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https://www.emerald.com/insight/1756-8692.htm

Received 9 June 2021
Revised 31 August 2021
24 October 2021
21 November 2021
Accepted 6 December 2021

Rice farmers' perceptions and response to climate variability, and determinants of adaptation strategies in the Republic of Benin

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Abstract

Purpose – The purpose of this study is to evaluate rice farmers' perceptions on the manifestations of the climate change and identify efficient strategies and determinants of adoption of these strategies in the Republic of Benin.

Design/methodology/approach – Surveys were conducted using participatory research appraisal tools and techniques, such as direct observation, individual interviews and field visits through a questionnaire for data collection. A total of 418 rice farmers across 39 villages located in the three climatic zones of the Republic of Benin were interviewed. Farmers' perceptions, temperature from 1952 to 2018 and rainfall from 1960 to 2018 data obtained from meteorological stations were analysed using descriptive and inferences statistics.

The authors would like to thank all the village chiefs, leaders of farmers' associations and rice farmers, who consented and shared their knowledge in the framework of this study.

Declarations

Funding: This study was funded by the French Institute for Sustainable Development (IRD) through the JEAI-GRAB « Genetic Resources and Agronomic Biodiversity in Benin » grant.

Conflicts of interest: The authors have no conflicts of interest to declare that are relevant to the content of this article.

Availability of data and material: Raw and treated data generated during the study are available from the corresponding author upon reasonable request.

Ethics approval: Not applicable.

Consent to participate: Data were collected under the previous consent of each participant.

Consent for publication: Not applicable.

International Journal of Climate Change Strategies and Management
Vol. 14 No. 4, 2022
pp. 332-353
Emerald Publishing Limited
1756-8692
DOI 10.1108/IJCCSM-06-2021-0059

Findings – All the surveyed farmers were aware of climate change and perceived diverse manifestations including the delay in rainfall regarded as the most important risk. They perceived that deforestation, no respect for the laws of nature and desacralization of morals, no respect for cultures and the traditional rainmakers are the main causes of climate change. The disruption of agricultural calendar and the reduction in rice yield were perceived as the main impacts of climate change in rice production. They used various approaches to adapt and mitigate climate change effects. The adoption of adaptation strategies was influenced either negatively or positively by the household size, land size, education level, membership to rice farmer's association, training in rice production, access to extension services, use of improved varieties and the location in climatic zones.

Research limitations/implications – For each climatic zone of the Republic of Benin, weather data were collected in only one meteorological station.

Practical implications – The study showed that it is important to educate rice farmers on the scientific causes of climate change for better resilience. There is an urgent need to train rice farmers in irrigation and water management techniques to cope with climate variability. To promote irrigation, the authors suggest the establishment of a subsidy and credit mechanism by the government. Factors that influenced adoption of efficient adaptation strategies to climate events must be taken into account for future adaptation policies in the Republic of Benin.

Originality/value – This study provided an overview of the perceptions and adaptations of rice farmers along the climatic gradient in the Republic of Benin. Therefore, the knowledge of the determining factors of the adaptation strategies used by rice farmers could be used in the setting up of effective climate change resilience policies in Benin.

Keywords Rice, Adaption strategies, Climate manifestations, Climate trends, Manifestations, Rainmaking, Adaptations' strategies

Paper type Research paper

1. Introduction

Climate change is one of the most disturbing and uncontrolled phenomenon that humanity is facing, and especially farmers. Throughout the world, the need to understand climate change has never been more urgent and important than in the 21st century, in a context of increase in the world population, projected to reach 9.8 billion (9.8 × 109) by 2050 [United Nations (UN), 2017]. With the evolutionary dynamics of the population, the need for food is increasing day by day, and it is urgent to carry out actions to reduce the effect of climate variability on agriculture to avoid facing the population hunger, which is increasing in the world due to climate variability (FAO, 2018). Simulation study, which uses 2014 as a baseline have shown that crop demand could increase between 25% and 70% in 2050 (Hunter *et al.*, 2017). Several studies have been undertaken and led to the conclusion that the main climatic variability manifestations are the increase of the temperature and the decrease in the rainfalls. Modelling of temperature data in the West African region has shown increases in maximum temperatures of 0.5°C to 0.9°C and beyond +1°C for minimum temperatures (GIEC, 2019). In Benin, from 1960 to 2008, the average rainfall has declined by 3.2 mm per year and the temperature has linearly increased to 0.03°C per year (Gnanglè *et al.*, 2011). One-degree Celsius increase in temperature results in a reduction in agricultural production in the estimated range of 3.1% to 7.4% (Zhao *et al.*, 2017). In northern Benin, another study reveals that the conventional analysis of the series of rainfall, temperature and wind speed confirms the increase in maximum and minimum temperatures but does not allow the detection of any difference in rainfall distributions and increased high winds (Guibert *et al.*, 2010).

These climate modifications have major consequences on agricultural activities and specifically on rice production, which is highly rainfall-dependent in the Republic of Benin (Soglo and Nonvide, 2019). Thus, climate change could lead to the decline in rice productivity, which, in turn, will reduce food availability and therefore pose a serious threat to food security (Chandio *et al.*, 2020). Kouton-Bognon *et al.* (2015) showed that an increase precipitation by 1% in the southern Benin increases rice income by 1.9%, while the increase in average temperature by 1% leads to the decrease in rice income by 0.5%. To avoid facing food insecurity in general and a decline in rice yield in particular, but also the deterioration of the environment resulting from climate variability, it is essential that producers strengthen their capacity to mitigation. One of the ways to achieve this is to understand daily the behaviour of climatic parameters based on modelling over time of past data. Such a study associated with farmer's perceptions and their adaptation strategies to cope with climate change could help mitigate the negative impacts of climate variability on the agriculture (Mtambanengwe, 2012). Although several studies have focused on climate change in the Republic of Benin, very little information on the perception of rice farmers on these manifestations, causes and impacts of climate change is documented. It is evident that this perception influences the farmers' adaptation strategies (Kolleh and Jones, 2018). Therefore, understanding farmers' perception of climate change is important to develop efficient adaptation strategies and highlight the climate impacts requiring policy-level interventions (Chhogyel *et al.*, 2020).

Without these measures, agricultural production in the Republic of Benin is expected to decrease by either 5% or 20% in 2025 (Paeth *et al.*, 2008; Yegbemey *et al.*, 2014). According to Adger (2003), adaptive capacities refer to the ability to adapt and recover from the impacts of climate change. For instance, Arimi (2014) found that shifting planting date until the weather conditions are more favourable, and using improved rice variety and chemical fertilizer are the three major adaptation practices used by rice farmers in Nigeria. In Ghana, rice farmers attempt to adapt to climate change using practices such as early planting field and rice transplantation (Zakaria and Matsui, 2020). In South Africa, farmers opted for the adoption of drought-tolerant varieties, which is the most common climate-response strategy (Elum *et al.*, 2017). On the contrary, Malaysian farmers added more water in the field for maintaining the required moisture level during the time of high temperature or sunshine (Alam *et al.*, 2012). Therefore, there is an urgent need to adopt adaptation strategies to address the impacts of climate change that ultimately could threaten food security and economy in the Republic of Benin. The objective of this study aims to document farmers' perceptions and identify the current rice farmers' adaptation strategies to cope with the manifestations of climate change, as well as their determinants.

2. Material and methods

2.1 Study area

The study was carried out in Benin (114,763 km^2), a West African country located between meridians 0° 40' and 3° 45' East longitude and parallels 06° 15' and 12° 25' North latitude. The population of Benin is estimated at 9,983,884 inhabitants, divided into a mosaic of sociolinguistic groups (INSAE, 2016). The three climatic zones of the Republic of Benin [Soudanian zone (9° 45'–12° 25' N), Soudano–Guinean zone (7° 30'–9° 45' N) and Guinean zone (6° 25'–7° 30' N)] were taken into account in this study. In the Soudanian zone, the unimodal rainfall regime is observed with an annual mean temperature from 30°C to 38°C. In the Soudano–Guinean zone, a transitional precipitation regime is observed with a mean annual temperature of 30°C. While in the Guinean zone, the climate is subequatorial with four uneven seasons, two rainy seasons and two dry seasons with annual mean ranging from 28°C to 32°C (Gnanglè *et al.*, 2011).

2.2 Survey

The survey was conducted in 39 villages [21 villages in the Soudanian zone, six in the Soudano–Guinean zone and 12 in the Guinean zone (Figure 1)] and involved 418 rice farmers. This number of surveyed farmers was estimated using the normal approximation of the binomial distribution proposed by Dagnelie (1998):

$$n = \frac{U^2_{1-\propto/2} \times p(1-p)}{d^2}$$

where n is the number of the surveyed rice farmers; $U^2_{1-\propto/2}$ = 1.96 is the quantile of a standard normal distribution for a probability value of 0.05; p = 0.11 is the proportion of rice producers population; and d is the expected error margin of any parameter to be computed from the survey and fixed at 0.03. The value of p was determined according to Adebo *et al.* (2018) by considering a single person interviewed per household, the number of agricultural households in the Republic of Benin (651,067 agricultural households) (INSAE, 2016) and the number of households involved in rice production (72,400 households) [Ministère de l'Agriculture, de l'Elevage et de la Pêche (MAEP), 2008].

Surveys were conducted using participatory research appraisal tools and techniques, such as direct observation, individual interviews and field visits through a questionnaire for data collection (Loko *et al.*, 2019). These villages were selected in collaboration with the agents of the Territorial Agencies for Agricultural Development in each region based on the accessibility of the area and on rice production statistics. The surveyed rice farmers were chosen randomly, and at least 10 rice farmers were surveyed in each village. Individual interviews were conducted with the help of translators in each area for data collection. Information collected were related to the socio-economic characteristics of rice farmers (education, age, sex, household size, years of experience in rice production, membership of a farmers' association, training in rice production, contact with extension services, land ownership, use of fertilizer, use of improved varieties and use of irrigation). Farmers' perceptions on the manifestation of climate change, causes and influence of rainmakers on rice production were also recorded. Approaches for adaptation to cope with each manifestation of climate change identified by the surveyed farmer were recorded.

2.3 Meteorological data

The climatological data (temperature and rainfall) over a minimum period of 58 years (1960–2018) and a maximum period of 66 years (1952–2018) were collected from the *Agence pour la Sécurité de la Navigation Aérienne* (ASECNA) of the Republic of Benin. The data were collected for three weather stations across the country: Kandi station for the Soudanian zone, Savè station for the Soudano–Guinean zone and Cotonou station for the Guinean zone. The analysis of these climatic data were used to compare farmers' perceptions of climate change manifestations and scientific observations (Paudel *et al.*, 2020).

2.4 Data analysis

Descriptive statistics (per cent, average and error type) were used to describe characteristic of rice farmers' surveyed and their response to the study. Descriptive statistics were performed using *R* software (R Core Team, 2019). Chi-square test and *t*-test were applied on the one hand to identify the relationship between the responses of the rice farmers surveyed and the different climatic zones of Benin and, on the other hand, to compare characteristics of adopters and non-adopters of strategies to cope with climate change. As applied by Asfaw *et al.* (2019), the effect

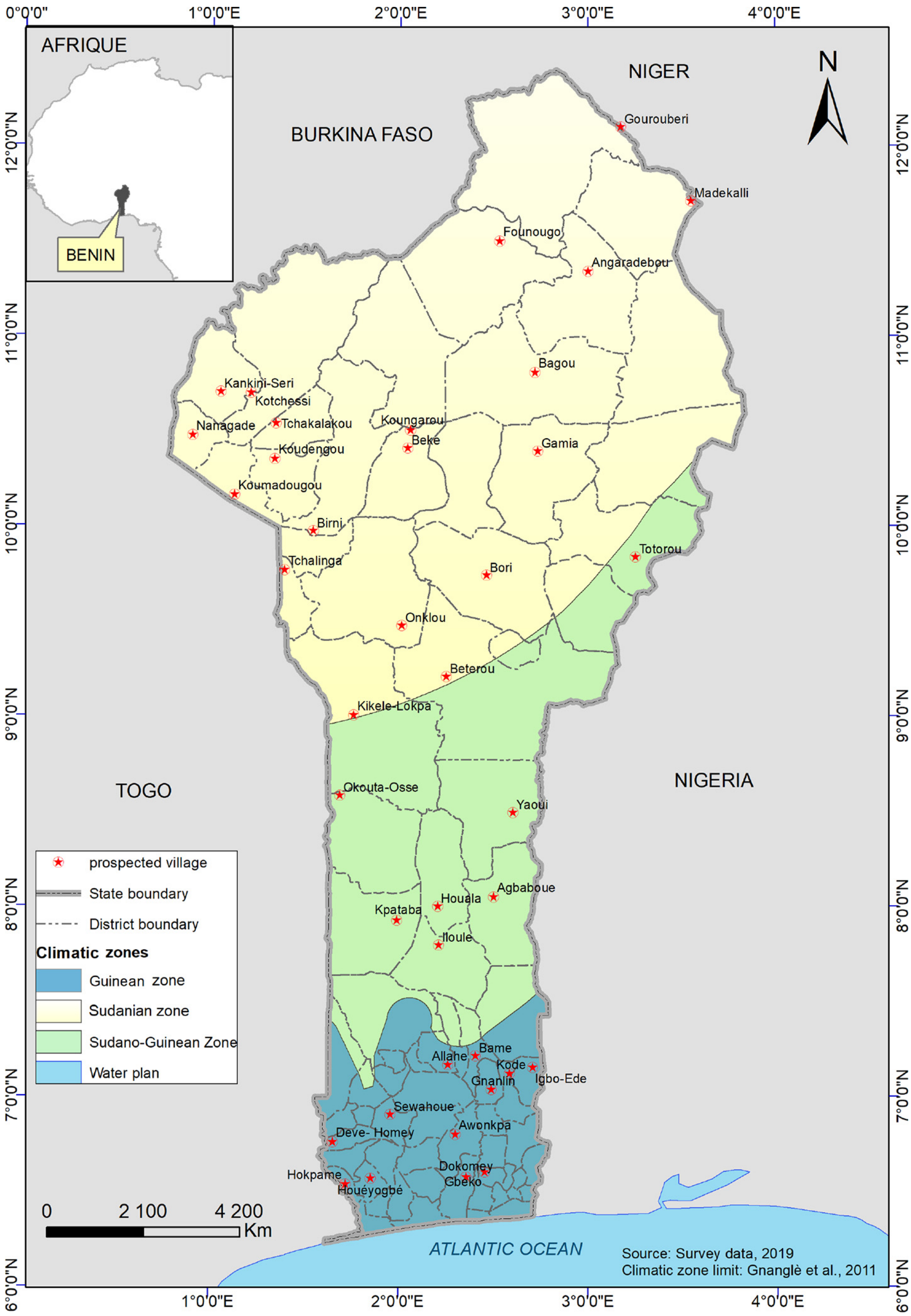

Figure 1.
Map of the Republic of Benin showing the 39 surveyed villages

size (ES) of chi-square test was interpreted as weak (ES < 0.1), fair (ES = 0.11–0.3), moderate (ES = 0.31–0.5), strong (ES = 0.51–0.8) and very strong (ES > 0.81).

The multinomial logistic regression was performed to identify the determinants of farmers' adaptation choice to climate change using *STATA* software (version 13.0). For that, farmers' adaptation practices in the study area were classified in five categories: use of adapted rice varieties (early varieties, flood-tolerant varieties, drought-tolerant varieties and dwarf varieties), change of farming calendar, use of irrigation systems, water management techniques and no adaptation. The explanatory variables used in the model were selected based on the literature review and presented in Table 1. The category – no adaptation was used as the base category in the multinomial logit model. The expected change in the probability of farmers to use a particular strategy to cope with climate change was estimated by calculating marginal effects.

The meteorological data were processed using the *Khronostat* software developed by the French National Institute for Sustainable Development (IRD) (Lubes-Niel *et al.*, 1998). The breaks of stationarity were highlighted on the rainfall series from the Pettitt (1979) test and Lee and Heghinian (1977) method. The Pettitt test is based on the Mann–Whitney two sample test (rank based) and allows the detection of a single shift at an unknown time t. The null hypothesis is no change in the distribution of a sequence of random variables; the alternative hypothesis is that the distribution function $F_1(x)$ of the random variables from X_1 to X_t is different from the distribution function $F_2(x)$ of the random variables from X_{t+1} to X_t (Mallakpour and Villarini, 2016). Before these tests, the inter-annual variability of rainfall levels was studied from calculations of positive and negative anomalies. As for the thermometric trends, an analysis of the inter-annual variability of the minimum, average and maximum temperatures of the study areas was carried out.

Variables	Description
Dependent variable	
Adaptation to climate change	Dummy = 1 if a farmer use at least one adaptation practice to climate change, 0 otherwise
Independent variables	
Education level	Dummy = 1 if the farmer has a secondary education or higher education level, 0 if the farmer is illiterate or has a basic education
Gender of the rice farmer	Dummy = 1 if respondent is male, 0 otherwise
Age	Number of years from birth
Experience in rice production	Number of years in rice farming
Household size	Number of family members
Land ownership	Dummy = 1 if the farmer owns land cultivated; 0 otherwise
Land size	Number of hectares of rice plots cultivated
Use of fertilizer	Dummy = 1 if farmer use fertilizer, 0 otherwise
Use of improved seed	Dummy = 1 if farmer use improved seed, 0 otherwise
Irrigation	Dummy = 1 if the farming rice is the irrigated system, 0 otherwise
Membership of rice farmers association	Dummy = 1 if yes, 0 otherwise
Training in rice production	Dummy = 1 if yes, 0 otherwise
Extension services	Dummy = 1 if the farmer has access to extension services, 0 otherwise
Soudanian zone	Dummy = 1 if the rice farmer is located in Soudanian zone, 0 otherwise
Soudano–Guinean zone	Dummy = 1 if the rice farmer is located in Soudano–Guinean zone, 0 otherwise
Guinean zone	Dummy = 1 if the rice farmer is located in Guinean zone, 0 otherwise

Table 1. Description of explanatory variables and descriptive statistics of the surveyed farmers in the study area

3. Results

3.1 Characteristic of surveyed rice farmers

The majority (74.5%) of surveyed rice farmers were men, and 84.9% of them were considered as illiterate. The structure of the age showed that 10.8% of the rice farmers' surveyed were young (age ` 30 years), 77.3% adults (30 years ` age ` 60 years) and 23.8% old persons (age > 60 years), with an average age of 44 years. In total, 73.2% of surveyed farmers had household sizes between 1 and 10 persons, 24.4% between 11 and 20 people and 2.4% between 21 and 34. The surveyed farmers had an average of 14 years of experience in rice cultivation, but very few (12.7%) practised irrigated rice production system. Most of farmers were members of a rice farmers association (63%), had received a training in rice production (65.7%) and had access to extension services (60.1%). The majority cultivated improved rice varieties (80.3%) and used fertilizer (77.9%).

3.2 Rice farmers' perceptions on the manifestations of climate change

All the surveyed rice farmers had ideas about the manifestation of climate change, their understanding about it differed according to their climatic zone (Table 2). The manifestations of climate change were dependent on the climatic zones of Benin based on the response of the people surveyed (χ^2 = 76.458; DF = 16; p-value = 0.000). The rain delay (21.3%) was the main manifestation of climate change perceived across all climatic zones. Heavy rains and floods (20% each) were the second most important climate change manifestations perceived by rice farmers located in the Guinean zone, while the decrease in the rain frequency (21.9%) and the strong winds (14.2%) were the second most important in the Soudano–Guinean zone and Soudanian zone, respectively. The drought (11.1%) and the fluctuation of the rains (7%) were, however, perceived across all the climatic zones, while the proliferation of pests and diseases was only perceived in the Soudano–Guinean zone and the Soudanian zone. Rice farmers in the Guinean and Soudanian zones mentioned the high temperature (4.8%) and the early stop of rains was listed by only a few farmers in the Soudanian zone (0.1%).

Table 2. Rice farmers' perception on manifestation of climate change in function of climatic zone of the Republic of Benin

Manifestations	Percentage of responses Guinean zone (N = 138)	Soudano–Guinean zone (N = 63)	Soudanian zone (N = 217)	Study area (N = 418)
Rain delay	22.1	23.1	20.4	21.3
Decrease in the frequency of rain	15.5	21.9	13.3	15.1
Heavy rains	20	21.4	9.3	14.7
Flood	20	15	11.2	14.4
Drought	12.3	11.6	10.2	11.1
Strong winds	–	–	14.2	7.6
Fluctuation of the rains	9.5	6.4	5.6	7
High temperature	0.6	–	8.6	4.8
Proliferation of pests and diseases	–	0.6	7.1	3.9
Early cessation of rains	–	–	0.1	0.1

Note: *N: Number of surveyed farmers

3.3 Rice farmers' perceptions of the causes of climate change

Most of surveyed rice farmers (80.9%) observed at least one cause of climate change (Table 3). However, deforestation (71.6%) was the main cause of climate change perceived by the most of farmers, followed by the no respect for restrictions (18.1%) and the traditional rainmakers (18.1%) for rice farmers living in Guinean zone. However, rice farmers living in the Soudanian zone perceived anthropogenic activities as the second most important cause of climate change, while some farmers in the Guinean and Soudano–Guinean zones considered God as the cause of climate change (Table 3). In the same way, farmers in the Guinean and Soudanian zone perceived no respect for the laws of nature and desacralization of morals. Human population growth (1.4%) and the use of herbicides (0.5%) can also be seen as causes of climate change by few rice farmers in the Soudanian zone. A small part of surveyed farmers thought that traditional rainmakers have an influence (beneficial or detrimental) on the rainfall and its timing (Table 4).

3.4 Climate trends

3.4.1 Climate trends in the Soudanian zone. Figure 2(a) shows the results of the application of the Pettitt test on annual rainfall series in the north Benin (Kandi station). Only the test of Lee and Heghinian showed a disruption in 1982 in the chronicle of annual rainfall (but not through the rank correlation test). The means of the sub-series before and after the

Causes	Percentage of responses Guinean zone (N* = 93)	Soudano–Guinean zone (N = 33)	Soudanian zone (N = 212)	Study area (N = 338)
Deforestation	48.9	96.9	77.7	71.6
Non respect of forbidden	18.1	–	3.2	7
Anthropogenic activities	–	–	10.7	6.7
Traditional rainmakers	18.1	–	–	5
Non respect of laws of nature	1.1	–	6	4.1
God	12.7	3.1	–	3.8
Human population growth	–	–	1.4	0.9
Desacralization of morals	1.1	–	0.5	0.6
Use of herbicides	–	–	0.5	0.3

Table 3. Rice farmers' perception on the causes of climate change in function of climatic zone of the Republic of Benin

Types of influence	Percentage of rice farmers Guinean zone (N = 138)	Soudano–Guinean zone (N = 63)	Soudanian zone (N = 217)	Study area (N = 418)
No influence on rice production	46.6	84.9	97.9	78.6
Blockage of rains that causes disturbance of rainy seasons	35.8	9.4	0.4	14.1
Relocate rains from one area to another	6.8	3.8	–	2.8
No control of the rain cycle	4.1	–	–	1.4
Low productivity	3.4	–	0.4	1.1
No control of production periods	2.0	–	–	0.8
Causes rains in the dry season	–	1.9	1.3	0.8
Rainfall delay	1.3	–	–	0.4

Table 4. Farmers' perception of the influence of traditional rainmakers on rice production

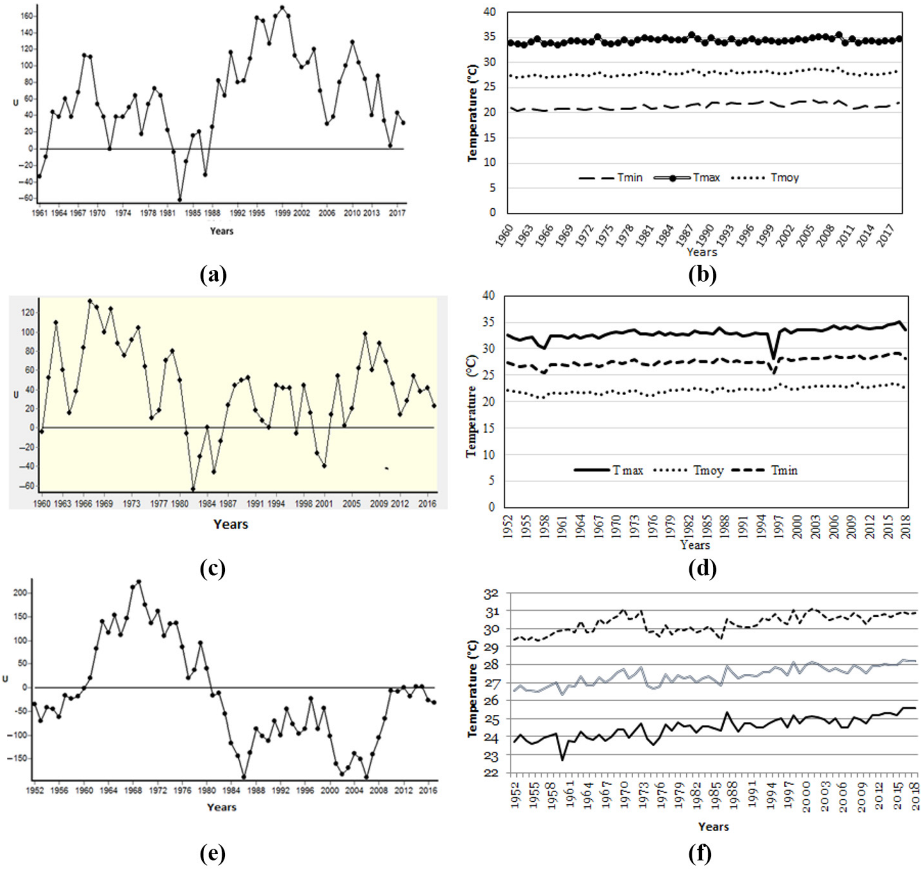

Figure 2.
Analysis of the break in rainfall stationarity (variable U of the Pettitt test) and inter-annual variation in mean temperature in the climatic zones of the Republic of Benin (1952–2018)

Notes: (a–b): Soudanian zone (Kandi station); (c–d) Soudano–Guinean zone (Savè station); and (e–f) Guinean zone

disruption were, respectively, 1,151.62727 mm and 1,172.83611 mm, that revealed a rainfall deficit of 0.15% before the disruption, meaning that the period from 1961 to 1982 might be wetter than that from 1983 to 2018. This indicates a slight change in rainfall over these two sub-periods, with inter-seasonal evolution making it possible to highlight the significant decline in seasonal rainfall levels over the 1983–2018 sub-period.

Figure 2(b) shows the evolution of the minimum and maximum annual temperatures observed at the Kandi station. The average annual temperatures recorded in this station during the 1960–2018 period were around 27.54°C. At the Kandi meteorological station, the average annual temperature was 27.97°C, the extreme values (35.55°C) were recorded in 2009 between March and April, while the minimum (20.32°C) in 1965–1966 from December to January. Overall, there is an increasing temperature trend between 1960 and 2018 in the study environment.

3.4.2 Climate trends in the Soudano–Guinean zone. Figure 2(c) shows the results of the application of the Pettitt test on annual rainfall in the central Benin (Savé station). A break in stationarity was observed around 1983 in the rainfall field used (95% significance), allowing to identify two sub-periods, from 1960 to 1982 and from 1983 to 2018.

The analysis of the inter-annual change in minimal and maximal temperatures [Figure 2(d)] showed a tendency for thermometric warming in the basin for the period concerned. Temperature went overall from 30.40°C in 1970 to 34.17°C in 2015, i.e. an increase of 3.77°C for maximal temperatures and from 21.79 to 23.47°C, i.e. 1.71°C for minimal ones.

3.4.3 Climate trends in the Guinean zone. Using a 95% significant Pettitt test on rainfall measurement, we observe [Figure 2(e)] here again two different subperiods, from 1952 to 1970 and from 1971 to 2018. The rainfall for the period from 1952 to 1970 remains higher than from 1971 to 2018, confirming that the years 1971 to 1990 are marked by rainfall decline demonstrated by previous studies in the study areas [Figure 2(e)].

The analysis of the inter-annual evolution of the maximum and minimum temperatures revealed a tendency for thermometric heating in the study environment for the same period [Figure 2(f)]. The minimal temperatures went from 23.68°C in 1952 to 25.37°C in 2018, an increase of 1.69°C.

3.5 Rice farmers' perceptions of the impact of climate change on rice production

The surveyed rice farmers perceived diverse impacts of climate change on rice production (Table 5). Considering the five main impacts of climate change, the answers given by the respondents depend on the climatic zones (χ^2 = 28.097; DF = 8; p-value = 0.000). Rice farmers perceived the disruption of the agricultural calendar (41.5%) and the drop of rice yield (41.4%) as the most common impacts of climate change on rice production in the study area, with insect attacks (8%) and the total loss of rice fields due to flooding (2.1%) also identified. The plant lodging (9.1%) was perceived by some rice farmers in the Soudanian zone with the yellowing of plants due to drought (0.7%), the rotting of mature rice grains (0.5%), the winding of rice leaves (0.2%), the unfertile soil (0.2%), the loss of sown seeds due to heavy rains (0.2%) and the loss of rice flowers due to strong winds.

Impacts	Percentage of responses Guinean zone (N = 138)	Soudano–Guinean zone (N = 63)	Soudanian zone (N = 216)	Study area (N = 417)
Disruption of agricultural calendar	48.5	52.5	35.7	41.5
Drop of rice yield	44.9	40.6	39.6	41.4
Insect attacks	4.9	3.9	10.4	8
Plant lodging	0.7	–	9.1	5.5
Total destruction of fields due to flooding	1.0	2.0	2.7	2.1
Yellowing of plants due to drought	–	–	0.7	0.4
Panicle sterility	–	1.0	0.5	0.4
Rotting of mature rice grains	–	–	0.5	0.3
Winding leaves	–	–	0.2	0.1
Soil poverty	–	–	0.2	0.1
Loss of sown seeds due to heavy rains	–	–	0.2	0.1
Loss of flowers due to strong winds	–	–	0.2	0.1

Table 5. Rice farmers' perception of the impact of climate change on rice production

3.6 Comparison of rice farmer's perceptions and empirical trend

The raw data on the temperature revealed an increasing trend in the study area. The same observation was made by rice farmer's confirming that they have a good knowledge about the climate change manifestation. When we considered the climatic zone of the respondents, we found that rice farmers in the Soudano–Guinean transition zone did not observe this change in temperature. The analysis of the raw data collected in the national stations of meteorology revealed a variation of the annual rainfall average between the different periods used for the modelling. Rice farmers, based on their statements, also observed this change: delay in rainfall, decrease in the frequency of rain; heavy rainfalls, flood and drought. These statements did not necessarily correlate with an annual variation as observed with the modelling using the meteorological data but expressed the changes in the rate of rainfall.

3.7 Rice farmers' approaches towards adaptation to cope with the manifestations

Half of surveyed rice farmers (50.3%) did not use any method to cope with climate change. The remaining used various types of adaptation measures depending on the climate manifestation (Table 6). For flooding, some flood-tolerant varieties were used in the Soudanian zone (24.7%), along with early varieties (8.8%) and few late matured varieties (1.8%). In the Guinean zone, farmers build dikes in rice fields for water storage (11.9%) and avoided sowing rice in March (0.7%). In the Soudano–Guinean zone, few rice farmers (1.9%) harvested rice on time to avoid flood.

Drought-tolerant varieties were only used by one third of rice farmers in the Soudanian zone (30%), while in the Soudano–Guinean (5.7%) and Soudanian (11.1%) zones, early varieties are used to cope with drought. Creation of channels to better serve the rice-growing area with water was practised by some rice farmers in the Soudano–Guinean zone. Only few farmers (0.8%) in the Guinean zone irrigated their rice fields to avoid drought stress, and few used mulches to avoid evaporation (0.6%) in the Soudanian zone.

3.8 Determinants of rice farmers' adaptation choice to climate change

The difference of characteristics between adopters and non-adopters of at least one adaptation strategy to cope with climate change is presented in Table 7. Statistical analysis showed that adopter had higher household size but cultivated smaller rice plots. In addition, there are significant differences between adopters and non-adopters in terms of education, membership to rice farmers' association, training in rice production, access to extension services, use of improved varieties and the location in a climatic zone. There is, however, no significant difference between adopters and non-adopters in terms of age, gender, experience in rice production, use of fertilizer, land ownership and irrigation systems.

Out of the 16 explanatory variables used in the multinomial logit model ($p < 0.0000$, 38.34% of explanation), three variables (land ownership, and farmers located in Soudano–Guinean and Guinean zones) negatively influenced the decision of rice farmers to use tolerant or resistant rice varieties (Table 8). However, the use of fertilizer and the location of rice farmers in Soudanian zone positively and significantly influenced their decision to use tolerant or resistant rice varieties. All the 16 explanatory variables had insignificant influence on farmers' decisions to change the farming calendar to cope with climate change. The membership of rice farmers to association negatively influenced the decision of rice farmers to use irrigation systems. The decision of farmers to use water

Table 6. Rice famers' adaptation approaches to some climate manifestations

Climate manifestations	Approaches	Guinean zone (N = 138)	Soudano–Guinean zone (N = 63)	Soudanian zone (N = 217)	Study area (N = 418)
Flood					
	No approach	87.4	98.1	64.7	76.4
	Flood-tolerant varieties	–	–	24.7	13.5
	Early varieties	–	–	8.8	4.8
	Construction of dikes for water evacuation	11.9	–	–	3.9
	Long cycle varieties	–	–	1.8	1
	Harvest quickly	–	1.9	–	0.2
	Avoid sowing rice in March	0.7	–	–	0.2
Drought					
	No approach	99.2	92.4	59.1	78.6
	Drought-tolerant varieties	–	–	29.2	14.2
	Early varieties	–	5.7	11.1	5.4
	Irrigation	0.8	–	–	1.1
	Creation of a channel to better serve the sown area with water	–	1.9	–	0.3
	Installation of barriers to block the flow of water out of the cultivated land	–	–	0.6	0.3
Strong winds					
	No approach	–	–	78.9	88.5
	Dwarf varieties	–	–	21.1	11.5
Rain delay					
	No approach	100	100	40.6	69.1
	Early varieties	–	–	59.4	30.9
Early cessation of rains					
	No approach	100	100	60.8	79.4
	Early varieties	–	–	39.2	20.3
High temperature					
	No approach	100	100	99.1	99.5
	Resistant varieties	–	–	0.9	0.5
Pests and diseases					
	No approach	100	100	92.1	96
	Pesticides	–	–	5.1	2.6
	Resistant varieties	–	–	2.8	1.4

Characteristics	Adopters	Non adopters	X^2	Effect size
Gender				
Male	156	156	0.028 ns	0.008 ns
Female	52	54		
Education				
Illiterate	185	170	5.212**	0.112**
Literate	23	40		
Membership of rice farmers association				
Yes	116	148	9.714**	0.152**
No	92	62		
Training in rice production				
Yes	116	159	18.470***	0.210***
No	92	51		
Access to extension services				
Yes	102	150	21.881***	0.229***
No	106	60		
Use of fertilizer				
Yes	159	167	0.578 ns	0.037 ns
No	49	43		
Use of improved varieties				
Yes	151	184	14.820***	0.188***
No	57	26		
Land ownership				
Yes	156	162	0.264 ns	0.025 ns
No	52	48		
Irrigation				
Yes	20	33	0.351 ns	0.092 ns
No	188	177		
Soudanian zone				
Yes	169	61	115.068***	0.525***
No	39	149		
Soudano–Guinean zone				
Yes	6	36	9.536**	0.237***
No	202	174		
Guinean zone				
Yes	30	109	66.182***	0.398***
No	178	101		

	Adopters	*Non adopters*	*t test*
Age	44.1 ± 0.8	43.7 ± 0.9	0.088 ns
Experience	14.5 ± 0.8	13.5 ± 0.7	1.005 ns
Household size	9.1 ± 0.3	8.2 ± 0.3	3.814**
Land size (ha)	1.0 ± 0.0	1.3 ± 0.1	5.465**

Note: ns: non-significant. **and ***statistically significant at 5 and 1%, respectively

Table 7.
Comparison of rice farmers adopting and not adopting strategies to cope with climate change

Table 8. Factors determining rice farmers' adaptation decision to climate change

Variables	Use of adapted rice varieties Coefficient	dy/dx	Change of farming calendar Coefficient	dy/dx	Use of irrigation Coefficient	dy/dx	Water management techniques Coefficient	dy/dx
Male headed household	−0.163	0.002	28.664	−2.199	−0.849	0.053	−0.714	−0.040
Age	0.004	0.011	−1.852	0.144	−0.036	0.006	0.023	0.006
Household size	−0.017	−0.018	4.328	−0.337	0.085	−0.016	−0.023	−0.017
Education	−0.055	0.065	−30.761	2.571	−18.482	1.742	0.584	0.160
Experience	−0.004	0.002	−1.114	0.090	0.009	0.003	−0.025	0.008
Land ownership	−0.722*	0.085	6.915	−0.685	16.288	−1.475	0.410	−0.104
Training in rice production	−0.507	−0.032	105.766	−8.246	−1.230	−0.132	0.246	−0.505
Membership of rice farmers association	0.109	−0.017	−1.379	0.113	−4.725*	0.375	1.002	−0.099
Use of fertilizer	0.865**	−0.262	−1.673	−0.516	−4.316	−0.557	17.300	−2.079
Irrigation	−0.033	0.262	−88.055	7.762	−17.439	2.769	−18.360	2.678
Extension services	−0.409	0.140	−60.088	4.739	2.723	0.008	−1.446*	0.477
Land size	−0.078	−0.002	10.435	−0.834	0.651	−0.100	0.393*	−0.095
Use of improved varieties	0.515	0.122	−58.625	5.352	−14.419	2.298	−16.814	2.305
Soudanian zone	1.564*	−0.206	−56.796	4.327	3.939	−0.353	0.437	0.108
Soudano–Guinean zone	−1.419**	0.173	−9.378	0.376	9.492	−1.160	8.146	−0.870
Guinean zone	−0.723**	0.074	−6.243	0.217	7.820	−0.940	5.695	−0.632
Constant	−0.213		−20.503		−21.736		−20.136	
Base category	No adaptation							
Number of observation	418							
Log likelihood	−241.96892							
LR chi^2 (63)	300.92							
Prob > chi2	0.0000							
Pseudo R^2	0.3834							

Note: *, **and ***statistically significant at 10, 5 and 1%, respectively management techniques to cope with climate was positively influenced by the land size but negatively influenced by the access to extension services.

4. Discussion

4.1 Rice farmers' perceptions and response to climate variability

This study shows that in the Republic of Benin, rice farmers are much more aware of climate change. Indeed, all the surveyed farmers observed at least one climatic variability in their locality. Variations in the intensity and frequency of rainfalls, and the increase in temperature are listed as the most important manifestations of climate change. Yam farmers mentioned the same manifestations of climate change in the Republic of Benin (Loko *et al.*, 2013) and the analysis of meteorological data corroborates these perceptions, especially with regard to the temperature (Mulenga *et al.*, 2017). In addition, others manifestations of climate change listed by farmers, such as flood, drought and violent winds, were also revealed by several previous studies in the Republic of Benin but in different proportions (Gnangle *et al.*, 2012; Soglo and Nonvide, 2019), attesting that surveyed rice farmers have a good perception of manifestations of climate change.

Similarly, to Ethiopian (Tesfahunegn *et al.*, 2016) and Nigerian (Ofuoku, 2011) farmers, deforestation is mentioned by the surveyed farmers as the most important cause of climate change. Indeed, deforestation contributes to carbon emissions, leads to extreme warming and have the capacity to reduce rainfall (Vargas Zeppetello *et al.*, 2020; Chapman *et al.*, 2020). Lokossou *et al.* (2020) also demonstrated that it could also result in the farmers' adaptation to climate variability, which leads them to practice extensive agriculture, the main factor of deforestation, and thus aggravating this effect. Therefore, deforestation practices by rural farmers through bushfires and charcoal making, for example, should be discouraged. In addition, as suggested by Soglo and Nonvide (2019), the promotion of reforestation is very important in the fight against desertification and strong winds.

Other causes of climate change observed by farmers in the Soudanian zone, such as anthropogenic activities, human population growth and use of herbicides, are well known as among the causes of climate change (Crowley, 2000; Bouwman *et al.*, 2020), thus underlining a good knowledge of climate change causes. However, in the Guinean zone, many surveyed farmers rely on religious or traditional beliefs to justify climate change. These surveyed farmers perceive the climate change manifestations as a penalty by God because there is no respect for restrictions, laws of nature and desacralization of morals. In the same way, rainmaking was also perceived by some surveyed farmers living in the Guinean zone as a cause of climate change. This perception is shared by the Pedi tribes of South Africa (Semenya, 2013), which believe that traditional rainmakers using rituals can influence weather conditions. However, the action of rainmakers was perceived by some surveyed farmers as negative for rice production due to their ability to block rains to protect some social events. Therefore, it is important to educate rice farmers on the scientific causes of climate change for a better resilience.

The disruption of agricultural calendar perceived as the main impact of climate change was corroborated by the results of Lokossou *et al.* (2020). Many farmers produce several crops in Republic of Benin, such as yam (Loko *et al.*, 2013), maize (Yegbemey *et al.*, 2014; Soglo and Nonvide, 2019) and sorghum (Dossou-aminon *et al.*, 2016), have also mentioned the disruption of agricultural calendar and the yield loss as a result of climate change. According to Mackill *et al.* (2011), rising temperature combined to rainfall variability leads to the important reduction of rice yield. The pressure of insect pests in rice fields as a result of climate change is corroborated by several studies that have shown the relationship between climatic factors and the proliferation of rice insect pests (Kwon *et al.*, 2012; Haider *et al.*, 2020). Unfertile soil are among the least observed impact of climate change, while several studies in the Republic of Benin have revealed the negative effects of climate change on soil fertility (Sale *et al.*, 2014; Adebiyi *et al.*, 2019). Although the surveyed farmers noted only negative impacts of climate change on rice production, some studies have shown that carbon dioxide emissions can positively influence rice yield (Chandio *et al.*, 2020).

Similar to Malaysian rice farmers (Alam *et al.*, 2012), the majority of surveyed farmers do not use any strategy to cope with climate change. This could be explained by the fact that a great number of surveyed rice farmers were illiterate and have meagre financial resources. Indeed, some studies revealed that education and access to credits increase the probability of farmers to adopt climate change adaptation strategies (Ali and Erenstein, 2017; Belay *et al.*, 2017). Some farmers reported various approaches focused on modification of crop practices (changing crop varieties, adjusting planting dates, etc.). Change of cultural practices of rice to cope with climate change was also practised by some farmers around the world, such as Malaysian (Akhtar *et al.*, 2019), Pakistani (Abid *et al.*, 2019) and Ethiopian (Belay *et al.*, 2017). Very few surveyed farmers in the study area use irrigation systems and water management techniques to cope with climate change; given their potential, there is an urgent need to train farmers in irrigation and water management techniques.

Our results show that farmers adopting at least one strategy to cope with climate change have a large family but cultivated smaller rice plots. This is not surprising because large families are better equipped to observe climate change through family discussions, which positively influences their adaptation (Tesfahunegn *et al.*, 2016). In addition, according to Belay *et al.* (2017) and Deressa *et al.* (2009), household size is associated with certain coping strategies that require labour-intensive activities and cultivating a small plot favours their implementation. Similarly, education level, membership to rice farmers association, access to extension services and training in rice production influenced the adaptation of rice farmers to climate change. Indeed, several studies showed that education increases the probability of farmers to use strategies to cope with climate change (Deressa *et al.*, 2009; Arimi, 2014; Abid *et al.*, 2015; Vijayasarathy and Ashok, 2015; Belay *et al.*, 2017; Asfaw *et al.*, 2019; Eshetu *et al.*, 2020; Paudel *et al.*, 2020). It is known that in contact to others farmers or extension services, farmers receive more information on the climate change impact, which favours the implementation of climate change adaptation (Eshetu *et al.*, 2020). However, the membership of farmers to farmer-based organizations negatively influences the decision of rice farmers to use irrigation to cope with climate change. Indeed, according to Nonvide *et al.* (2017), the high cost of irrigation systems is the main constraint of adoption of irrigation by Beninese farmers. Therefore, the low funding of farmers' associations does not allow them to promote irrigation. Knowing that access to credit positively influences the decision to farmers to use irrigation to cope with climate change (Deressa *et al.*, 2009), we suggest the establishment of a subsidy and credit mechanism by the government to Beninese rice farmers to boost the rice production.

The use of adapted rice varieties to cope with climate change manifestations by the surveyed farmers is negatively influenced by land ownership. Similar results were obtained by Abid *et al.* (2015), which observed that land owners compared to tenants are less likely to adapt their farming to cope with climate change. This could be justified by the fact that land tenants are more attentive to their farm income and, therefore, more willing to use climate change adaptation. The localization of rice farmers in the diverse climatic zones has a significant effect on the use of resistant varieties. In fact, the negative effect of the Soudano–Guinean and Guinean zones could be explained by the fact that local rice varieties allowing for a greater resilience are mainly grown in the Soudanian zone (Loko *et al.*, 2021). It is, therefore, important that rice varieties adapted to each climatic zone should be identified and promoted to boost rice production in the Republic of Benin.

There is no surprise that the use of fertilizer positively and significantly influences farmer's decision to use adapted rice varieties. Indeed, improved rice varieties and fertilizers are promoted together by extension services to boost rice production in rural areas. The positive influence of land size on farmers' decision to use water management techniques is also not surprising, as some studies showed the positive relationship between land size and water management technology adoption (Fosu-Mensah *et al.*, 2012; Amare and Simane, 2017). However, the negative influence of the access to extension services on farmers' decision to use water management techniques to cope with climate is surprising, as it is known that access to extensions services increases the probability of farmers to adopt water management techniques such as drip irrigation and digging of new bore-wells (Vijayasarathy and Ashok, 2015). This could probably be explained by the frequency and quality of contacts with extension services. Therefore, it is important that the various stakeholders in agricultural development (non-governmental organizations, government extension services, international institutes and private partners) regularly train Beninese rice farmers on water management techniques to strengthen their resilience to climate change.

4.2 Study implications for rice production in Benin

One of the factors that affect high rice yield in Benin is climate variability. This study documented for the purpose of extension the techniques used by rice farmers in Benin to cope with the effects of climate variability on rice cultivation. It is important to note that these techniques will be improved by scientists before their vulgarization in the field for a better future for rice cultivation. The study showed that it is important to educate rice farmers on the scientific causes of climate change for a better resilience. There is an urgent need to train rice farmers in irrigation and water management techniques to cope with climate variability. To promote irrigation, we suggest the establishment of a subsidy and credit mechanism by the government. Factors identified that influence adoption of efficient adaptation strategies against climate events must be taken into account in any future adaptation policies against climate change in the Republic of Benin.

5. Conclusions

The changes in climate observed by Beninese rice farmers agree with available scientific data. This supports the notion that local perceptions of climatic changes can be used to complement climatic studies based on meteorological records. Our study showed that climate changes are mainly observed through patterns in rainfall variability. Based on the high importance that rainfall has on crop production, especially rice production, we highlight the urgent need to seriously take care of any factors that influence it. The different local strategies recorded through this study can serve as references of all efficient and sustainable actions to be taken for climate resilience. The adoption of adaptation strategies was influenced by the household size, land size, education level and membership to rice farmers' association, training in rice production, access to extension services, use of improved varieties and the location in climatic zones. However, other factors influenced the adoption of adapted rice varieties, use of irrigation and water management techniques. All these factors must be taken into account in any future adaptation policies against climate change in the Republic of Benin.

References

Abid, M., Scheffran, J., Schneider, U.A. and Ashfaq, M. (2015), "Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan", *Earth System Dynamics*, Vol. 6 No. 1, pp. 225-243, doi: 10.5194/esd-6-225-2015.

Abid, M., Scheffran, J., Schneider, U.A. and Elahi, E. (2019), "Farmer perceptions of climate change, observed trends and adaptation of agriculture in Pakistan", *Environmental Management*, Vol. 63 No. 1, pp. 110-123, doi: 10.1007/s00267-018-1113-7.

Adebiyi, K.D., Maiga-Yaleu, S., Issaka, K., Ayena, M. and Yabi, J.A. (2019), "Déterminants de l'adoption des bonnes pratiques de gestion durable des terres dans un contexte de changement climatique au Nord bénin: cas de la fumure organique", *International Journal of Biological and Chemical Sciences*, Vol. 13 No. 2, pp. 998-1010, doi: 10.4314/ijbcs.v13i2.34.

Adebo, H.O., Ahoton, E.L., Quenum, F.J.B., Adoukonou-Sagbadja, H., Bello, O.D. and Chrysostome, C.A. A.M. (2018), "Ethnobotanical knowledge of jute (corchorus olitorius L.) in Benin", *European Journal of Medicinal Plants*, Vol. 26 No. 1, pp. 1-11.

Adger, W.N., Huq, S., Brown, K., Conway, D. and Hulme, M. (2003), "Adaptation to climate change in the developing world", *Progress in Development Studies*, Vol. 3 No. 3, pp. 179-195, doi: 10.1191/1464993403ps060oa.

Akhtar, R., Masud, M.M. and Afroz, R. (2019), "Perception of climate change and the adaptation strategies and capacities of the rice farmers in Kedah, Malaysia", *Environment and Urbanization ASIA*, Vol. 10 No. 1, pp. 1-17, doi: 10.1177/0975425318822338.

Alam, M.M., Siwar, C., Molla, R.I., Talib, B. and bin Toriman, M.E. (2012), "Paddy farmers' adaptation practices to climatic vulnerabilities in Malaysia", *Mitigation and Adaptation Strategies for Global Change*, Vol. 17 No. 4, pp. 415-423, doi: 10.1007/s11027-011-9333-7.

Ali, A. and Erenstein, O. (2017), "Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan", *Climate Risk Management*, Vol. 16, pp. 183-194, doi: 10.1016/j.crm.2016.12.001.

Amare, A. and Simane, B. (2017), "Determinants of smallholder farmers' decision to adopt adaptation options to climate change and variability in the Muger Sub basin of the upper Blue Nile basin of Ethiopia", *Agriculture Food Security*, Vol. 6 No. 64, pp. 1-20, doi: 10.1186/s40066-017-0144-2.

Arimi, K. (2014), "Determinants of climate change adaptation strategies used by rice farmers in southwestern Nigeria", *Journal of Agriculture and Rural Development*, Vol. 115 No. 2, pp. 91-99, available at: http://nbn-resolving.de/urn:nbn:de:hebis:34-2014121946886

Asfaw, A., Simane, B., Bantider, A. and Hassen, A. (2019), "Determinants in the adoption of climate change adaptation strategies: evidence from rainfed-dependent smallholder farmers in North-Central Ethiopia (Woleka Sub-basin)", *Environment, Development and Sustainability*, Vol. 21 No. 5, pp. 2535-2565, doi: 10.1007/s10668-018-0150-y.

Belay, A., Recha, J.W., Woldeamanuel, T. and Morton, J.F. (2017), "Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia", *Agriculture Food Security*, Vol. 6 No. 24, p. 24, doi: 10.1186/s40066-017-0100-1.

Bouwman, T.I., Andersson, J.A. and Giller, K.E. (2020), "Herbicide induced hunger? Conservation agriculture, Ganyu labour and rural poverty in Central Malawi", *Journal of Development Studies*, Vol. 57 No. 2, doi: 10.1080/00220388.2020.1786062.

Chandio, A.A., Magsi, H. and Ozturk, I. (2020), "Examining the effects of climate change on rice production: case study of Pakistan", *Environmental Science and Pollution Research*, Vol. 27 No. 8, pp. 7812-7822, doi: 10.1007/s11356-019-07486-9.

Chapman, S., Syktus, J., Trancoso, R., Salazar, A., Thatcher, M., Watson, J.E.M., Meijaard, E., Sheil, D., Dargusch, P. and McAlpine, C.A. (2020), "Compounding impact of deforestation on Borneo's climate during El niño events", *Environmental Research Letters*, Vol. 15 No. 8, pp. 1-12, doi: 10.1088/1748-9326/ab86f5.

Chhogyel, N., Kumar, L., Bajgai, Y. and Hasan, M.K. (2020), "Perception of farmers on climate change and its impacts on agriculture across various altitudinal zones of Bhutan Himalayas", *International Journal of Environmental Science and Technology*, Vol. 17 No. 8, pp. 3607-3620, doi: 10.1007/s13762-020-02662-8.

Crowley, T.J. (2000), "Causes of climate change over the past 1000 years", *Science*, Vol. 289 No. 5477, pp. 270-277, doi: 10.1126/science.289.5477.270.

Dagnelie, P. (1998), *Statistiques Théoriques et Appliquées [Theoretical and Applied Statistics]*, De Boeck and Larcier SA, Paris, France.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. and Yesuf, M. (2009), "Determinants of farmers' choice of adaptation methods to climate change in the Nile basin of Ethiopia", *Global Environmental Change*, Vol. 19 No. 2, pp. 248-255, doi: 10.1016/j.gloenvcha.2009.01.002.

Dossou-Aminon, I., Dansi, A., Ahissou, H., Cissé, N., Vodouhè, R. and Sanni, A. (2016), "Climate variability and status of the production and diversity of sorghum (Sorghum bicolor (L) Moench) in the arid zone of northwest Benin", *Genetic Resources and Crop Evolution*, Vol. 63 No. 7, pp. 1181-1201, doi: 10.1007/s10722-015-0310-y.

Elum, Z.A., Modise, D.M. and Marr, A. (2017), "Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa", *Climate Risk Management*, Vol. 16, pp. 246-257, doi: 10.1016/j.crm.2016.11.001.

Eshetu, G., Johansson, T., Garedew, W. and Yisahak, T. (2020), "Determinants of smallholder farmers' adaptation options to climate change in a coffee-based farming system of southwest Ethiopia", *Climate for Development*, Vol. 13 No. 4, pp. 318-325, doi: 10.1080/17565529.2020.1772706.

FAO, IFAD, UNICEF, WFP and WHO (2018), "The state of food security and nutrition in the world 2018. Building climate resilience for food security and nutrition, Rome, FAO", ISBN 978-92-5-130571-3, pp. 1-220, available at: www.fao.org/3/I9553EN/i9553en.pdf

Fosu-Mensah, B.Y., Vlek, P.L. and MacCarthy, D.S. (2012), "Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana", *Environment, Development and Sustainability*, Vol. 14 No. 4, pp. 495-505, doi: 10.1007/s10668-012-9339-7.

GIEC (2019), "IPCC special report on the consequences of global warming of 1.5°C relative to pre-industrial level ond associated global greenhouse gas emissions trajectories, against the context of strengthening the global response to climate change, sustainable development and the fight against poverty", ISBN, 978-92-9169-253-8, p. 110, available at: www.ipcc.ch/site/assets/uploads/2019/08/Edited-SPM_Approved_Microsite_FINAL.pdf

Gnanglè, C.P., Glèlè Kakaï, R., Assogbadjo, A.E., Vodounnon, S., Afouda, Y.J. and Sokpon, N. (2011), "Tendances climatiques passées, modélisation, perceptions et adaptations locales au bénin", *Climatologie*, Vol. 8, pp. 27-40, doi: 10.4267/climatologie.259.

Gnangle, P.C., Egah, J., Baco, M.N., Gbemavo, C.D., Glèlè Kakaï, R. and Sokpon, N. (2012), "Perceptions locales du changement climatique et mesures d'adaptation dans la gestion des parcs à karité au Nord-Bénin", *International Journal of Biological and Chemical Sciences*, Vol. 6 No. 1, pp. 136-149, doi: 10.4314/ijbcs.v6i1.13.

Guibert, H., Alle, U.C., Dimon, R.O., Dedehouanou, H., Vissoh, P.V., Vodouhe, S.D. and Agbossou, E.K. (2010), *Correspondances Entre Savoirs Locaux et Scientifiques: perceptions Des Changements*

Climatiques et Adaptations Étude en Région Cotonnière du Nord du Bénin, ISDA, Montpellier, France, available at: http://agritrop.cirad.fr/556081/1/document_556081.pdf

Haider, I., Akhtar, M., Noman, A. and Qasim, M. (2020), "Population trends of some insect pests of rice crop on light trap and its relation to abiotic factors in Punjab Pakistan", *Pakistan Journal of Zoology*, Vol. 53 No. 3, pp. 1015-1023, doi: 10.17582/journal.pjz/20190822060844.

Hunter, M.C., Smith, R.G., Schipanski, M.E., Atwood, L.W. and Mortensen, D.A. (2017), "Agriculture in 2050: Recalibrating targets for sustainable intensification", *BioScience*, Vol. 67 No. 4, pp. 386-391, doi: 10.1093/biosci/bix010.

Institut National de la Statistique et de l'Analyse Économique (INSAE) (2016), "Rapport résultats provisoires du recensement général de la population et d'Habitat 4", Rapport d'étude Cotonou, available at: www.insae-bjorg (accessed 5 November 2020).

Kolleh, J.B. and Jones, T.M. (2018), "Analysis of rice farmers' perception of climate change in the Ketu North District, Volta Region of Ghana", *International Journal of Agriculture Forestry*, Vol. 8 No. 4, pp. 144-149.

Kouton-Bognon, B.Y.F., Arouna, A. and Cledjo, P. (2015), "Impact des changements climatiques sur le revenu rizicole au Sud-Bénin", *Annales Des Sciences Agronomiques*, Vol. 19, pp. 251-262.

Kwon, Y.S., Chung, N., Bae, M.J., Li, F., Chon, T.S. and Park, Y.S. (2012), "Effects of meteorological factors and global warming on rice insect pests in Korea", *Journal of Asia-Pacific Entomology*, Vol. 15 No. 3, pp. 507-515, doi: 10.1016/j.aspen.2012.05.004.

Lee, A.F.S. and Heghinian, S.A. (1977), "A shift of the mean level in a sequence of independent normal random variables: a Bayesian approach", *Technometrics*, Vol. 19 No. 4, pp. 503-506.

Loko, Y.L.E., Orobiyi, A., Toffa, J., Medegan Fagla, S., Gavoedo, M.D. and Tamo, M. (2019), "Farmers' knowledge, perceptions and management practices for termite pests of maize in Southern Benin", *Open Agriculture*, Vol. 4 No. 1, pp. 554-574, doi: 10.1515/opag-2019-0052.

Loko, Y.L., Dansi, A., Agre, A.P., Akpa, N., Dossou-Aminon, I., Assogba, P. and Sanni, A. (2013), "Perceptions paysannes et impacts des changements climatiques sur la production et la diversité variétale de l'igname dans la zone aride du Nord-Ouest du bénin", *International Journal of Biological and Chemical Sciences*, Vol. 7 No. 2, pp. 672-695, doi: 10.4314/ijbcs.v7i2.23.

Loko, Y.L.E., Ewedje, E.E., Orobiyi, A., Djedatin, G., Toffa, J., Gbemavo, C.D., Tchakpa, C., Gavoedo, D., Sedah, P. and Sabot, F. (2021), "On-farm management of rice diversity, varietal preference criteria, and farmers' perceptions of the African (Oryza Glaberrima steud.) versus Asian rice (Oryza sativa L.) in the republic of Benin (West Africa): implications for breeding and conservation", *Economic Botany*, Vol. 75 No. 1, pp. 1-29, doi: 10.1007/s12231-021-09515-6.

Lokossou, R.S., Akponikpè, P.B.I., Akouèhou, G.S., Matilo, A.O., Prudencio, M., Glèlè Kakaï, R. and Ganglo, J. (2020), "Trend analysis of growing season characteristics and agro-climatic risks in the Trois Rivières Forest reserve agro-ecosystems in North Benin", *Theoretical and Applied Climatology*, Vol. 141 Nos 1/2, pp. 645-656, doi: 10.1007/s00704-020-03179-3.

Lubes-Niel, H., Masson, J.M., Paturel, J.E. and Servat, E. (1998), "Variabilité climatique et statistiques étude par simulation de la puissance et de la robustesse de quelques tests utilisés pour vérifier l'homogénéité de chroniquesv", *Revue Des Sciences De L'eau*, Vol. 11 No. 3, pp. 383-408, doi: 10.7202/705313ar.

Mackill, D.J., Ismail, A.M., Pamplona, A.M., Sanchez, D.L., Carandang, J.J. and Septiningsih, E.M. (2011), "Stress tolerant rice varieties for adaptation to a changing climate", *Crop, Environment and Bioinformatics*, Vol. 7, pp. 250-259, doi: 10.30061/CEB.201012.0004.

Mallakpour, I. and Villarini, G. (2016), "A simulation study to examine the sensitivity of the Pettitt test to detect abrupt changes in mean", *Hydrological Sciences Journal*, Vol. 61 No. 2, pp. 245-254, available at: https://www.tandfonline.com/doi/full/10.1080/02626667.2015.1008482

Ministère de l'Agriculture, de l'Elevage et de la Pêche (MAEP) (2008), "Plan stratégique de relance du secteur agricole. Repport, MAEP, bénin", available at: http://extwprlegs1.fao.org/docs/pdf/ben149176.pdf

Mtambanengwe, F., Mapfumo, P., Chikowo, R. and Chamboko, T. (2012), "Climate change and variability: smallholder farming communities in Zimbabwe portray a varied understanding", *African Crop Science Journal*, Vol. 20 No. 2, pp. 227-241.

Mulenga, B.P., Wineman, A. and Sitko, N.J. (2017), "Climate trends and farmers' perceptions of climate change in Zambia", *Environmental Management*, Vol. 59 No. 2, pp. 291-306, doi: 10.1007/s00267-016-0780-5.

Nonvide, G.M.A., Sarpong, D.B., Kwadzo, G.T.M., Anim-Somuah, H. and Amoussouga, G.F. (2017), "Farmers' perceptions of irrigation and constraints on rice production in Benin: a stakeholder-consultation approach", *International Journal of Water Resources Development*, Vol. 34 No. 6, pp. 1001-1021, doi: 10.1080/07900627.2017.1317631.

Ofuoku, A.U. (2011), "Rural farmers' perception of climate change in Central agricultural zone of Delta state, Nigeria", *Indonesian Journal of Agricultural Science*, Vol. 12 No. 2, pp. 63-69, doi: 10.21082/ijas.v12n2.2011.

Paeth, H., Capo-Chichi, A. and Endlicher, W. (2008), "Climate change and food security in tropical west africa – a dynamic-statistical modelling approach", *erdkunde*, Vol. 62 No. 2, pp. 101-115, doi: 10.3112/erdkunde.2008.02.01.

Paudel, B., Zhang, Y., Yan, J., Rai, R., Li, L., Wu, X., Chapagain, P.S. and Khanal, N.R. (2020), "Farmers' understanding of climate change in Nepal Himalayas: important determinants and implications for developing adaptation strategies", *Climatic Change*, Vol. 158 Nos 3/4, pp. 485-502, doi: 10.1007/s10584-019-02607-2.

Pettitt, A. (1979), "A non-parametric approach to the change point problem", *Applied Statistics*, Vol. 28 No. 2, pp. 126-135.

R Core Team (2019), *R: A Language and Environment for Statistical Computing*, Vienna, Austria.

Sale, A., Folefack, D.P., Obwoyere, G.O., Wati, N.L., Lendzemo, W.V. and Wakponou, A. (2014), "Changements climatiques et déterminants d'adoption de la fumure organique dans la région semi-aride de kibwezi au Kenya", *International Journal of Biological and Chemical Sciences*, Vol. 8 No. 2, pp. 680-694, doi: 10.4314/ijbcs.v8i2.24.

Semenya, D.K. (2013), "The making and prevention of rain amongst the Pedi tribe of South Africa: a pastoral response", *Teologiese Studies/Theological Studies*, Vol. 69 No. 1, pp. 1-5, doi: 10.4102/hts.v69i1.1175.

Soglo, Y.Y. and Nonvide, G.M.A. (2019), "Climate change perceptions and responsive strategies in Benin: the case of maize farmers", *Climatic Change*, Vol. 155 No. 2, pp. 245-256, doi: 10.1007/s10584-019-02452-3.

Tesfahunegn, G.B., Mekonen, K. and Tekle, A. (2016), "Farmers' perception on causes, indicators and determinants of climate change in Northern Ethiopia: implication for developing adaptation strategies", *Applied Geography*, Vol. 73, pp. 1-12, doi: 10.1016/j.apgeog.2016.05.009.

United Nations (UN) (2017), "World population prospects: the 2017 revision, key findings and advance tables", Working Paper No. ESA/P/WP/248, available at: https://population.un.org/wpp/Publications/Files/WPP2017_KeyFindings.pdf

Vargas Zeppetello, L., Parsons, L., Spector, J., Naylor, R., Battisti, D., Masuda, Y. and Wolff, N.H. (2020), "Large scale tropical deforestation drives extreme warming", *Environmental Research Letters*, Vol. 15 No. 8, pp. 1-7, doi: 10.1088/1748-9326/ab96d2.

Vijayasarathy, K. and Ashok, K.R. (2015), "Climate adaptation in agriculture through technological option: determinants and impact on efficiency of production", *Agricultural Economics Research Review*, Vol. 28 No. 1, pp. 103-116, doi: 10.5958/0974-0279.2015.00008.7.

Yegbemey, R.N., Kabir, H., Awoye, O.H.R., Yabi, J.A. and Paraïso, A.A. (2014), "Managing the agricultural calendar as coping mechanism to climate variability: a case study of maize farming in Northern Benin, West Africa", *Climate Risk Management*, Vol. 3, pp. 13-23, doi: 10.1016/j.crm.2014.04.001.

Zakaria, A.R. and Matsui, K. (2020), "Smallholder rice farmers' adaptation capacity to climate change in the Bawku zone of Ghana", *International Journal of Environmental Science and Development*, Vol. 11 No. 5, pp. 256-262, doi: 10.18178/ijesd.2020.11.5.1259.

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D.B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J.-L., Elliott, J., Ewert, F., Janssens, I.A., Li, T., Lin, E., Liu, Q., Martre, P., Müller, C., Peng, S., Peñuelas, J., Ruane, A.C., Wallach, D., Wang, T., Wu, D., Liu, Z., Zhu, Y., Zhu, Z. and Asseng, S. (2017), "Temperature increase reduces global yields of major crops in four independent estimates", *Proceedings of the National Academy of Sciences*, Vol. 114 No. 35, pp. 9326-9331, available at: www.pnas.org/content/pnas/114/35/9326.full.pdf?ftag=MSFd61514f

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