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# Drivers and Constraints of Climate-Smart Agriculture Practices Adoption Among Vegetable Farmers in Parakou, North Benin

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**Abstract:** This study analyzed the adoption drivers and barriers of Climate Smart Agriculture (CSA) practices among vegetables farmers in the North-Benin. Methods: Data on the socio-economic characteristics, climate change perception, environmental factors, and CSA practices were collected from 100 vegetables farmers randomly surveyed during individual interviews and analyzed using descriptive statistic, statistic inference, and multivariate probit. Results: Most of the vegetable farmers were young people with about 11 years of experiences. Most of farmers (67%) were men. About 94% of farmers felt climate change. The climate change perception depends significantly at 5% threshold, to socioeconomic characteristics of vegetables farmers. CSA practices used were mainly organic manure (95%), crop rotation (53%), reduction of cultivated area (43%), drip irrigation (17%), and livestock integration (12%). Men were more oriented to crop rotation and reduction of cultivated area use than women. Age increasing was a barrier to the drip irrigation adoption whereas the size of household was a driver of the livestock integration and drip irrigation adoption. Access to credit and belonging to a farmers' association contribute positively to well water adoption. Conclusions: Extension services and decision makers could consider these drivers and barriers for accelerating the CSA practices adoption in vegetables farming.

**Keywords:** adoption, vegetable farms, sustainable agriculture, climate change, Benin

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## 1. Introduction

Climate change and population growth are the main challenges affecting the achievement of household's food security in the world and particularly in Sub-Saharan Africa (FAO, 2023). According to the sixth report of Intergovernmental panel on climate change (IPCC, 2022), different systems such as humans, ecosystems and food production system are significantly exposed to various climate change risks. For example, increase in temperature by 1.5°C before 2040 may lead to the widespread, irreversible, and invasive impacts of climate change on humanity and ecosystems (IPCC, 2022). From 2021 to 2022, food insecurity through hunger increased by 11 million in Africa (FAO, 2023). Also, it is estimated that Africa's urban population will increase by more than 950 million by 2050 (OECD and SWAC, 2020). The question of how to sustainably feed this growing population in urban and peri-urban areas remains the great challenge of all the time and has become more urgent to be addressed in the face of climate change (FAO, 2023). Indeed, climate change causes decrease in crop yields and a disruption of food system productivity (Dupar, 2019). In Benin, climate change is characterized by the variability and recurrence of extreme weather events including devastating floods, long droughts, heat waves, torrential rains, among others (Akponikpe et al., 2019). Climate risks such as the recurrence of severe droughts, heat waves, floods, etc. are affecting food security (Beny et al., 2022). These consequences have increased the vulnerability status of people leaving in rural areas (Lou et al., 2024) and have exacerbated the scarcity of resources, especially water for producing vegetables crops in urban and peri-urban areas (Mwaura et al., 2021).

Vegetables mostly constitute one of the best means for improving food security, especially in West-African countries such as Benin. Many of vegetables consumed in this country play an important role in agricultural development and nutrition (Snoek et al., 2023). About 79 of 126 traditional African vegetables are with high nutritional values for some species found in Benin, Ghana and Togo (van Zonneveld et al., 2021). Vegetables farming is seen as an opportunity for smallholders to gain a substantial income from the sale of their products specially for young people in urban and peri-urban areas (Petrikova et al., 2024). This has made the activity gained space despite the fast urbanization in main cities and thereby increasing the production, for example, from more than 634 167 tons of vegetables during the agricultural campaign 2020-2021 to 2022-2023 (Ministère de l'Agriculture, de l'Elevage et de la Pêche, (MAEP, 2022)). However, in Benin, food insecurity keeps increasing, from 9.6% in 2017 to 25.5% of households (3 140 236 persons) in 2022 (WFP, 2022). Therefore, more efforts need to be made for improving the productivity of vegetables farming in Benin, especially in the face of climate change. Tapping into the desire and engagement of young people in vegetable farming, suitable technologies need to be provided while practices need to be re-adjusted for adapting to climate change (IPCC, 2022).

Unfortunately, agriculture including vegetables farming is highly vulnerable to climate change (Egah et al., 2024). According to Husson and Lefèvre (2023), climate change affects vegetable farming mostly plant growth, product quality at harvest, nutritional quality of vegetables, etc. Bisbis et al. (2018) show that temperature and lack of water which are the climate parameters modify the photosynthesis process of the vegetable's crops. Climate change creates favor conditions to insects for their development and destroying the vegetables (Morel and Cartau, 2023). Floods become frequent and destroy the vegetables crop on the farms (Egah et al., 2024). Boillot et al. (2025) showed that rising the temperature decreased the yield of watermelon in climate change context. These situations compromise crop yields and affect negatively the food systems which become vulnerable to climate change (Nematchoua et al., 2019). These situations are more critical in the urban area where the effects of climate change or variability are from the drought and floods. For example, the lack of adequate drainage systems causes the floods which contaminates the water table used for vegetables production (World Bank, 2021). This affects the health of the farmers who use the contaminated water and chemical inputs for production. To fit this situation, climate smart agriculture promoting is a way to reduce the vegetables system vulnerability to climate change.

From the last decade, climate-smart agriculture (CSA) has emerged as a holistic approach to address climate change issues in a more sustainable manner by integrating three important aspects called pillars namely, (i) productivity, (ii) adaptation and (iii) mitigation/ resilience (Kpadonou et al., 2019). According to FAO (2021), the approach of CSA is based on: increasing agricultural income and yield, resilience adapting and building of people to climate change, and reducing GHG emissions. CSA practices are agricultural practices that enable producers to sustainably increase their productivity and income in the face of climate change (Eta et al., 2023; Pelemo et al., 2024). CSA practices promote climate mitigation benefits and agricultural adaptation for improving food security in the climate change context (Eta et al., 2023; Pelemo et al., 2024; Lou et al., 2024). There are many criteria with some of theme packaged or used in tools for assessing the climate smartness of a given agricultural practice (Akponikpe et al., 2024). However, adoption of CSA practices is driven by different factors with barriers that need to be shifted. Many studies have revealed determinants for adopting agricultural innovations and CSA practices in particular. The adoption factors such as sociodemographic and psychological factors, practices attributes, characteristics of farm and systemic and policy factors could be drivers or barriers of CSA adoption (Li et al., 2024). Therefore, bringing out these factors could contribute to speed-up the ongoing scaling-up process of CSA Worldwide and mainly in Africa. However, there are scarce data regarding barriers and drivers for adoption of CSA in urban and peri-urban areas, especially in Benin Republic. This study aims at contributing to the adoption of CSA practices in urban and peri-urban areas, especially for vegetables farming in Northen Benin. To reach out this objective, a mixt methodology was implemented.

## 2. Materials and Methods

### *2.1 Study Area*

This study was conducted in the Parakou municipality which is the biggest city in the northern Benin. The city is located at latitude 9°21' North, and longitude 2°36' East, with an average altitude of 350 m and a modest geographic relief (Figure 1).

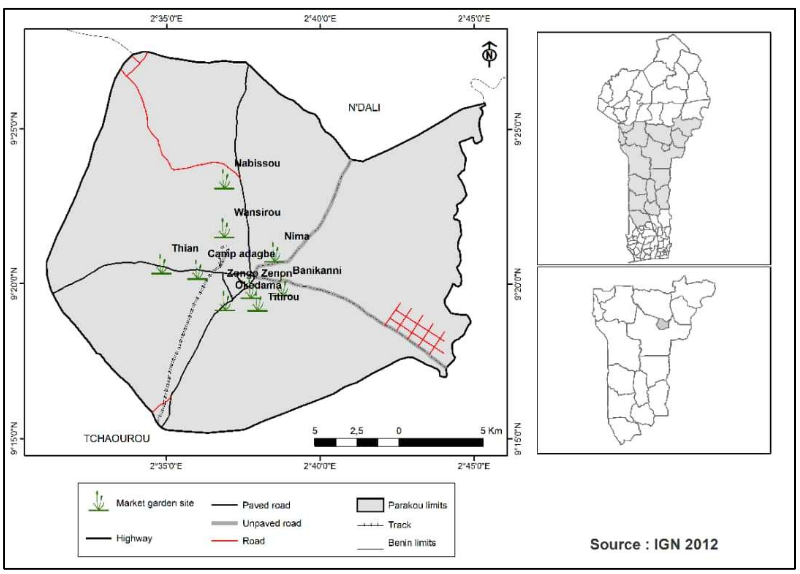


Figure 1: Map of the Municipality of Parakou

Parakou municipality is divided by three districts with 41 neighborhoods and villages. It is also a cosmopolitan city due to the presence of several socio-ethnical groups such as Batonou (29,4%), Fon (18,7%), Dendi (15,4 %) and Yoruba (14,9 %). Yom, Lokpa, Peulh, Adja, etc. are the other sociocultural groups in minority. Population is estimated for more than 425,149 inhabitants and its density is 903 inhabitants/km² in 2024.

Annual rainfall varies from 1,000 to 1,200 mm (Yolou, 2019). Water resources come mainly from the Okpara and Yéroumaro sources (Yolou, 2019). However, during the dry season (February to May) when vegetables farming is more intensive, waterways contributing to these sources remained dry. During this season, the Okpara, located around 12 km east of the town, and which is one of the major tributaries of the Ouémé basin is the only permanent surface water source for agricultural activities. Consequently, vegetables farming activities are mainly done in the lowlands along sides of its waterways.

### *2.2 Sample and sampling design*

The population of the study include all vegetables farmers in Parakou municipality. Multi stage sampling procedure was used in selecting the sample size. The first stage involved mapping of all existing vegetables production sites within the Parakou municipality. In total, 12 vegetables farming sites were identified. In second stage, 9 vegetable sites were randomly selected from the list of the 12 existing vegetable sites using the random number of Excel software. After calculating the random number, the 9 sites with high number were considered for the study. In 3rd step, all studied population was considered for the survey. All farmers working in each of the selected sites were surveyed, justifying the variation of the total interviewers' number per site (Table 1). In total, 100 farming of vegetables farmers were surveyed in the sites. All of the vegetable farmers included in the population consent to participate to the study.

**Table 1:** Number of respondents according to vegetables sites

| Vegetables sites | Number of surveyed people |
|---|---|
| Banikanni | 6 |
| Camp adagbe | 16 |
| Nabissou | 19 |
| Nima | 6 |
| Okedama | 4 |
| Thian | 3 |
| Titirou | 10 |
| Wansirou | 21 |
| Zongo-Zénon | 15 |
| **Total** | **100** |

Source: Field surveys, November 2022

*2.3 Data collection and analysis*

This study combined quantitative and qualitative methods. Data were collected in two stages. Firstly, one focus group discussion (FGD) with the vegetable farmers was organized per site to (i) describe the details of the work to the vegetable farmers and (ii) collect CSA practices used by these farmers. Participants of this FGD were all vegetables farmers working in each site (Table 1). In total, 9 FGD were organized using interview guide. Secondly, data on socio-demographic characteristics such as age, gender, agricultural assets, experience in vegetables farming, education level, access to an extension service, household size, religion, sociocultural groups, access to credit, membership in an organization of vegetables farmers, perception on climate change, climate change, and CSA practices used were collected individually (per farmer). These data were collected by statement during an individual interviews using a digital questionnaire programmed in KoboCollect.

Statistical analysis was done using a descriptive statistic, independence test, test t of Student, and a multivariate Probit. The mean and standard deviation were calculated for quantitative variables such as age, household size, agricultural assets, and experience in vegetables production. Frequencies or percentage were calculated for qualitative variables like gender, socio-cultural groups, level of education, religious beliefs, access to credit, membership in an organization, contact with an extension service and CSA practices used. Independence test and test t of Student were used to establish the linkage first between climate change perception and sociodemographic characteristics and secondly between climate change perception and adaptation practices used.

Multivariate probit model was used to analyze the barriers and drivers to the adoption of CSA practices by the vegetable farmers. Dependent variables were CSA practices used whereas the independent variables were sociodemographic data. The Probit model for adoption of CSA practices adoption resulted in the following dichotomous system of equations:

$$Y_1 = 1 \; if \; U_1^* > U_0^*, Y_1 = 0 \; if \; otherwise$$
$$Y_2 = 1 \; if \; U_2^* > U_0^*, Y_2 = 0 \; if \; otherwise$$
$$Y_3 = 1 \; if \; U_3^* > U_0^*, Y_3 = 0 \; if \; otherwise$$

$$Y_4 = 1\ if\ U_4^* > U_0^*, Y_4 = 0\ if\ otherwise$$
$$Y_5 = 1\ if\ U_5^* > U_0^*, Y_5 = 0\ if\ otherwise$$
$$Y_6 = 1\ if\ U_6^* > U_0^*, Y_6 = 0\ if\ otherwise$$

In linear form, the above equation can be translated into empirical model. Assuming that farmer i adopts a combination of CSA practices j (dependent variable) that could take the value of 1 (if adopted) or 0 (if not), the equation can then be written as follow:

$$Practice_j = \alpha_1 SEX_i + \alpha_2 AGE_i + \alpha_3 GS_i + \alpha_4 TAM_i + \alpha_5 APO_i + \alpha_6 ASV_i + \varepsilon_i$$

$\alpha$ represents the coefficients to be estimated and εi the error terms.

Based on the utility function sought by the farmer, he will likely tend to adopt a combination of practices to maximize his profit. Thus, modeling drivers and barriers to the adoption of CSA practices based on a logit or Probit regression model will result in biased estimates of the factors influencing strategy adoption (Adekambi and Hinnou, 2020). It is therefore preferable to use a multivariate Probit model because it uses Monte Carlo simulation techniques to simultaneously estimate the multivariate Probit regression equation system (Adekambi and Hinnou, 2020). In this model, the main CSA practices used by the farmers were considered for modeling. The independent variables were quantitative and qualitative variables in the specification of the multivariate Probit model (Table 2). The methods allowed to get the relevant results related to sociodemographic characteristics of respondents, perception and adaptation practices of vegetables farmers, CSA practices used by the vegetables farmers and barriers and drivers of CSA practices adoption.

**Table 2:** Specification of the Probit regression model

| Code | Name of the variable | Type of the variable | Modality | Expected signs | References |
|---|---|---|---|---|---|
| | | | Dependent variable | | |
| CSA | Adoption of CSA practice | Dichotomic | 1= yes; 0= No | | - |
| | | | Independent variables | | |
| SEX | Sex of respondent | Dichotomic | 0=Female; 1=Male | + | Yabi et al. (2016); Sodjinou et al. (2015) |
| AGE | Age of the respondent | Continue | - | +/- | Adebiyi et al. (2019) ; Li et al. (2024) ; Gemtou et al. (2024) |
| GS | Socio-cultural group | Nominal | 1=Bariba*; 2=Dendi; 3=Nago; 4=Other | +/- | Ngondjeb et al. (2011) ; Adebiyi et al. (2019) |
| TAM | Household size | Continue | - | + | Adekambi & Hinnou (2020) |
| APO | Membership in an organization | Dichotomic | 0=No; 1=Yes | + | Balasha & Fyama (2020) ; Li et al. (2024) |
| ASV | Access to credit | Dichotomic | 0=No; 1=Yes | + | Adebiyi et al. (2019); Gemtou et al. (2024) |

*The variable represented by the Bariba modality is taken as the reference variable
Source: Field surveys, November 2022

## 3 Results

### *3.1 Socio-demographic characteristics of respondents*

The average age of the interviewed vegetables farmers was about 41 years (±11.12 years), showing that vegetable farmers in Parakou are old between 30 and 52 years (Table 3). The average household' size was 5 persons (±3.028) with 2 agricultural assets (±0.913). Vegetable farmers working at the surveyed sites have more than ten years of experience in vegetable farming. About 67% of them were men whereas 33% were woman. The dominant sociocultural group was Bariba (29%). Most of the vegetable farmers (47%) had at least a primary formal education level whereas only 7% of them had no formal education. In terms of religion, about 43% of them were Muslim. More than half of the respondents (52%) had access to agricultural credit or small loans during the last five years. About 37% of them belong to a vegetable's farmers organization or cooperative and only 12% has access to an agricultural extension service.

**Table 3:** Socio-demographic characteristics of surveyed households

| Type of variables | Variables | Mean | Standard deviation |
|---|---|---|---|
| Quantitative variables | Age | 40.52 | 11.12 |
| | Household size | 5.12 | 3.03 |
| | Agricultural assets | 1.71 | 0.91 |
| | Experience in vegetables production | 10.55 | 8.46 |
| | **Variables** | **Modalities** | **Percentage (%)** |
| Qualitative variables | Gender | Female | 33 |
| | | Male | 67 |
| | Socio-cultural groups | Bariba | 29 |
| | | Dendi | 15 |
| | | Idatcha | 18 |
| | | Nago | 11 |
| | | Other | 27 |
| | Level of education | No education | 17 |
| | | Primary | 47 |
| | | Secondary | 30 |
| | | University | 06 |
| | Religious beliefs | Christian | 39 |
| | | Muslim | 43 |
| | | Animist | 08 |
| | Access to credit | No | 33 |
| | | Yes | 67 |
| | Membership in an organization | No | 63 |
| | | Yes | 37 |
| | Contact with an extension service | No | 88 |
| | | Yes | 12 |

Source: Field surveys, November 2022

### 3.2 *Perception and adaptation of vegetables farmers to climate change*

According to the farmers, about 94% of surveyed stated that there is climate change whereas 6% did not perceive the climate change. The climate change perception depends significantly at 5% threshold, to sociocultural groups ($p < 0,05$), marital status ($p < 0,01$), and the belonging to farmers organizations ($p < 0,05$). Also, age ($p < 0,001$), households size ($p < 0,01$), number agricultural assets ($p < 0,01$), number of experience years in vegetables production ($p < 0,001$) and high-income level ($p < 0,001$) positively influenced the perception of climate change (Table 4).

**Table 4:** Linkage between climate change perception and sociodemographic variables of surveyed

| Sociodemographic variables | Modalities | Climate change perception | | Statistical test |
|---|---|---|---|---|
| | | No (%) | Yes (%) | |
| Sex | Male | 66,7 | 67,0 | |

| **Sociodemographic variables** | **Modalities** | **Climate change perception** | | **Statistical test** |
|---|---|---|---|---|
| | | **No (%)** | **Yes (%)** | |
| | Female | 33,3 | 33,0 | X²= 0,000; df= 1; p= 0,986 |
| Ethnie | Other | 100,0 | 41,5 | X²= 7,801; df= 3; p= 0,050 |
| | Bariba | 0,0 | 30,9 | |
| | Dendi | 0,0 | 16,0 | |
| | Nago | 0,0 | 11,7 | |
| Marital status | Single | 0,0 | 20,2 | X²= 17,504; df= 3; p= 0,001 |
| | Divorced | 16,7 | 0,0 | |
| | Married | 83,3 | 71,3 | |
| | Veuve | 0,0 | 8,5 | |
| Religion | Christian Catholic | 33,3 | 19,1 | X²= 4,882; df= 3; p= 0,181 |
| | Evangelical Christian | 50,0 | 27,7 | |
| | Muslim | 0,0 | 45,7 | |
| | Endogenous religions | 16,7 | 7,4 | |
| Belonging to farmers organization | No | 100,0 | 60,6 | X²= 3,749; df= 1; p= 0,053 |
| | Yes | 0,0 | 39,4 | |
| Benefit of project support | No | 100,0 | 87,2 | X²= 6,644; df= 1; p= 0,084 |
| | Yes | 0,0 | 12,8 | |
| Access to credit | No | 33,3 | 48,9 | X²= 0,550; df= 1; p= 0,458 |
| | Yes | 66,7 | 51,1 | |
| Age | - | 31,33 | 41,11 | t= -5,483; df= 14,427; p= 0,000 |
| Education level | - | 1,00 | 1,27 | t= -,979; df= 6,123; p= 0,365 |
| Households size | - | 3,83 | 5,20 | t=-3,087; df= 20,387; p= 0,006 |
| Number of agricultural assets | - | 1,00 | 1,76 | t= -7,927; df= 93,000; p= 0,000 |
| Number of experiences years in vegetable production | - | 3,17 | 11,02 | t= -7,868; df= 59,365; p= 0,000 |
| Income level | - | 2,83 | 3,55 | t= -3,885; df= 7,612; p= 0,005 |

Source: Field surveys, November 2022

All of surveyed perceived flooding recurrence independently to climate change (Figure 2).

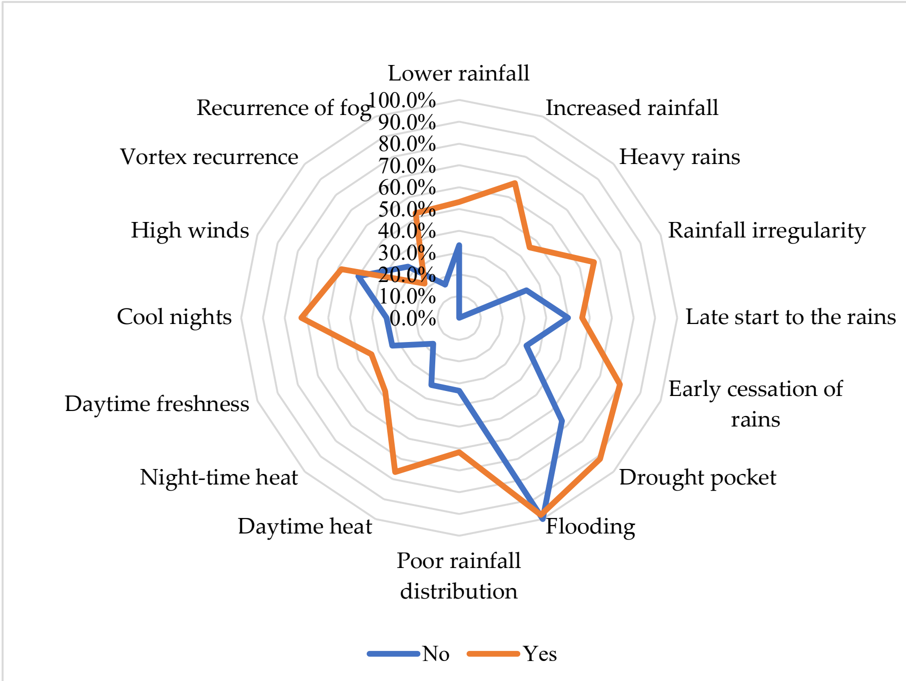


**Figure 2:** Perception of surveyed on climate change
Source: Field surveys, November 2022

According to climate change perception, most of surveyed (more than 66%) perceived significantly increased rainfall (df= 1; p= 0,001), daytime heat (df=1; p= 0,019), cool nights (df=1; p= 0,043), heavy rains (df=1; p= 0,028), rainfall irregularity (df=1; p= 0,09), early cessation of rains (df=1; p= 0,009), drought pocket (df=1; p= 0,049) and recurrence of fog (df=1; p= 0,09) as climate change manifestations (Figure 2).

The shifting of rainfall patterns has put vegetables farmers in a dilemma regarding the forecasting and planification of their activities. According to many of them, agricultural calendar has been altered with rain coming surprisingly when it is less expected and being absent when most needed. Erratic and heavy rainfall has led to the flooding of most of the vegetable production. About 98% of the vegetable farmers mentioned flood as one of the main factors triggering their activities. In the face of these climate challenges, eleven (11) adaptation practices are used by farmers (Table 5).

**Table 5:** Linkage between climate change perception and adaptation strategies

| Adaptation strategies | Modalities | Climate change perception (%) | | | Statistical test | | |
|---|---|---|---|---|---|---|---|
| | | No | Yes | Total | $\chi^2$ | df | p |
| Early seeds | No | 33,3 | 33,0 | 33,0 | 0,000 | 1 | 0,986 |
| | Yes | 66,7 | 67,0 | 67,0 | | | |
| Late sowing | No | 100,0 | 56,4 | 59,0 | 4,436 | 1 | 0,035 |
| | Yes | 0,0 | 43,6 | 41,0 | | | |
| Organic manure | No | 0,0 | 5,3 | 5,0 | 0,336 | 1 | 0,562 |
| | Yes | 100,0 | 94,7 | 95,0 | | | |
| Well creation | No | 83,3 | 67,0 | 68,0 | 0,690 | 1 | 0,406 |
| | Yes | 16,7 | 33,0 | 32,0 | | | |
| Area reduction | No | 100,0 | 54,3 | 57,0 | 4,815 | 1 | 0,028 |
| | Yes | 0,0 | 45,7 | 43,0 | | | |
| Change in agricultural calendar | No | 0,0 | 3,2 | 3,0 | 0,197 | 1 | 0,657 |
| | Yes | 100,0 | 96,8 | 97,0 | | | |
| Association of crops | No | 83,3 | 30,9 | 34,0 | 6,923 | 1 | 0,009 |
| | Yes | 16,7 | 69,1 | 66,0 | | | |
| Adoption of short-cycle crops | No | 16,7 | 7,4 | 8,0 | 0,651 | 1 | 0,420 |
| | Yes | 83,3 | 92,6 | 92,0 | | | |

| Adaptation strategies | Modalities | Climate change perception (%) | | | Statistical test | | |
|---|---|---|---|---|---|---|---|
| | | No | Yes | Total | $\chi^2$ | df | p |
| Livestock integration | No | 100,0 | 87,2 | 88,0 | 0,870 | 1 | 0,351 |
| | Yes | 0,0 | 12,8 | 12,0 | | | |
| Irrigation | No | 100,0 | 81,9 | 83,0 | 1,307 | 1 | 0,253 |
| | Yes | 0,0 | 18,1 | 17,0 | | | |
| Crop rotation | No | 100,0 | 43,6 | 47,0 | 7,198 | 1 | 0,00 |
| | Yes | 0,0 | 56,4 | 53,0 | | | |

Source: Field surveys, November 2022

Based on the independence test, four adaptation practices were linked to climate change in the threshold of 5%. These practices were the late sowing (p < 0,05), the area reduction (p < 0,05), the association of crops (p < 0,01) and the crop rotation (p < 0,001).

### *3.3 CSA practices used by vegetables farmers*

Six of these practices could be potentially classified as CSA practices. These CSA practices are the use of organic manure, the use of crop rotation, reduction of the cultivated area, construction of wells, use of drip irrigation and livestock integration on the vegetables site (Table 6).

**Table 6**: Determinants of climate smart practices

| Variables | Use of organic manure | | Creation of wells | | Reduction of the cultivated area | | Livestock integration | | Drip irrigation | | Crop rotation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| Gender (male) | 0.001 | 0.049 | 0.097 | 0.102 | 0.386*** | 0.101 | 0.089 | 0.065 | 0.136* | 0.080 | 0.237** | 0.108 |
| Age | 0.001 | 0.003 | -0.006 | 0.007 | 0.006 | 0.006 | 0.002 | 0.004 | -0.009* | 0.005 | 0.002 | 0.007 |
| Dendi | -0.110* | 0.062 | -0.207 | 0.128 | 0.146 | 0.127 | -0.217 ** | 0.082 | 0.100 | 0.100 | -0.094 | 0.135 |
| Nago | -0.155** | 0.072 | -0.068 | 0.148 | 0.073 | 0.146 | -0.160* | 0.094 | -0.112 | 0.115 | 0.046 | 0.156 |
| Idatcha | 0.049 | 0.065 | 0.247* | 0.135 | -0.151 | 0.133 | -0.278** | 0.086 | - 0.238** | 0.105 | - 0.379*** | 0.142 |
| Household size | 0.007 | 0.011 | 0.028 | 0.023 | 0.037 | 0.023 | 0.026* | 0.015 | 0.046** | 0.018 | 0.039 | 0.026 |
| Access to credit | 0.057 | 0.043 | 0.200** | 0.089 | -0.092 | 0.088 | -0.063 | 0.056 | 0.149** | 0.069 | -0.027 | 0.094 |
| Membership in an organization | 0.061 | 0.048 | 0.263*** | 0.098 | - 0.284*** | 0.097 | - 0.281*** | 0.063 | - 0.159** | 0.077 | -0.091 | 0.104 |
| Constant | 0.847*** | 0.114 | 0.380 | 0.236 | -0.128 | 0.233 | 0.0918 | 0.150 | 0.238 | 0.184 | 0.229 | 0.249 |
| Overall significance (p) | 0.0763 | | 0.0076 | | 0.0000 | | 0.0000 | | 0.0007 | | 0.0029 | |
| F | 1.858606 | | 2.824671 | | 5.027709 | | 5.673043 | | 3.775094 | | 3.215055 | |
| $R^2$ | 14,04% | | 19,89% | | 30,65% | | 33,28% | | 24,92% | | 22,04% | |

Source: Field surveys, November2022

These CSA practices were classified in two categories: CSA practices used for soil fertility management and CSA practices used for water mobilization and utilization (Table 6). The study revealed that vegetable farmers in Parakou usually combined organic manure with improved seed varieties. Organic manure is usually made of crop residues and poultry manure for improving soil fertility. Most of the farmers (95%) use this practice in their vegetable farms.

Crop rotation consists in making a succession of various vegetable crops on the same plot. This practice is very important for integrated soil fertility and pests' management according to the statement of the farmers. The practice was mentioned by about 53% of the respondents.
Adaptation strategy of reduction of cultivated area is used by 43% of the respondents. It is used mainly during flooding conditions when cultivated areas are taken over by over and reduced. Others farmers also apply this strategy as a mean of their capacity, where more attention and resources are needed to maintain vegetable crops production despite hard climate conditions.
As described earlier, vegetable farms are usually located a long side a waterway. Due do water scarcity as a result of climate change, some farmers made a construction of wells in their site to mobilize groundwater. About 32% of the farmers relied on this strategy mainly during the dry season.
Few farmers (17%) mentioned the use of drip irrigation as one of the efficient water management techniques. The main reason could be the investment costs and maintenance required by this technique.
Only 12% of the vegetable farmers apply livestock integration in the field. This practice consists of allowing animals (mainly cows) to stay in their farms mainly during nighttime for a short period of before the production cycle or season. The idea is to benefits from these animals' excrements (dungs and urines) to enrich their soils. This integration of livestock in the vegetable farming is beneficial for both farmers (improvement of soil fertility) and headers (use of some crop residues and place for integrating their animals).
In conclusion, CSA practices used by vegetable farmers in Parakou municipality allow to better manage soil fertility, water mobilization and cultivated areas.

### *3.4 Barriers and drivers of CSA practices adoption by vegetable farmers*

Barriers and drivers of CSA practices adoption depend on each CSA practices.

#### 3.4.1. Adoption of organic manure

The regression model estimated for the adoption of organic manure shows a significant level at 10% threshold (p=0.0763) (Table 6). The adjusted R2 of the model is equal to 14.04%. This implies that 14% of the organic manure adoption was explained by variations of the independent variables. Belonging to Dendi and Nago ethnic groups negatively influenced adoption of organic manure at 5% threshold. Therefore, it shows that vegetables farmers belonging to sociocultural groups of Dendi and Nago are likely not to adopt organic manure compared to Bariba ethnic group. This could mean that vegetables farmers of these groups do not own many cattle neither do they find it easy making gentle agreements with the pastoralists.

#### 3.4.2. Adoption of wells digging

The regression model of digging and use of wells was significant at 1% threshold (p=0.0076) (Table 6). The adjusted R2 of the model (R2= 19.89%) shows that the adoption of the well realization was explained up to 20% by the independent variables introduced in the model. Belonging to Idatcha sociocultural group, access to credit or small loans, and belonging to a vegetable farmers organization/association positively influenced the adoption and use of well at 5% threshold. It means, sociocultural group of Idatcha is likely to adopt this strategy than the Bariba group. Likewise, vegetables farmers who have access to credit or small loans adopt the strategy of digging and use of wells in their farm. Indeed, wells digging requires relatively high initial investment cost that farmers cannot gather as a go from their one season revenues. Based on the statement of the surveyed farmers, the cost of wells digging varied between 300 000 FCFA (USD 500) to 500 000 FCFA (USD 900) in the town. It has been shown that having access to credit allows vegetables farmers to get the required inputs resources they need including irrigation materials and financial resources for wells construction. This same justification stands for the reason why access to credit positively influenced the adoption of well construction and use as CSA practice. Being a member of a vegetables farmers organization or association positively influenced the adoption of wells. This result indicated that farmers belonging to an organization benefit from suitable advice and coaching that would encourage them to engage in a construction of wells to mobilize groundwater as CSA practice.

3.4.3. Reduction of the cultivated area

Adoption of the reduction of cultivated area as CSA practice was estimated significant by the model (p=0.0000) (Table 6). The adjusted R2 of the model shows that 31% of variation of the adoption of reduction of cultivated area was explained by the independent variables. Gender and holding of a membership of farmers' organization were highly significant at 1% level. Sex positively influenced the adoption of cultivated area reduction. It was appeared that men adopt reduction of cultivated area as CSA strategy more than women because the men stated that they reduced the cultivated crop for having the time to follow the crops and concentrated the inputs for increasing the yield while the women did not access to inputs like the men. So, the women preferred cropping more area than the men before hoping a minimum production for selling. On the other hand, belonging to a vegetable farmers organization negatively influenced the adoption of this practice. Farmers who are part of an organization or association do not see the relevance of such practice as they tend to extend or shift their cultivation area from flooded places to a more suitable area.

3.4.4. Livestock integration

Table 5 shows that livestock integration practice was significant (p=0.0000) based on the model. The adjusted R2 of the model shows that 33.28% of the variation of the livestock integration adoption was explained by the variations of the independent variables introduced into the model. Factors influencing the adoption of this practice are membership in an organization, sociocultural groups (Dendi, Nago and Idatcha) and household size. Membership in an organization negatively influenced the adoption of livestock integration strategy at 5% threshold. This means that vegetables farmers who belong to an organization adopt livestock integration less than the others because belonging in the organization allowed them to access to inputs. Then, these farmers did not need to require the livestock integration. Sociocultural groups (Dendi, Nago and Idatcaha) negatively influenced the adoption of livestock integration. Vegetable farmers belonging to these sociocultural groups adopt this strategy less than Bariba group who are pioneer in this practice. The positive influence of household size at 5% threshold on adoption of livestock integration revealed as the size of the household increases, farmers are likely to adopt livestock integration as CSA practice. Farmers need more efforts for integrating the livestock and thereafter prepare the soil for sowing by homogenizing the spread of the excrements over the cultivated area.

3.4.5. Drip irrigation

The estimated regression model for drip irrigation was significant at 1% level (p=0.0007) (Table 6). The explanatory power of the model ($R^2$= 24.92%) shows that 25% of the variations of the adoption of the drip irrigation strategy were explained by variations of the independent variables. Gender, household size and access to credit positively influenced the adoption of drip irrigation at 5% threshold. These results suggest that men adopt drip irrigation than women because the men had access to production resources instead the women. The drip irrigation requires more investment which the women could not do. The women had less access to finance than the men. Similarly, farmers having access to credits or small loans are likely to adopt drip irrigation compared to others. Furthermore, bigger the size of the household, higher is the chance for farmer to adopt drip irrigation technique as CSA practice like a climate change adaptation practice. Indeed, most of the vegetables farmers are the men who have means to invest and install irrigation system on their field. This is not the case of women who depends mainly on their husbands and have less decision power and resources. This vulnerable condition of women is unfortunately more favored by the inaccessibility of credits or small loans, as men have more access to credits than women.

3.4.6. Crop rotation strategy

Adoption of crop rotation as CSA practice was estimated to be highly significant ($p=0.0029$). The explanatory power of the model ($R2= 22.04\%$) shows that 22% of the variations of the crop rotation adoption were explained by the independent variables introduced in the model. Gender positively influenced the adoption of crop rotation at 5% threshold because the men preferred to use wisely the cultivated area by crop rotation than women, whereas sociocultural group of Idatcha negatively influenced adoption of this practice.

Belonging to such association or cooperative facilitate access to chemical fertilizers, then, holding a membership of farmers organization affected negatively the crop rotation strategy adoption. The positive influence of household size on the adoption of livestock integration could be justified not only by the need of more labor for taking care of the animals and arranging their excrements on the field but also on the prestige of being owner of these livestock for those from Bariba sociocultural group. Gender, household size and access to credit have positive influence on the adoption of drip irrigation.

Findings from this study show the complexity of CSA practices adoption process as significantly influence by socioeconomic factors. Hence, some factors are drivers to the adoption of CSA practices in urban and peri-urban vegetable production areas, whereas others are barriers. These findings are discussed in linkage to other scientific works in the discussion section.

## 4. Discussion

The overall trend that has emerged from the results of this study is that vegetables farmers in Parakou municipality perceived climate change in urban and sub-urban area through the shorten of the rainy season, the increase of flood occurrence, the variation and change in the rainfall patterns and the rising of temperature. Similar perceptions were also identified by Egah et al. (2024) as manifestations of climate change in Tchaourou, one of the closest municipalities to Parakou that is less affected by urbanization. The authors found that the main consequences of climate change in Tchaourou municipality are drought spells, storm winds, floods, torrential rains, early and late rainfall (Egah et al., 2024). It clearly appeared that urban and peri-urban areas are less affected by storm winds due to the existence of buildings near vegetable farming sites and dry spells as farmers usually cultivate their crops alongside waterways. These might be the main reasons why many vegetables farmers in Parakou city did not mention these consequences of climate change. Vegetables farmers adopt many practices for adapting to these impacts of climate change.

As clarified earlier, only six of these practices could be potentially classified as climate smart based on results presented by Kpadonou et al. (2019). These CSA practices are the use of organic manure, the use of crop rotation, reduction of the cultivated area, construction of wells, use of drip irrigation and livestock integration on the vegetable's sites. Gemtou et al. (2024) through a worldwide systematic review categorized agricultural practices in several potential CSA groups. Practices identified in this study correspond to Gemtou et al.'s categories such as the use of renewable energy sources (apply with the drip irrigation), organic farming (here represented by the use of organic manure), natural resources preservation (which among to the efficient use of water resources and in this study stands for groundwater mobilization and the use of drip irrigation). On the other hand, reduction of cultivated area and livestock integration were identified by Egah et al. (2023a) and Egah et al. (2024) as adaptation practices used in rural areas of northern Benin. About the use of livestock integration, it is therefore a kind of gentle agreement between agropastoralists and vegetable farmers. Its climate smartness capacity lies on the fact that the use of the animals' excrements significantly improves soil fertility and thereby improving crop productivity. On the other hand, gathering animals' excrements at one place and sequestration. In conclusion, CSA practices used by vegetable farmers in Parakou municipality allow to better manage soil fertility, water mobilization and cultivated areas.

This study showed that sociodemographic factors, years of experiences in vegetables production and membership in an farmers organization influenced adoption of CSA practices. Specifically, sociocultural groups of Dendi and Nago were less likely to adopt organic manure as compared to

Bariba group. Vegetables farmers of these groups do not own many cattle neither do they find it easy making gentle agreements with the pastoralists. The useful advice and assistances provided by fellow farmers during meetings and farms visits helps the members to adopt the well construction. The positive influence of household size on the adoption of livestock integration could be justified not only by the need of more labor for taking care of the animals and arranging their excrements on the field but also on the prestige of being owner of these livestock for those from Bariba sociocultural group. Gender, household size and access to credit have positive influence on the adoption of drip irrigation. Indeed, most of the vegetables farmers are the men who have means to invest and install irrigation system on their field. This is not the case of women who depends mainly on their husbands and have less decision power and resources (Egah et al., 2023b). This vulnerable condition of women is unfortunately more favored by the inaccessibility of credits or small loans, as men have more access to credits than women. Indeed, it has been shown that having access to credit allows vegetables farmers to get the required inputs resources they need including irrigation materials and financial resources for wells construction (Chimi et al., 2024). This same justification stands for the reason why access to credit positively influenced the adoption of well construction and use as CSA practice.

Thus, there are numerous drivers and barriers to the adoption of CSA practices by vegetable farmers in urban and peri-urban area like Parakou municipality. According to Gemtou et al. (2024), CSA practices adoption could be influenced mainly by the sociodemographic and psychological factors, practices attributes, characteristics of farm and systemic and policy factors in rural area. This factors diversity was demonstrated by Pronti et al. (2024) who based their argumentation on the literature review to conclude that determinants of adoption of agricultural innovations could be on multiple-fold: those related to farm and farmers characteristics, institutional environment, geographic and climate characteristics. Similarly, barriers and drivers to the adoption of CSA practices identified in this study could be also classified in these categories, mainly in (i) farm and farmers characteristics (extension services, age, sociocultural group, gender, etc), (ii) institutional environment (membership in organization, access to credit, etc.). Dazé and Dekens (2017) highlighted that ethnicity is one of factors that influences smallholder farmers vulnerability to climate change and in turn their predisposition to adopt adaptation or mitigation measures as also shown in this study. Furthermore, Mahdhi et al. (2019) and Kabore et al. (2019) identified access to credit as one of the major factors determining the adoption of adaptation strategies, particularly on water and soil conservation strategies, while Chimi et al. (2024) also demonstrated that having a membership with a farmer's organization or association influences adoption of CSA practices.

Findings from this study show the complexity of CSA practices adoption process as significantly influence by socioeconomic factors. It is clear that no specific factor could not stand alone as driver or barrier to the adoption (Rizzo et al., 2024) as they influenced one another. Hence, some factors are drivers to the adoption of CSA practices in urban and peri-urban vegetable production areas, whereas others are barriers. Additionally, adoption process does consider psychological factors, the attributes or perception on the innovation by the users, systemic and policy factors, etc. (Gemtou et al., 2024). In general, these factors depend on the type of innovation, the context of use and the environment.

## 5. Conclusions

Climate change in urban and peri-urban area of the Parakou municipality is perceived by vegetable farmers as variation and change in rainfall patterns, shorting of rainy season, rise in temperature, increase in flood occurrence and early cessation of rain. Vegetable farmers use CSA practices to adapt to these negative effects of climate change. These are the use of organic manure, digging of wells for groundwater mobilization, livestock integration, drip irrigation, crop rotation and reduction of the cultivated area. Adoption of CSA practices by vegetable farmers in the urban and peri-urban areas of Parakou depends on the sociodemographic characteristics of the farmers which are the drivers or barriers of the adoption. These factors vary according to the CSA practices to be adopted. Therefore, drivers for the adoption of CSA practices by these farmers are related to the sociodemographic characteristics of the farmers while barriers to the adoption of these practices are technical and economic factors that directly affect the production. These drivers and barriers were categorized in sociodemographic factors, farmers factors and the environmental factors. The level of influence on the adoption varies on the type of factor. Actions for speeding-up the adoption process of CSA practices in urban and peri-urban area like Parakou municipality in favor to vegetable farmers could be focused on activating levers like access to credits or small loans with no or less refund rate and encouraging farmers to accept enrolment in farmers association and actively participate in group activities.

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