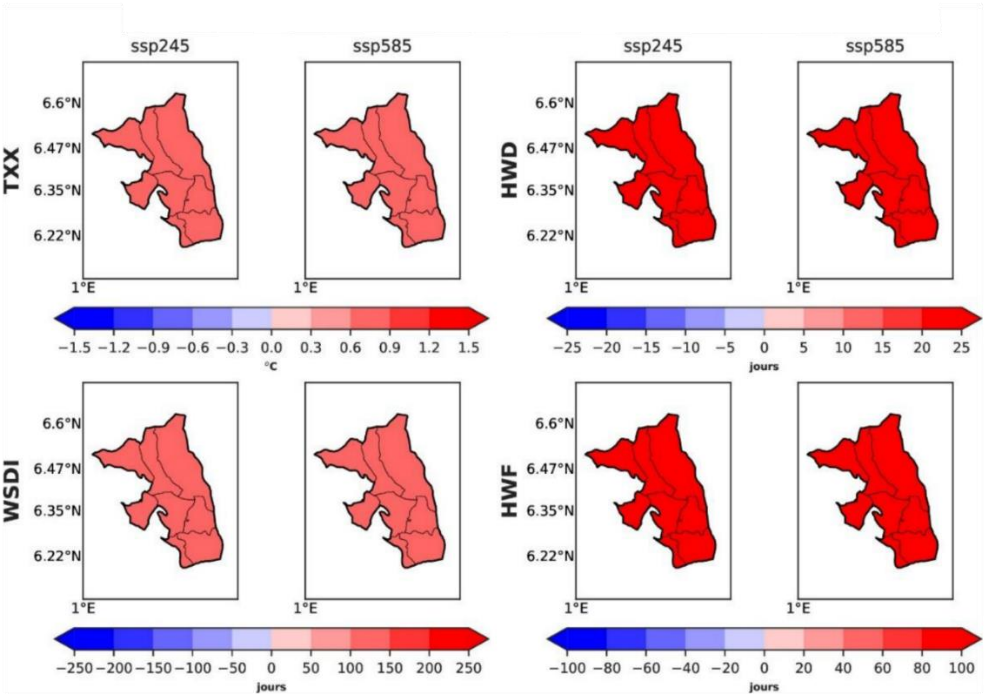

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Figure 8 : Spatial distribution of projected changes in heat stress indicators under the SSP2.4-5 and SSP5.8-5 scenarios in the municipality of Zio 1, for the future period 2021 - 2050 compared to the 1985-2014 baseline.

Climatic characteristics in the municipalities of Zou

Climatic characteristics over the historical period (1981-2022)

The spatial distribution of rainfall (figure 9) and temperature at 2m for the DJF, MAM, JJA and SON seasons in the municipalities of Zou for the period 1981-2022 is discussed in this section. This spatial distribution shows similarities between the CRU and ERA5 data. For example, for rainfall, both types of data, the MAM, JJA and SON seasons are the wettest (> 90 mm/month). In addition, for the JJA season, the rainfall increases as we move towards the north of Zou for both types of data, except that it is higher for the ERA5 data. Regarding the temperature at 2m, the DJF and MAM seasons are the hottest as shown by both types of data, with temperatures reaching 29.25 °C for the CRU data and 28 °C for the ERA5 data during the MAM season. The JJA season, which is the wettest, is the least hot in the municipalities of Zou.

Seasonal rainfall (1981-2022)

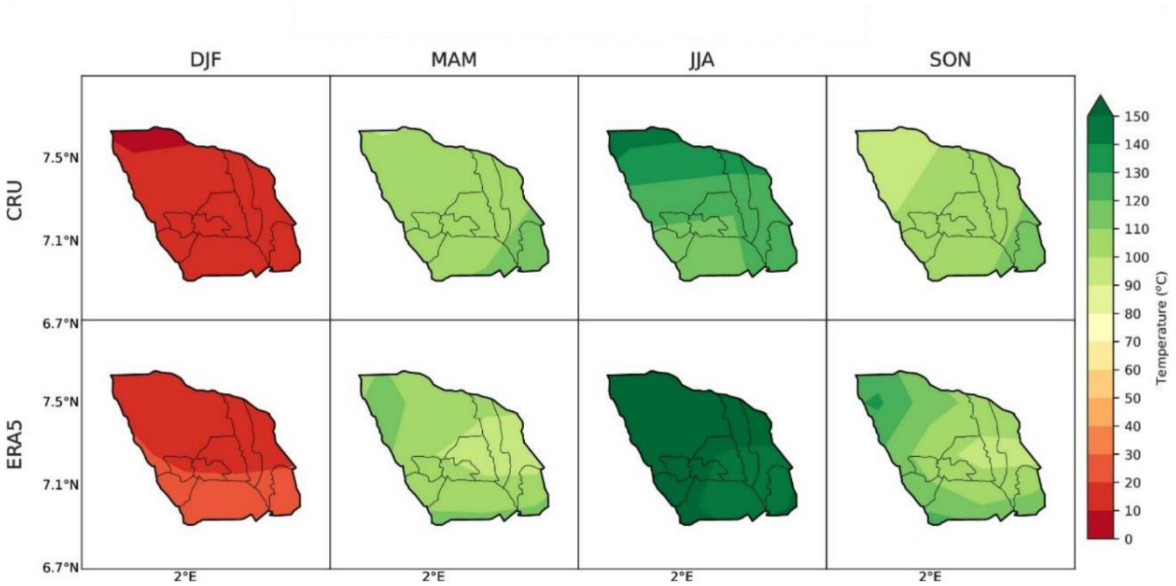

Figure 9 : Spatial distribution of the seasonal average over the period 1981-2022 of rainfall in the municipalities of Zou; DJF (first column), MAM (second column), JJA (third column) and SON (fourth column) from CRU (top row) and ERA5 (bottom row) data.

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Average temperature (1981-2022)

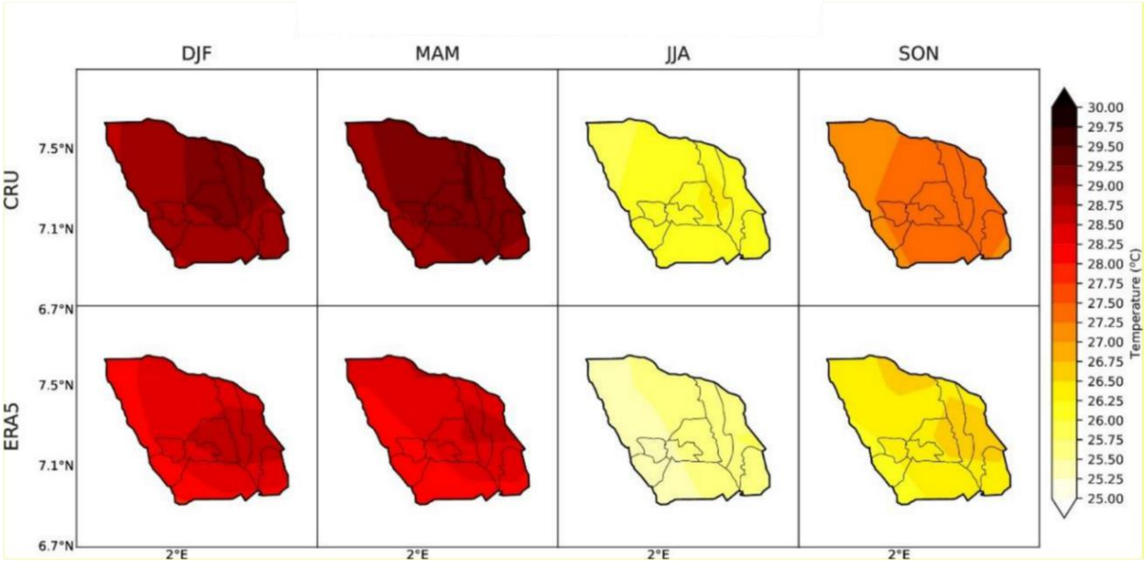

Figure 10 : Spatial distribution of the seasonal average over the period 1981-2022 of the 2m temperature in the municipality of Zio 1; DJF (first column), MAM (second column), JJA (third column) and SON (fourth column) from CRU (top row) and ERA5 (bottom row) data.

Projected change in climate characteristics over the period 2021-2050

Projected change in rainfall and temperature at 2m

The spatial distribution of changes in rainfall and 2m temperature over the future period 2021-2050 in the municipalities of Zou, compared to the reference period 1985-2014, are presented in figures 11 and 12.

The results show that for the SSP2-4.5 scenario, the analysis shows a non-significant decrease in rainfall during the MAM rainy seasons and a significant increase at the 95% confidence level for the SON season for both scenarios. This increase during the SON season could exceed 15 mm across the entire Zou.

For 2m temperature, the analyses show a significant increase at the 95% confidence level across most of the Zou, regardless of the scenario (figure 12). However, this increase is higher in the case of the SSP5-8.5 scenario. For example, while the increase is less than 1°C in all seasons for SSP2-4.5, it is greater than 1°C for the SSP5-8.5 scenario. This increase in temperature at 2m could increase evapotranspiration in this study area and thus impact several socio-economic activities. These results show the need for mitigation measures to avoid reaching the SSP5-8.5 scenario.

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Projected change in rainfall (2021-2050)

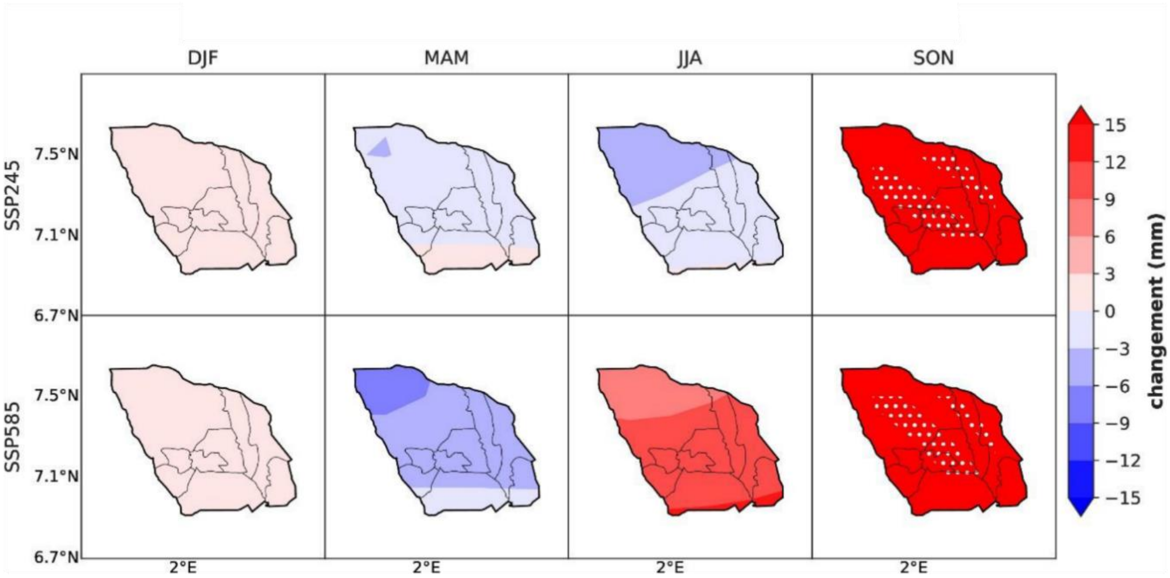

Figure 11 : Projected change in seasonal rainfall (in mm) for the period 2021-2050 relative to the 1985-2014 baseline for DJF (first column), MAM (second column), JJA (third column) and SON (fourth column) from the mean of downscaled CMIP6 climate models (SSP2.4-5 top row; SSP5.8-5 bottom row).

Projected change in average temperature (2021-2050)

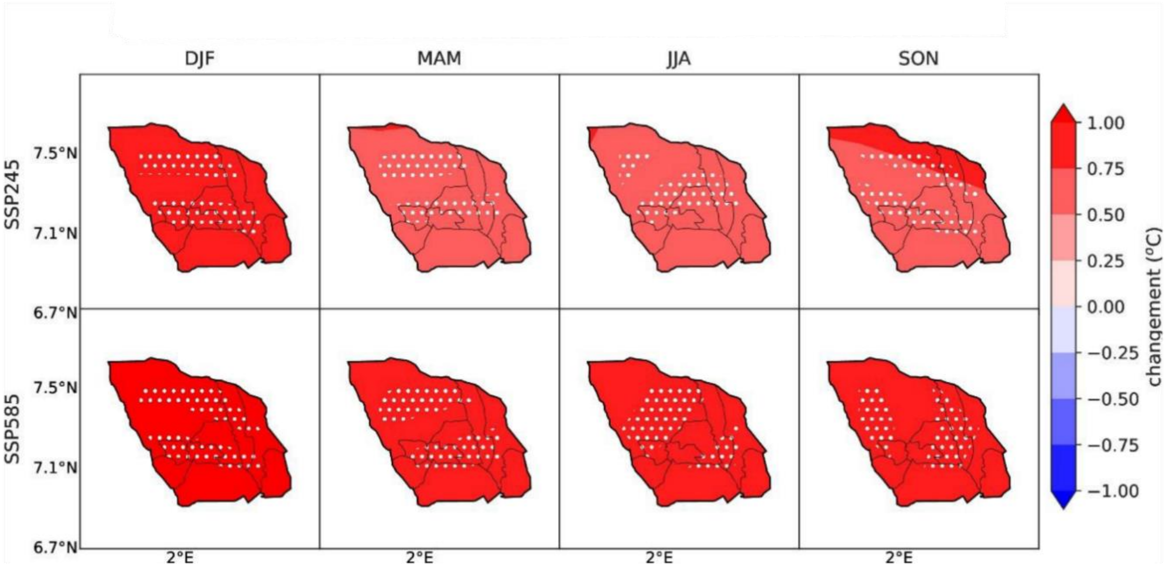

Figure 12 : Projected 2m temperature change (°C) for the period 2021–2050 relative to the 1985–2014 baseline for DJF (first column), MAM (second column), JJA (third column), and SON (fourth column) from the mean of downscaled CMIP6 climate models (SSP2.4-5 top row; SSP5.8-5 bottom row). Dots represent significant values at the 95% confidence level.

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Projected change in heavy rain and heat stress indices

The spatial distribution of future changes in four heavy rainfall indicators for the two scenarios (SSP2.4-5 and SSP5.8-5) in the municipalities of Zou, over the period 2021-2050 is presented in Figure 13. A general increase in two indicators (RX5DAY and PRCPTOT) across all municipalities of Zou for both SSPs is predicted by the overall average of the models, while a decrease in R95PTOT is predicted in the municipalities for the scenarios. With the increase in PRCPTOT associated with the increase in RX5DAY, the municipalities of Zou may experience flood events in the future period (2021-2050) compared to the past situation. This situation could have negative repercussions on the socio-economic activities of the area. In the short term, it could also lead to the destruction of infrastructure, affecting both buildings and transport infrastructure. In addition, it could cause crop destruction, loss of livestock and deterioration of public health due to the spread of waterborne diseases.

Figure 14 presents the spatial distribution of future changes in simulated heat stress indicators in Zou municipalities for the future period (2021-2050) compared to the baseline period (1985-2014) and for the SSP2-4.5 and SSP5-8.5 scenarios. Compared with the baseline period, the analysis shows a widespread increase in the four indicators (TXX, HWD, HWF, and WSDI) in Zou municipalities over the future period. For example, the increase in TXX across Zou is almost uniform and is around 1.2°C for SSP5-8.5 while it is around 0.9°C for SSP2-4.5. The hot spell duration index (WSDI) could increase by 150 days under the SSP2-4.5 and SSP5-8.5 scenarios compared to the historical period. Similar to the WSDI, the overall average of the models predicts an increase in heatwave frequency (HWF) and heatwave duration (HWD) indicators in Zou municipalities for both SSP scenarios. These future characteristics of heat stress indicators could have negative impacts on socioeconomic activities in the region. For example, the intensification of heat waves could increase water demand for irrigation, thus putting additional pressure on water resources in the affected areas. In addition, these extreme conditions could lead to infrastructure deterioration, including concrete cracking, plaster cracking, and corrosion of plumbing systems.

Projected change in heavy rainfall indices (2021-2050)

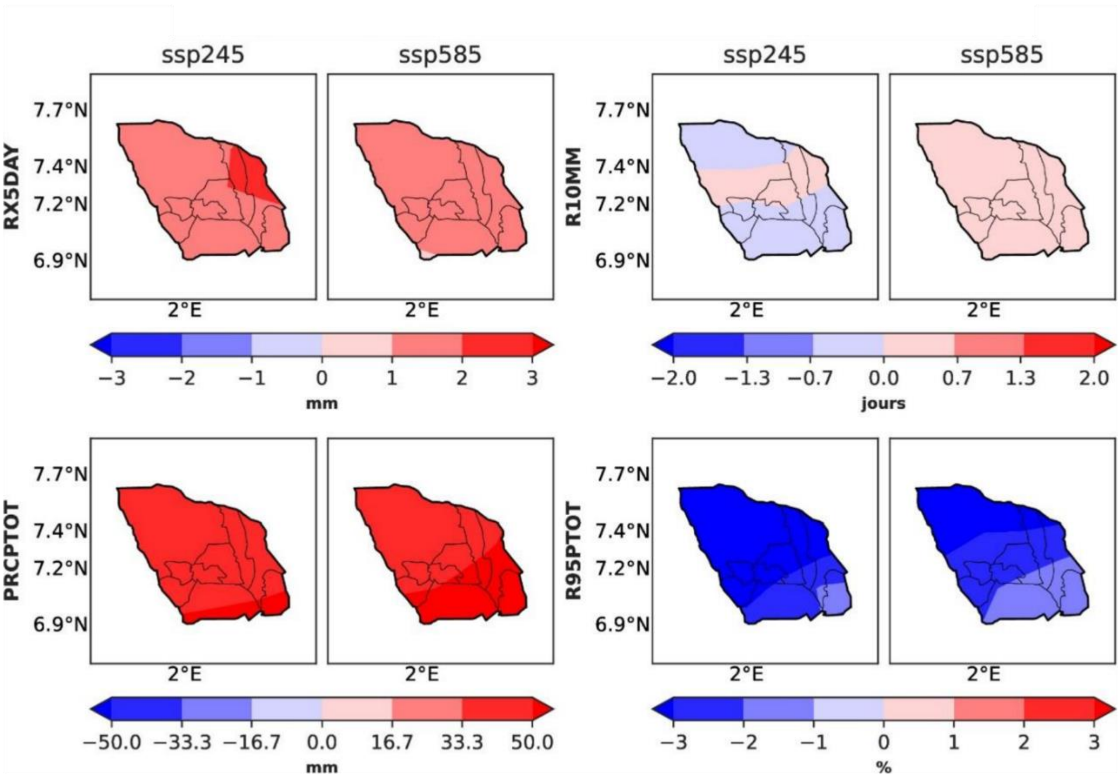

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Figure 13 : Spatial distribution of projected changes in flood indicators under the SSP2.4-5 and SSP5.8-5 scenarios in the commune of Zou, for the future period 2021 - 2050 compared to the 1985-2014 reference.

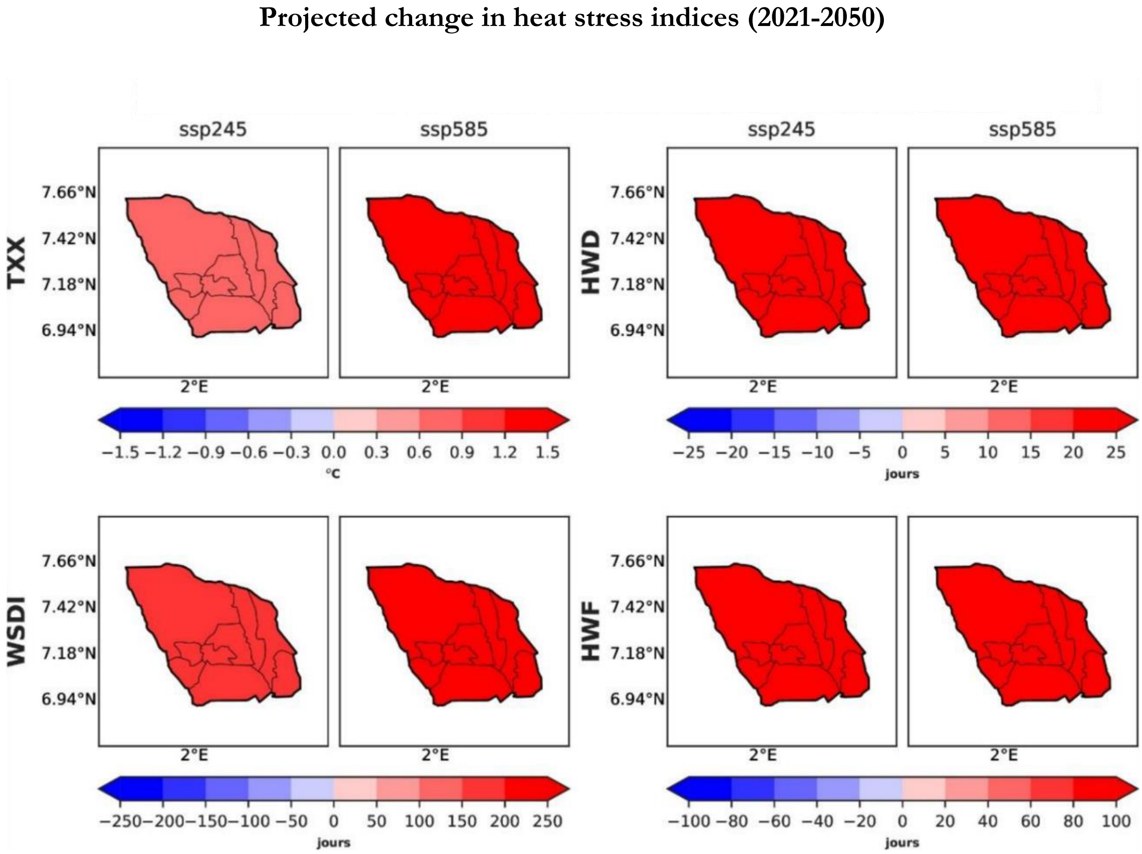

Figure 14 : Spatial distribution of projected changes in flood indicators under the SSP2.4-5 and SSP5.8-5 scenarios in the commune of Zou, for the future period 2021 - 2050 compared to the 1985-2014 reference.

In light of the above, climate variation has negative impacts in the municipalities of Zio1 and Zou. For example, in Djagblé irrigated area in the municipality of Zio1, floods reduce rice yields by 6 tons per hectare (6 t/ha). They generate additional costs of more than 2,000 FCFA (more than 3 euros) per day for motor pump rental and 25 liters/ha of fuel to drain water from flooded plots. In the municipalities of Zou as in Zio1, income from maize, for example, has been negatively impacted in recent years by variations in temperature and average rainfall. Temperature variation leads to a decline in maize income. The agricultural sector, dominated by the main crops of maize, cassava and rice, is particularly sensitive to climate vulnerability due to its dependence on weather conditions and natural resources. These include dependence on rainfall, droughts and water scarcity, temperature variability, floods, erosion and soil degradation.

Implementation of climate planning in the municipalities of Zio1 and Zou

The research highlighted the impacts of climate variation on socio-economic activities and infrastructure in the municipalities of Zio1 and Zou. Despite this climate vulnerability situation in our study area, municipalities attach little importance to the implementation of climate planning. Projects included in the SEACAP have a very low implementation rate. Mayors and municipal executives favor socio-economic projects that do not integrate climate aspects. This choice is made strategically to attract their electorate. The choice of projects to implement is often guided by political reasons. Projects that integrate the climate dimension are not a priority for municipalities. They consider that climate projects are less appreciated by the population. Consequently, mayors prefer to live by popular opinion and choose to invest in "concrete" (for example, the construction of market sheds, the construction of schools, the drilling of boreholes). These projects, carried out in the municipalities of Zio1 and Zou, do not integrate the dimension of climate

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variation. This observation is made for infrastructure projects such as the construction of schools, sanitation facilities, commercial infrastructure and others. It should be noted that after the completion of these projects, we witness in some cases flooding of markets, schools, or the destruction of infrastructure by strong winds because the infrastructure was undersized and did not integrate the risks associated with climate change.

Analysis of local planning documents, namely Municipal Development Plans (MDP) and Sustainable Energy Access and Climate Action Plan (SEACAP), shows a significant disparity in the implementation rates of the two (2) local planning tools.

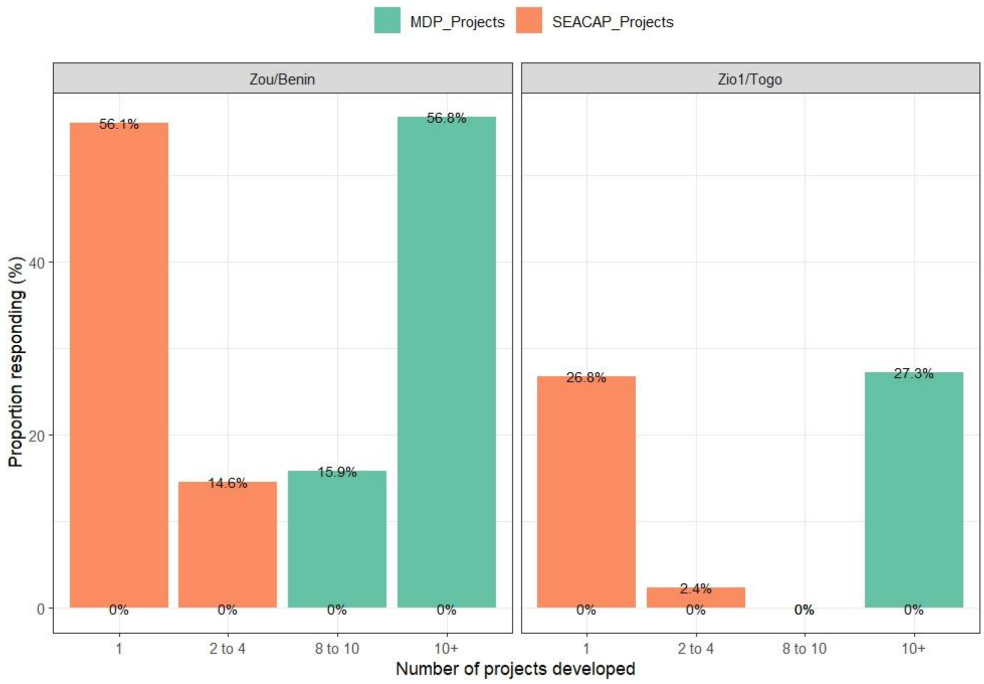

Figure 15 : Proportion of respondents according to the type of projects carried out in the municipalities of Zio1 and Zou.

This graph represents the proportion (%) of respondents based on the number of projects implemented as part of the MDP and SEACAP implementation in the municipalities of Zio1 and Zou over the period 2019 to 2023.

In the Zou locality, 56.1% of the population acknowledged that only one SEACAP project had been implemented, while 56.8% stated that more than 10 MDP projects had been implemented.

In the Zio1 municipality, 26.8% of the population acknowledged that only one SEACAP project had been implemented, while 27.3% stated that more than 10 PDC projects had been implemented. The chi-square test shows that the difference between the proportions of respondents is statistically significant at the 5% level (p-value < 2.2e-16). The analyses show that municipalities give priority to MDP projects to the detriment of projects from SEACAP.

Discussion

The research examined the difficulties associated with implementing climate planning in the municipalities of Zio1 and Zou despite the impact of climate variation in our study area. Indeed, our research reveals that climate variation has impacts in the municipalities of Zio1 and Zou. Vulnerable populations, especially farmers, are the main victims of this situation because they have very limited means to adapt to climate variation. Vulnerability therefore constitutes a major limitation in adapting to climate change. This result is

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consistent with the analysis of Heltberg and Bonch-Osmolovkiy (2010). For these two authors, poor populations are the least equipped to adapt to the impacts of climate change. Other research also argues that the increase in droughts and floods due to climate variation can increase the risk of farmers losing their livelihoods (Kissi, 2023). These results are consistent with studies conducted by authors such as Ngoma (Ngoma & al., 2021), Arifah (Arifah & al., 2021) and Harvey (Harvey & al., 2014) who have shown the impacts and risks of climate change in the socio-economic field including agriculture and other sectors. For Chédé (2012), the vulnerability of farmers to climate change in Benin is observed by an early or late start of the rains, an increase in temperature, a longer duration of the dry season or a reduction in the duration of the rainy seasons. Regarding the vulnerability of the agricultural sector, the Scientific Support Project for National Adaptation Plan Processes (PAS-PNA-Benin, 2019) shows that Benin, like Togo and other West African countries, is suffering the adverse effects of increasingly strong climate variability and the recurrence of extreme weather phenomena, namely devastating floods, long droughts, etc. Adejuwon et al. (1990) also note a delay in the start of the rainy seasons in the analysis of data from weather stations spread across different climatic zones in Nigeria. Afouda (1990), Boko (1988), Bokonon-Ganta (1987) and Vissin (2007) also noted a decrease in annual rainfall amounts, the late start and early end of the rainy season, and the frequency of rainy breaks in the heart of the rainy season. Agriculture's contribution to Gross Domestic Product in Togo is becoming increasingly uncertain given rainfall variability, which compromises agricultural productivity (KLASSOU K. S., 2011). This reduction in agricultural yields has consequences for the local economy in the municipalities of Zio1 and Zou, as well as for infrastructure.

Climate variation also impacts infrastructure systems in the municipalities of Zio1 and Zou. For Nasr et al. (2020), extreme climate events such as floods, increased rainfall, droughts, and heat waves represent a new risk to infrastructure, creating significant challenges for decision-makers.

Conclusion And Suggestions

Municipalities in Togo and Benin are increasingly exposed to climate change, resulting in rising temperatures. This situation affects agriculture, water resources, and public health, among other things. Despite this change, implementing climate action is not a priority for municipalities.

This research analyzed the implementation of Sustainable Energy and Climate Action Plans (SEACEAP) in the municipalities of Zio1 (Togo) and Zou (Benin).

The objective is to show the impacts of climate change at the local level and to analyze the implementation of climate planning documents in the municipalities.

Despite the impacts of climate change on socioeconomic activities at the local level, municipal governments place little importance on implementing climate planning. This analysis is also confirmed by field surveys. The majority of respondents stated that municipalities show little interest in implementing climate action.

The investigations, based on quantitative and qualitative methods, show that the implementation of climate actions is not a priority for municipal councils in general, and particularly for municipal executives. Many projects carried out at the local level are not designed to take climate variation into account. Although several socioeconomic activities are highly subject to climate variation, climate change considerations in development actions are not systematic in the municipalities of Zio1 and Zou. This situation has significantly impacted the implementation of the SEACAP in the municipalities of Zio1 and Zou.

To conclude this research, we recommend that state institutions responsible for climate change, planning, and development in municipalities in Togo and Benin strengthen the technical capacities of municipalities in developing projects sensitive to climate risks and in seeking climate change-related financing. Our recommendations also concern the integration of priority municipal projects into the NDCs of the various countries.

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Authors' contributions: All authors participated equally in all phases of writing this article. They all read this version of the manuscript and approved its publication.

Conflicts of Interest: The authors declare that there is no conflict of interest.

Institutional Review Board Statement: The study was conducted in accordance with the guidelines of the Declaration of Helsinki and the provisions of the Research and Innovation Charter of the University of Lomé of June 9, 2020.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. The principles of anonymity, confidentiality and the liberty to refuse or stop an interview in progress were respected.

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