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Impact of climate adaptation strategies on the net farm revenue of underutilised indigenous vegetables' (UIVs) production in Southwest Nigeria

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ABSTRACT

This paper examined the impact of climate adaptation strategies employed by Underutilised Indigenous Vegetables (UIVs) farmers on UIVs' net revenue of adopters and non-adopters of adaptation strategy in Southwest Nigeria. This was with a view to determine the factors that determined UIVs net revenue in the study area. Both quantitative and qualitative primary household data from 191 UIVs producers, with secondary climate data from Nigeria Meteorological agency were used. An efficient endogenous switching regression model (ESRM) was used to estimate the effect of climate change adaptation strategy on UIVs net revenue. The results show that farmers' perception of climate change showed a high temperature and a high variability in rainfall pattern. The adaptation strategies mostly employed by the UIVs farmers is cultivating along river banks (98%) while the least was agroforestry and perennial plantation (4%). Meanwhile, all the farmers who adopted farmers that adopted Agroforestry and perennial plantation and Agricultural good practices did not experience loss in UIVs production. The factors that determined the likelihood of adopting climate adaptation strategy include years of experience (0.0335, $p<0.1$) in UIVs production, access to climate information (0.7895, $p<0.1$) and agro ecological zone (0.7889, $p<0.1$). Further, factors that determine the net revenue from UIVs for adopters were access to information on climate change 0.2428, $p<0.1$), off-farm income (0.6526, $p<0.01$), precipitation (0.0045, $p<0.1$), precipitation square (0.−0.00002, $p<0.1$) and Ondo location (0.4470, $p<0.05$). Age (0.1261, $p<0.1$), agro ecological zone (4.2682, $p<0.1$), off-farm income (−1.1765, $p<0.05$) and precipitation square (0.0001, $p<0.01$) determined the UIVs revenue for non-adopters. The promotion of UIVs should therefore be advocated by the government and non-government agencies since high temperature does not have significant effect on its revenue. Also, provision of relevant information on climate change is essential for farmers as this will enhance farmers' likelihood of adopting appropriate climate change adaptation strategy considering the type of crop they cultivate and the peculiarity of their agro ecological zones. Also, vegetables' farmers are encouraged to engage in agroforestry and perennial plantation.

1. Introduction

Vegetables are grown worldwide and play major and multiple roles in human life. They are mostly grown for their nutritious, medicinal and economic importance. In human nutrition, they are good sources of vitamins, minerals, fibre and phytochemicals (Schreinemachers et al., 2018; Ülger et al., 2018). Vegetable consumption delivers taste and palatability, increases appetite and prevent constipation. In the recent times, many are conscious of their well-being, therefore, vegetable-embellished diets are advocated for because of its health benefits (Ülger et al., 2018). Inclusion of vegetables in the daily diet has been strongly associated with improvement of good vision, gastrointestinal health, and reduction in the risk of heart disease, stroke, diabetes and some forms of cancer (Keatinge et al., 2010). Also, vegetable production is good source of income that is steady and regular to meet the daily expenditure. Their production is more lucrative compared to field crops (Dias and Ryder, 2011), this is because most vegetables are of very short production cycle which allows multiple cropping round the year and as such can bring quick return on investment. Likewise, vegetables production is an important source of raw materials for many industries. Their perishable nature demand for storage and processing and as such provides more and regular employment opportunities in both urban and rural areas.

Despite the identified numerous health and economic benefits of vegetables, low productivity, especially in developing countries such as Nigeria remains a serious obstacle in vegetable production (Adeoye, 2020). According to FAOSTAT, 2020, average vegetable yields across

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Nomenclature

Abbreviations	Full meaning
UIVs	Underutilised Indigenous Vegetables
ESMR	Endogenous Switching Regression Model
FAOSTAT	Food and Agriculture Organization Statistics
NiCanVeg	Nigeria Canada Vegetable Project
LGAs	Local Government Areas
FGDs	Focus Group Discussions
FIML	Full Information Maximum Likelihood

sub-Saharan Africa, Southeast Asia and South Asia are estimated to be only 36%, 48% and 64%, respectively, of East Asia, resulting in short supply of nutrient-rich vegetables. A range of factors such as technological factors, which includes soil and soil fertility management; weed and pest management; irrigation and water management and socioeconomic factors such as inadequate access to land; traditional methods of cultivation; inadequate access to credit; inadequate processing and storage facilities; small farm size; and inadequate access to farm inputs, had been identified as factors that are responsible for the low productivity, profitability and availability of vegetables and other crops (Adeoye, 2020; Xaba and Masuku, 2013a; Udimal et al., 2017; Xaba and Masuku, 2013b). This hazardous situation degenerated further as a result of climate change through increasing temperatures, changing precipitation patterns, and greater frequency of extreme weather events (Pareek et al., 2017). The consequences of the climate change are prolonged drought and increased insect infestations which have negative impact on farms and crops with severe economic corollaries (Bifulco and Ranieri, 2017; Seneviratne et al., 2012). No doubt, climate change has become a normal part of the earth's system, some levels of continued climate change and variability is inevitable, and some impacts of climate change are also unavoidable (Sojobi et al., 2016).

Crops generally react negatively to climate change but vegetables are more sensitive to adverse climatic condition (Abewoy, 2018), this is probably because most vegetables are herbaceous plants with short production cycle and any adverse condition during this short period can result into a great loss (Prasad and Chakravorty, 2015; Naik et al., 2017). A recent study of global vegetable and legume production concluded that if greenhouse gases emissions continue on their current trajectory, vegetable yields could fall by 35% by year 2100 due to high temperature, water scarcity and increased salinity and ozone (Scheelbeek et al., 2018). In general, any disorder caused by climate change in local vegetable production will in no doubt, result in the loss of income for vegetable farmers and lead to an increase in vegetable price fluctuation in the domestic markets, which poses a threat to regional nutrition security. In order to alter this calamitous course, human society must continue to adapt to a changing world (Raghuvanshi et al., 2001). There is therefore, an urgent need to strengthen the adaptive capacity of vegetables to the changing climate.

Meanwhile, it is suggested that underutilised indigenous vegetables (UIVs) will likely play a key role in climate-resilient vegetables, although they currently constitute a small share of agro-food systems (Prasad and Chakravorty, 2015; Scheelbeek et al., 2018; Nnamani et al., 2009; Mabhaudhi et al., 2016). However, in the recent times awareness is being created by researchers among farmers, marketers and consumers about the importance of these indigenous vegetables. Many indigenous vegetables are highly nutritious, containing several micronutrients plus nutraceuticals. Their appropriateness to marginal niche and low-input environments offers opportunities for low greenhouse gases emissions from an agro-ecosystems, production, and processing perspective, as well as their climate adaptive capacity. These indigenous vegetables also signify a broad gene pool for future vegetable crop improvement (Sambo, 2014; Kuo et al., 2020).

Unfortunately, there is limited quantitative and qualitative information supporting the key role indigenous vegetables play in climate resilient pathway (Padulosi et al., 2011; Pachauri et al., 2014; Chivenge et al., 2015). Most of the knowledge of UIVs adaptation to climate change remains hidden in the indigenous knowledge systems, and this may explain why certain communities have continued to preserve and utilise certain UIVs. The limited quantitative empirical information is a pointer to the fact that UIVs remain under-researched as well, although there have been some studies on these neglected and underutilised crops in Sub-Saharan Africa in the recent times, in order to tap into their potentials. A research by Adebooye and Opabode (2004), for example, was particular about the conservation of these indigenous crops in order to prevent them from going into extinction, especially as the reliance on a handful of major crops has inherent agronomic, nutritional, and economic risks, which is not sustainable in the long run (Ebert, 2014). Ayanwale et al. (2011), Aju et al. (2013) and Tanimonure et al. (2017) also studied the value addition and marketing potentials of some of these UIVs, and saw good business prospect in them, especially for women folks. Some of the representatives of these leafy vegetables, tuber crops, cereals and grain legumes that fit into the class of underutilised crops were identified by Chivenge et al. (2015), Maroyi (2011), Shrestha (2013). And it was equally found out that they are potential future crops for smallholder farmers, as sources of nutrition and income, especially in this era of climate change. Study by Sambo (2014) showed that underutilised crops could offer scientists a rich source of genetic materials for modification, which could hold potential key to developing resilient and drought-tolerant crops. Recent research found out that these underutilised indigenous crops have the ability to grow under water-scarce conditions, and that the key to future food and nutrition security may lie in their untapped potentials (Mabhaudhi et al., 2016). More recent research shows qualitatively that the impact of climate change on indigenous vegetables is both positive and negative and the predicted negative effect of climate change on indigenous vegetables cannot be ignored (Chepkoech et al., 2018). As such, UIVs farmers, therefore, adopt a number of adaptation strategies to prevent or mitigate the effect of climate change on their production activities.

IPCC defines climate change adaptation as: 'the process of adjustment to actual or expected climate and its effects. Adaptation is the reaction by individuals, groups, communities, nations and governments to actual or expected changes in climatic conditions or their effects. It is aimed "to reduce the vulnerability of human or natural systems to the impacts of climate change and climate-related risks, by maintaining or increasing adaptive capacity and systems resilience" (OECD, 2011). As a result of adaptation measures, farmers are able to increase their resilience to the negative influence of climate change. Hence, adaptation increases the coping range of farmers.

The study aims at examining the impact of climate adaptation strategies employed by UIVs farmers on UIVs net revenue of adopters of adaptation strategy in Southwest Nigeria and the objectives of the study therefore, are to (i) profile the UIVs that are cultivated and their responses to outcomes of climate variables in the study area, (ii) examine UIVs farmers' perception of climate variability and its effect on UIVs production activities (iii) assess the adaptation strategies adopted by the farmers to cope with the adverse effects of climate change (iv) evaluate the socioeconomic and farm related factors that determined whether or not a UIVs farmer will adopt adaptation strategy and (v) establish the factors that determine UIVs net revenue of adopters and non-adopters in the study area. This study will add to the existing literature on the resilience of UIVs to climate variability and change in Sub-Saharan Africa.

2. Methodology

2.1. Study area

The study area was South Western Nigeria as presented in Fig. 1. The area lies between longitude 2^0 31^1 and 6^0 00^1 East and Latitude

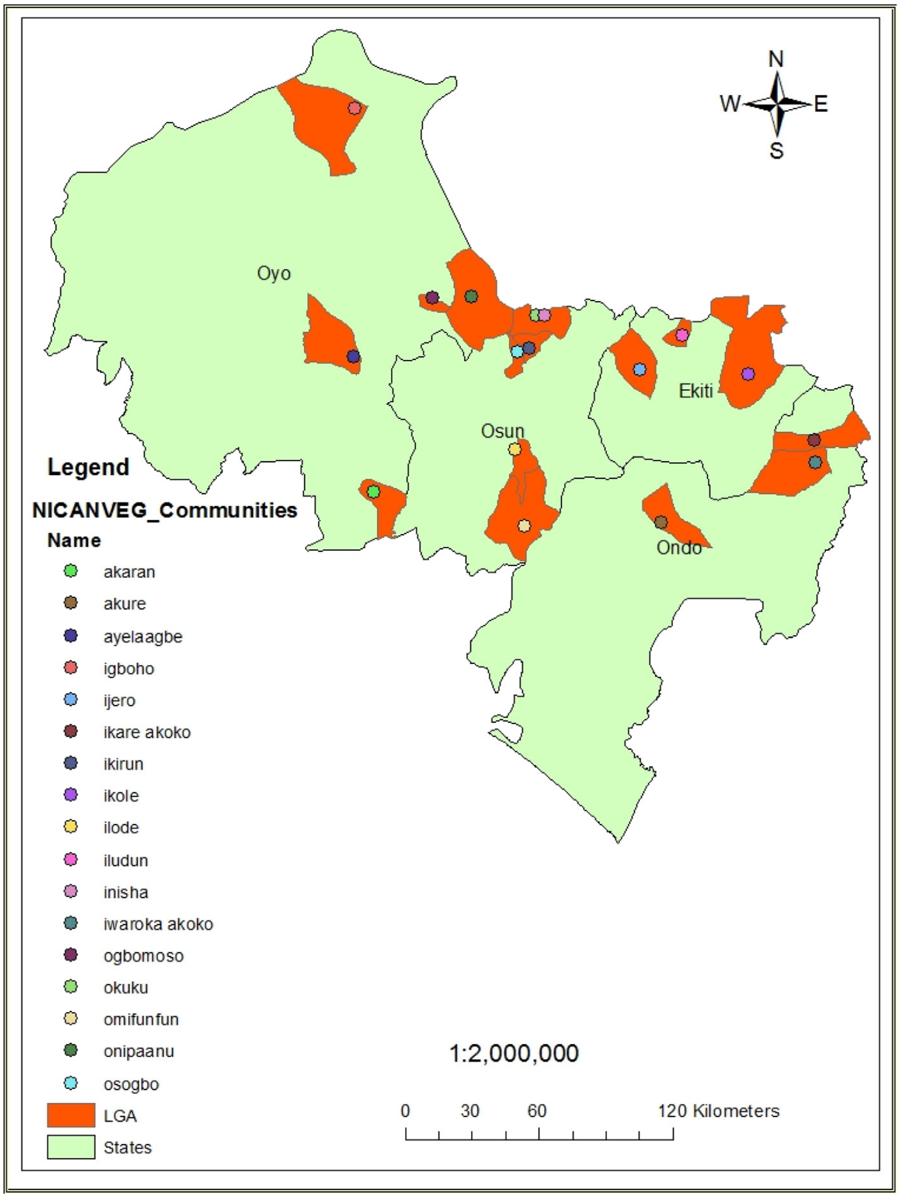

Fig. 1. Sample study Local Government Areas in Southwest Nigeria.

6^0 21^1 and 8^0 37^1 North. The study area is bounded in the East by Edo and Delta States, in the North by Kwara and Kogi States, in the West by the Republic of Benin and in the south by the Gulf of Guinea. The region constitutes about one sixth (~163,000 km^2) of the total land area of Nigeria and comprises of six States (Oyo, Ogun, Osun, Ondo, Ekiti and Lagos) and is distinctly divided into three major agro-ecological zones (Rain Forest zone, Swamp Forest zone and Derived Savannah zone) with diverse climatic conditions. The forest agro-ecological zone has annual rainfall in the range of 1600 to 2400 mm, with cropping seasons between April and November with dry spells from December to March. The soil types in this zone depend largely on parent rock, where the underlying rocks are granite or clay, the soil is a rich clayey loam. On the other hand, the derived savannah agro-ecological zone has mean annual rainfall ranging from 800 to 1500 mm with cropping seasons between June and November. The soil types range from the sandy to clayey in texture with soil reaction ranging from acidic to slightly basic. Soil fertility statuses and crop species diversity also vary widely in different locations in the region. The study was carried out in two of the three agro-ecological zones, namely rainforest and derived savannah zones where UIVs were promoted in a project tagged NiCanVeg. (Swamp Forest zone was not included because NiCanVeg project was not implemented in the two States that fall under this zone).

All the 17 NiCanVeg communities in sixteen Local Government Areas (LGAs) were selected from Ekiti, Ondo, Osun and Oyo states. In order to ensure representativeness and due to limited budget, a simplified formula Eq. (1), developed by Kothari (2004) was used to calculate the sample size of the respondents at the communities' level. A 95% confidence level, 5% estimated percentage and P = 0.5, were assumed in the equations.

$$n = \frac{Z^2 X p X q X N}{e^2 X (N-1) + Z^2 X p X q} \tag{1}$$

where n is the sample size, N is the population size, e is the estimated proportion, p is sample proportion, $q = 1 - p$ and z is the value of the standard variate at a given confidence level and to be worked out from table showing area under Normal Curve.

Based on this formula, the respondents' sample size is approximately 191 (which was about 50% of the direct beneficiaries of NiCanVeg project in the study area).

In each NiCanVeg site, the NiCanVeg farmers were stratified into male and female to ensure random selection of both sexes and 50% of the total farmers from each community were randomly selected from NiCanVeg farmers' lists. This proportionate sampling procedure was necessary because the number of farmers in each community or site differs.

Mixed-methods research design involving both the quantitative and qualitative research approaches was used to elicit information from the respondents. The quantitative study involved face-to-face data collection with the use of well-structured questionnaire, the questionnaires were administered by trained students (enumerators) from the Faculty of Agriculture, Obafemi Awolowo University to ensure the quality of the data. Before the data collection, there was an "advance notification" sent to the respondents to let them know that the survey would be conducted in their communities. The enumerators and the supervisor were led to the communities by the NiCanVeg field manager who was already familiar with the farmers and the communities. Focus Group Discussion (FGD) was conducted to gather qualitative data from the respondents. Eight FGDs (two per State) were organised among the UIVs farmers.

Both descriptive statistics and econometric analyses were used to analyse the data collected from the respondents. Descriptive statistics such as frequency counts, means, percentages among others, were employed to describe the socio-economics characteristics of the respondents, the climate change adaptation strategies adopted and the perceived effects of climate change on UIVs production activities. Content analysis was used to summarise the qualitative data collected through the FGDs. For the econometrics analysis, endogenous switching regression was employed.

2.2. Endogenous switching regression model

This article examines the impact of climate adaptation strategies on the net farm revenue of UIVs production. The evaluation focuses on whether adoption of adaptation strategies improved farm profits, which is estimated with an endogenous switching regression model following Läpple et al. (2013). This method controls for self-selection bias due to unobserved characteristics, such as the farmer's ability, that may affect both adoption and net farm revenue. There are two stages in endogenous switching regression model, the first stage involves modelling of the adoption behaviour with the limited-dependent variable method. In the second stage, I estimate another decision variable (net revenue) separately for each group (adopters and non-adopters), conditional on the adoption decision. So, a binary probit model is used in the first stage to model the adoption behaviour, and in the second stage, separate regression models are used to model UIVs net revenue function conditional on a specified criterion function. Following Ali and Abdulai (2010), Asfaw et al. (2012) and Paltasingh and Goyari (2018), the decision to adopt adaptation strategy can be modelled in the framework of utility maximisation. The difference between the utilities from adoption (UAi) and non-adoption (UNi) of adaptation strategies of climate change may be denoted as G*, such that the ith household would like to adopt the given if UAi is greater than UNi. In other words, the ith household will adopt when $G^* = U\text{Ai} - U_{\text{Ni}} > 0$. But, G* is unobservable. So, we can express it as a function of observable factors in this latent variable model (probit model) as follows:

$$G_i^* = \beta X_i + \mu_i \text{ with } G_i = \begin{cases} 1 \text{ if } G_i^* > 0 \\ 0 \text{ if } G_i^* \leq 0 \end{cases} \tag{2}$$

Where G is the dichotomous variable that takes the value 1 if farmer is an adopter of adaptation strategies of climate change and 0 otherwise; β is the vector of unknown parameters to be estimated, and X is the vector of explanatory variables comprising socioeconomic characteristics of farmer, the climate variables and farm specific characteristics; and u is the random error term with 0 mean and variance as σ^2. Maximum likelihood estimation procedure is employed to estimate the vector of probit coefficients β. Now, the adoption of adaptation strategies also affects the UIVs net revenue (Y). Let the UIVs net revenue (Y) be a function of conventional and non-conventional factors then Ji is the vector of those exogenous factors. In switching regression method, as UIVs net revenue (Y) is conditional on adaptation strategies adoption status, I use two separate profit functions for adopters and non-adopters of adaptation strategies as follows:

$$\begin{aligned} Y_{1i} &= \alpha_1 J_{1i} + \epsilon_{1i} \quad \text{if } G_i = 1 \\ Y_{0i} &= \alpha_0 J_{0i} + \epsilon_{0i} \quad \text{if } G_i = 0 \end{aligned} \tag{3}$$

The variables Y_1 and Y_0 are the net revenue for the adopters of adaptation strategies and non-adapters, respectively. For a given household, Y_1 or Y_0 is observable depending on the values of the criterion function in Eq. (1). Therefore, the ordinary least squares (OLS) estimates of parameter vector J_1 or J_0 will be biased as they suffer from sample selection bias. The errors ϵ_1 and ϵ_0, conditional on sample selection criterion will have non-zero expected values (Lee and Trost, 1978; Maddala, 1983). Finally, the error terms u, ϵ_1, and ϵ_0 are assumed to have a trivariate normal distribution with 0 mean and non-singular covariance matrix expressed as follows:

$$\text{COV}(\epsilon_{1i}, \epsilon_{0i}, u_i) = \begin{pmatrix} \sigma^2_{\epsilon 1} & \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 1 u} \\ \sigma_{\epsilon 1 \epsilon 0} & \sigma^2_{\epsilon 0} & \sigma_{\epsilon 0 u} \\ \sigma_{\epsilon 1 u} & \sigma_{\epsilon 0 u} & \sigma^2_u \end{pmatrix} \tag{4}$$

Where $\sigma 2$ u is the variance of the error in the criterion Eq. (1); $\sigma^2\epsilon_1$ and $\sigma^2\epsilon_0$ are the variance of the errors ϵ_1 and ϵ_0, respectively, in profit functions in Eq. (2); and $\sigma_{\epsilon 1\text{u}}$ and $\sigma_{\epsilon 0\text{u}}$ are the covariance of error terms u, ϵ_1, and ϵ_0. The outcome functions in Eq. (2) are not observed simultaneously. So, the covariance between ϵ_1 and ϵ_0 is not defined (Maddala, 1983). However, a significant inference of the error structure is that as the error u of criterion function is correlated with the error terms of the net revenue functions in Eq. (2), the expected values of the error terms are non-zero, conditional on the sample selection, and expressed as:

$$E\left[\epsilon_{1i} | G_i = 1\right] = \sigma_{\epsilon 1 u} \frac{\phi(\beta X_i / \sigma)}{\phi(\beta X_i / \sigma)} \equiv \sigma_{\epsilon 1 u \lambda_{1i}} \tag{5}$$

$$E\left[\epsilon_{0i} | G_i = 0\right] = \sigma_{\epsilon 0 u} \frac{\phi(\beta X_i / \sigma)}{1 - \phi(\beta X_i / \sigma)} \equiv \sigma_{\epsilon 0 u \lambda_{0i}} \tag{6}$$

where ϕ(.) and Φ(.) are the standard normal probability density function and standard normal cumulative density function, respectively. $\lambda_{1\text{i}}$ and $\lambda_{0\text{i}}$, i.e., the estimated ratio of ϕ(.), and Φ(.) evaluated at βXi is the inverse Mills ratio. If the estimated covariance $\sigma_{\epsilon 1\text{u}}$ and $\sigma_{\epsilon 0\text{u}}$ are statistically significant, it implies that adoption decision and profitability outcome variables are correlated. So, we find the evidence of endogenous switching and reject the null hypothesis of no sample selection bias (Lokshin and Sajaia, 2004). The full information maximum likelihood (FIML) estimation method is considered to be the most efficient one to estimate the endogenous switching regression model (Asfaw et al., 2012; Di Falco et al., 2011; Lokshin and Sajaia, 2004). It estimates simultaneously the criterion equation (probit model) and the profitability outcome functions to give consistent standard errors. On the basis of the trivariate normal distribution for the error terms, the logarithmic likelihood function for the system of Eqs. (1) and (2) can be given as:

$$\begin{aligned} LnL = \sum_{i=0}^{N} G_i [\ln \phi \left(\frac{\epsilon_{1i}}{\sigma_{\epsilon 1}} \right) - ln\sigma_{\epsilon 1} + ln\Phi(\boldsymbol{\phi}_{1i})] \\ + (1 - G_i)[\ln \phi \left(\frac{\epsilon_{0i}}{\sigma_{\epsilon 0}} \right) - ln\sigma_{\epsilon 0} + \ln(1 - \Phi(\boldsymbol{\phi}_{0i}))] \end{aligned} \tag{7}$$

Where $\boldsymbol{\phi}_{ji} = \frac{\beta X_i + \gamma_j \epsilon_{ji} / \sigma_j}{\sqrt{1 - \gamma_j^2}}$, j = 0, 1 with γ_j denoting the correlation coefficient between the error term of criterion function, i.e., u_i and the errors of outcome functions, i.e., ϵ_{ji}. The entire system of the equations is jointly estimated by full information likelihood method.

Table 1
Variables and summary statistics.
Source: Field survey, 2016.

Variable	Non-adopters		Adopters		Mean difference
	Mean	SD	Mean	SD	
Age of respondent	45.28	13.65	42.18	14.16	3.10***
Years of formal education	9.07	4.80	9.23	4.68	−0.17
Years of UIVs production experience	10.79	7.24	12.79	9.61	−2.00***
UIVs Land area	0.11	0.18	0.22	0.49	−0.12
Access to climate information (1/0)	0.48	0.51	0.73	0.45	−0.25
Agro ecological zone	0.69	0.47	0.85	0.36	−0.16
Net revenue	9,420,215	14,100,000	16,700,000	27,020,000	−72,76,625***
Off farm income	5,47,848.30	5,80,313.8	10,43,479	21,09,412	−4,95,630.40***
Average monthly temperature	31.44	2.33	31.66	2.36	−0.22
Average monthly precipitation	114.95	91.98	116.54	82.39	−1.59***
Farm distance from market	5.60	4.02	6.12	4.57	−0.52***
Farm distance from home	1.70	1.58	2.21	3.41	−0.53***

3. Results and discussion

3.1. Variable description

The study used both quantitative and qualitative primary data. The quantitative data were collected using structured questionnaire from 191 UIVs producers in four of the six states in Southwest Nigeria. Also, quantitative data from 8 FGDs (2 FGDs per state) were collected. The data collected include UIVs' household socioeconomic characteristics, their perception to climate change and the various adaptation strategies adopted over the years, information on various vegetables planted, the reasons why they plant the vegetables and the responses of the vegetables to the perceived negative effects of climate variability in the study area. The study incorporated monthly temperature and precipitation from 2000–2014 into the analysis. The description of the variables used in the analysis is presented in Table 1. The result shows that the non-adopters are significantly older than the adopters. There is no significant difference between their years of formal education, UIVs vegetable land area, access to climate change information, agro-ecological zone, and average monthly temperature of adopters and non-adopters in the study area. Meanwhile, the adopters had significantly higher mean values of the years of UIVs production experience, net revenue from UIVs, off-farm income, average monthly precipitation, farm distances from market and home than the non-adopters.

3.2. Annual rainfall trend in Southwest Nigeria between year 2000 and 2014

The trend analysis of rainfall from Meteorological data between 2000 and 2014 in the area under study is presented in Fig. 2. The trend shows that there is no particular trend in average annual rainfall, as the rainfall pattern has been erratic. In year 2000, the average annual rainfall is high and falls in 2001. In 2002, the rainfall increases, falls in 2003, remains a little steady in 2004, and falls in 2005. The highest average rainfall within the period under study is in 2008 and since then, the average annual rainfall keeps rising and falling, although the quantitative trend shows increasing trend in average annual rainfall amount in the study area. The result of regression analysis between rainfall and time shows that an increase in one-year period results in a corresponding increase in the amount of average annual rainfall by 1.22 mm (Fig. 2). rainfall shows a view contrary to the information contained in the meteorological recorded data. The majority of UIVs producers perceived reduction in rainfall. This lack of congruence could be as a result of the farmers assessing rainfall in relation to the needs of UIVs at a particular time; small change in quantity, onset and cessation of rain over days make a big difference in the hearts of farmers, whereas the Meteorological data is more likely to measure total and large effects (Lemmi, 2013).

3.3. Annual temperature trend in Southwest between 2000 and 2014

The trend analysis of the meteorological data of temperature between 2000 and 2014 shows an increasing trend. The regression between average annual temperature and time shows that an increase in one-year period results in an increase in the average temperature of the area by 0.003 °C (Fig. 3). This result is also in line with Chepkoech et al. (2018), who also found increasing trend in the temperature of study area.

3.4. Underutilised indigenous vegetables and their tolerance to climate change variables

Table 2 summarises the distribution of the UIVs cultivated by the respondents in order of their economic importance (that is profit accrued to farmers) their insect resistance (ability of vegetable to either naturally or through genetic engineering resist insect damage) and drought tolerance (ability of a plant to maintain its biomass production during arid or drought conditions) across the four States that the study covered. The summary reveals that about 13 indigenous vegetables were identified and more than 50% are found across the entire southwest region, only few UIVs are State specific. For instance, it is only in Osun State that red amaranth is produced in commercial quantity. Also, it is only in Oyo State (northern part) that *Solanum zuccagnianum* (locally called osun) is cultivated in commercial quantity. Aside Ondo State where ugu is the most economically important UIV, amaranth species remain the most economically viable UIV in the region. It is also noteworthy that respondents in Oyo State ranked two different UIVs as first economic important vegetables. While the UIVs producers in the northern part of the State ranked *Solanum zuccagnianum* as number one economically important UIV, those in the southern part ranked amaranth species as the number one in term of economic importance.

Further, field pumpkin, fluted pumpkin and waterleaf were identified as most insect and drought resistant. While Jute mallow and amaranth species were the least resistant to insect and drought.

3.5. Adopter and non-adopter of climate change strategy and their perceptions of climate change

Perception is the way something is regarded, understood or interpreted. It is one of the first important steps in the process of designing some form of change in farmers' livelihood system to adapt to the changing climate. In order to get essential information and insight into farmers' perception of climate change, two most important elements of climate: rainfall and temperature were considered in this study as presented in Table 3. About 15% of the sample respondents did not adopt any climate adaptation strategy while the remaining 89% adopted one form of adaptation strategy or the other (Fig. 3). It was interesting to know that both the adopter and non-adopter of climate change adaptation strategy believed that there is change in both the

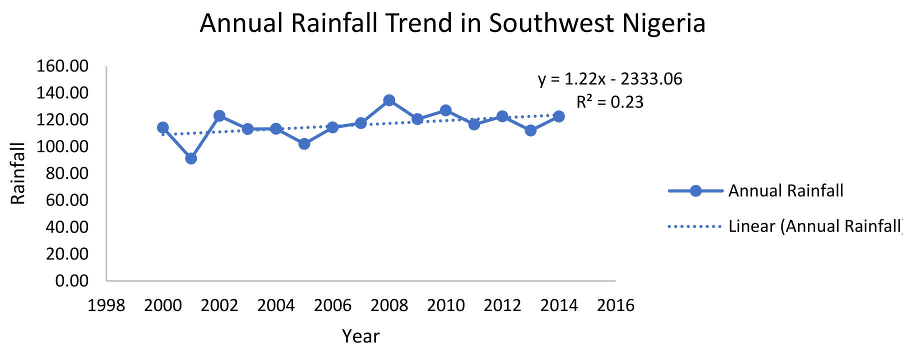

Fig. 2. Annual Rainfall Trend in Southwest Nigeria.

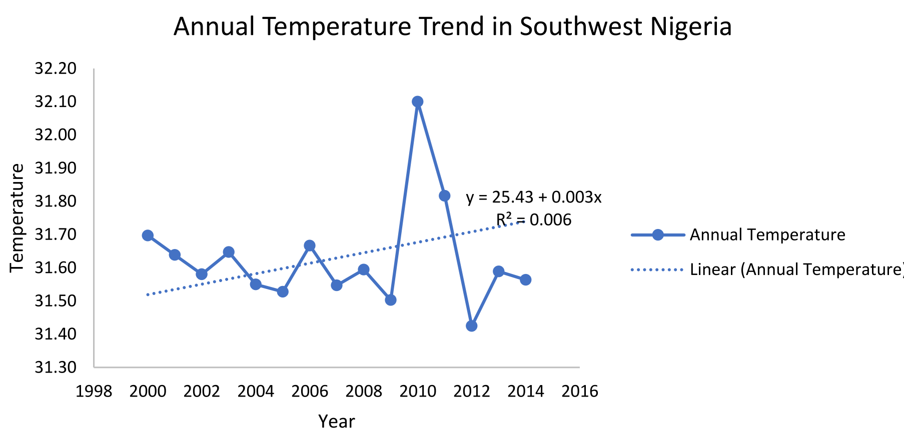

Fig. 3. Annual Temperature Trend in Southwest Nigeria.

rainfall and temperature pattern over the years. Majority (74.67%) of the adopters were of the opinion that the rainfall is decreasing in quantity, about 21% noticed erratic rainfall and 4.32% opined that rainfall is increasing. Most (51.72%) of the non-adopters were of the opinion that rainfall is increasing. About 20.69% noticed decrease in rainfall. On the perception of UIVs farmers on temperature, majority (96.91%) adopters and non-adopters (72.41%) perceived increase in temperature. Generally, most UIVs farmers perceived decrease in rainfall and increase in temperature. This result is in tandem with Ayanlade et al. (2017) who also found that high percentage (67%) of farmers perceived change in climate change in Southwest Nigeria.

3.6. Perceived effects of climate change on UIVs production activities by adopters and non-adopters of climate change adaptation strategies

Table 4 presents the perceived effects of climate change on UIVs production activities in the study area. The result reveals that climate change has negative effects on the vegetable, although the effects of climate change on vegetables differ from one vegetable to another. The first negative effect identified by the UIVs producers was drought. The unprecedented hike in temperature and irregular patterns of precipitation have resulted in increased events of droughts (Arora, 2019). The responses of the respondent confirmed this finding, about 92% of the adopters were of the opinion that the drought has increased significantly over the years as a result of reduction and/or erratic pattern of rainfall. Although, most (37.93%) non-adopters were of the opinion that there has not been change in the severity of draught in the study area. The excerpts of the farmers during the FGDs further establish the negative effects of drought on the production activities of UIVs:

The erratic rainfall has brought problem to we farmers because most of what we plant did not germinate on time and some even got burnt in the soil as a result of prolong drought

[*FGD with Farmers in Ilesha, Osun State.*]

About 76% of the respondents indicated that the effect of insect infestation has increased greatly in recent times, compared to the past. The excerpts from the FGDs affirm this:

There is reduction in our output due to climate change; there are some insects destroying our farm produce. To the extent that we have to take some of the species of the insect to laboratory for them to help us find solution to it because the insecticide we do use before are no longer effective

[*FGD with farmers in Ilesha, Osun State.*]

… also what we have experienced this year has never been experienced before. That we plant all vegetables and insect and pest spoilt everything for some vegetables. Pest also spoilt all the maize. When it is about to fruit, they spoilt it

[*FGD with farmers in Ile-Ife, Osun State.*]

There is no positive impact. Our expectation has been dashed because there is irregularity in rainfall. Our profits are low because insects infested our farm and destroyed it

[*FGD with farmers in Iwaroka, Ekiti State.*]

Also, the response of most (69%) adopters to the effect of climate change on soil fertility was negative. Consequently, both the output and

Table 2
Distribution of UIVs production in the study area.
Source: Field survey, 2016.

Local name	English name	Scientific name	Economic importance	Insect resistance	Drought tolerance
Osun state					
Tete Abalaye	White amaranth	Amaranth viridis	1	9	9
Red Tete/Tete Ijesa	Red amaranth	Amaranth cruentus	2	10	10
Ewedu	Jute mallow	Corchorus olitorius	3	11	11
Ugu	Fluted pumpkin	Telfairia occidentalis	4	4	2
Igbagba/Gboma	African eggplant	Solanum macrocarpon	5	5	3
Worowo	Bologi	Solanecio biafrae	6	3	5
Soko	Quail grass	Celosia argentea	7	6	7
Waterleaf	Waterleaf	Talinum fruticosum	8	2	4
Ebolo	Fire weed	Crassocephalum crepidoides	9	8	8
Elegede	Field pumpkin	Cucurbita moschata	10	1	1
Ogunmo	Garden huckleberry	Solanum scabrum	11	7	6
Oyo state					
Osun	–	Solanum zuccagnianum	1	7	4
Tete Abalaye	White amaranth	Amaranth viridis	1	8	8
Ogunmo	Garden huckleberry	Solanum scabrum	2	5	5
Ewedu	Jute mallow	Corchorus olitorius	3	9	9
Igbagba/Gboma	African eggplant	Solanum macrocarpon	4	2	2
Soko	Quail grass	Celosia argentea	5	6	3
Ugu	Fluted pumpkin	Telfairia occidentalis	6	1	1
Odu	Black nightshade	Solanum nigrum	7	4	6
Ebolo	Fire weed	Crassocephalum crepidoides	8	3	7
Ondo state					
Ugu	Fluted pumpkin	Telfairia occidentalis	1	2	4
Igbagba/Gboma	African eggplant	Solanum macrocarpon	2	3	5
Tete Abalaye	White amaranth	Amaranth viridis	3	8	8
Soko	Quail grass	Celosia argentea	4	4	3
Elegede	Field pumpkin	Cucurbita moschata	5	1	1
Ogunmo	Garden huckleberry	Solanum scabrum	6	5	6
Worowo	Bologi	Solanecio biafrae	7	7	2
Odu	Glossy nightshade	Solanum nigrum	8	6	7
Ekiti state					
Abalaye	White amaranth	Amaranth viridis	1	8	8
Igbagba/Gboma	African eggplant	Solanum macrocarpon	2	4	2
Ugu	Fluted pumpkin	Telfairia occidentalis	3	3	1
Ewedu	Jute mallow	Corchorus olitorius	4	9	9
Waterleaf	Waterleaf	Talinum fruticosum	5	1	3
Odu	Glossy nightshade	Solanum nigrum	6	6	7
Soko	Quail grass	Celosia argentea	7	5	5
Worowo	Bologi	Solanecio biafrae	8	2	4
Ogunmo	Garden huckleberry	Solanum scabrum	9	7	6

Table 3
Adopters and non-adopters' perception of rainfall and temperature.
Source: Field survey, 2016.

Farmers' perception	Rainfall			Temperature		
	Adopter	Non-adopter	Pooled	Adopter	Non-adopter	Pooled
No change	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
Yes, increasing	7(4.32)	15(51.72)	22(11.52)	157(96.91)	21(72.41)	178(93.19)
Yes, decreasing	121(74.69)	6(20.69)	127(66.49)	3(1.85)	6(20.69)	9(4.71)
Erratic	34(20.99)	4(13.79)	38(19.90)	0(0.00)	0(0.00)	0(0.00)
Indifference	0(0.00)	4(13.79)	4(2.09)	2(1.23)	2(6.90)	4(2.09)

income from the UIVs production has been on the decline while most of the non-adopters were of the opinion that both the UIVs output and income are increasing. About 69% adopters experienced reduction in output and income accrued to them. Excerpts from the FGDs conducted buttress these facts thus:

> *Since there is irregularity in rainfall, we do not really get the normal output, so it has reduced our income*
>
> [*FGD with farmers in Igboho, Oyo State.*]

The reduction in yields of crops worsen as a result of proliferation of weeds and pests resulted from climate change (IFPRI, 2009; Pareek et al., 2017). The result from the analysis carried out and the responses from the FGDs buttressed this finding, about 78% of the adopters indicated increase in the infestation of insects in the recent times. The excerpts from the FGDs also confirmed this thus:

> *Although, there is good market for vegetables now, but the insect infestation has reduced our output which resulted in low income, and this had brought financial difficulties on farmers*
>
> [*FGD with farmers in Ilesha, Osun State.*]

> *... it caused low production and output because there is shortage of water to the plant. Due to lack of rain and intense heat, if we plant 1000 seeds, 300 might survive and the survived plants will have low output. It also causes discouragement to the farmers. The climate change affected the environments, farmers, the Local Government and the people generally, because it is what we harvest that we take to the market to sell. Every market is affected*
>
> [*FGD with farmers in Iwaroka, Ekiti State.*]

Table 4
Perceived effects of climate change on UIVs production activities.
Source: Field survey, 2016.

UIVs farmers' perceived effects of climate change	Adopters		Non-adopters		Pooled	
	Freq	%	Freq	%	Freq	%
Change in drought						
No change	0	0.00	11	37.93	11	5.76
Yes, increasing	149	91.98	2	6.90	151	79.06
Yes, decreasing	7	4.32	6	20.69	13	6.81
Indifference	2	1.23	4	13.79	6	3.14
No response	4	2.47	6	20.69	10	5.24
Change in insects infestation						
No change	0	0.00	10	34.48	10	5.24
Yes, increasing	127	78.40	2	6.90	129	67.54
Yes, decreasing	13	8.02	5	17.24	18	9.42
Indifference	3	1.85	10	34.48	13	6.81
No response	19	11.73	2	6.90	21	10.99
Change in soil fertility						
No change	0	0.00	0	0.00	0	0.00
Yes, increasing	10	6.17	18	62.07	28	14.66
Yes, decreasing	111	68.52	2	6.90	113	59.16
Indifference	31	19.14	9	31.03	40	20.94
No response	10	6.17	0	0.00	10	5.24
Change in UIVs output						
No change	0	0.00	0	0.00	0	0.00
Yes, increasing	36	22.22	13	44.83	49	25.65
Yes, decreasing	112	69.14	2	6.90	114	59.69
Indifference	4	2.47	9	31.03	13	6.81
No response	10	6.17	5	17.24	15	7.85
Change in annual earnings						
No change	0	0.00	0	0.00	0	0.00
Yes, increasing	36	22.22	15	51.72	51	26.70
Yes, decreasing	111	68.52	3	10.34	114	59.69
Indifference	5	3.09	10	34.48	15	7.85
No response	10	6.17	1	3.45	11	5.76
Changes in the land area allotted to UIVs						
No change	0	0.00	0	0.00	0	0.00
Yes, increasing	100	61.73	17	58.62	117	61.26
Yes, decreasing	50	30.86	2	6.90	52	27.23
Indifference	1	0.62	8	27.59	9	4.71
No response	11	6.79	2	6.90	13	6.81

These signs we have seen, God should prevent famine and food scarcity because this one that there is no regular rainfall, we cannot get farm product and the one we are planting are not growing well, because there is no enough water to help it to germinate and the soil temperature was too high for the crops. So, God should just have mercy on us

[*FGD with farmers in Ogbomosho, Oyo State*]

3.7. UIVs farmers' perception of climate change across study area of south-west Nigeria

Fig. 4 (a–f) present the graphical representation of UIVs farmers' perception of climate change for rainfall, temperature, drought, insect infestations, soil fertility and land allotted to UIVs across the four states of study. The study results (Fig. 2a) indicate that large number of farmers from Ekiti (45%), Osun (81%) and Oyo (71%) perceived decrease in rainfall while larger percentage (50%) of farmers in Ondo State perceived increase in rainfall compare to 27% that indicate decrease in rainfall. The location of Ondo State in the rain forest agro ecological zone of Nigeria might be responsible for this result. The perception of the majority of farmers for temperature indicate increase in temperature across the four States. In fact, 100% farmers in Osun and Oyo States indicate increase in temperature. Also, across the study area, the perception of UIVs farmers of the effects of climate change on drought, insect infestations and land allotted to UIVs, indicate increase while their perception to soil fertility show decrease across the four states. No doubt, all these resultant effects of climate change will have negative consequences on agricultural production. Studies carried out by Pareek et al. (2017) established outbreak of insect infestations as a result of climate change and Bifulco and Ranieri (2017) confirmed prolonged drought as the aftermath of climate change. It is worthy of note that larger percentage (36%) of UIVs farmers in Ondo State indicate that soil fertility is increasing as against the 32% who believed that soil fertility is decreasing. This result could be as a result of differences in agro ecological zones in which the States are located. This result is similar to Seo et al. (2009), who also found that effect of climate change is different across agro ecological zones in Africa. They submitted that savannah regions are more vulnerable to climate change than the rain forest. Also, Egbetokun et al. (2014) found that response of crop yield to climate change varies from one state to the other.

3.8. Adaptation strategies adopted by the UIVs farmers

A number of adaptation strategies were adopted by the UIVs farmers in order to weather the negative effects of climate change (Fadairo et al., 2019). The adaptation strategies adopted by the UIVs farmers are presented with pie chart in Fig. 5. From the figure, only about 15% of the farmers do not adopt any strategy. This result is similar to Fadina and Barjolle (2018), who also identified only 14.2% of the sample respondent as non-adopter of climate change adaptation strategy but at variance with Fadairo et al. (2019) who found that all vegetable farmers adopted one form of adaptation strategy or the other. The contrasting views might probably have resulted from the differences in the sample location. For instance, Fadairo et al. (2019) sampled derived savannah area in Nigeria, where water is needed for vegetables

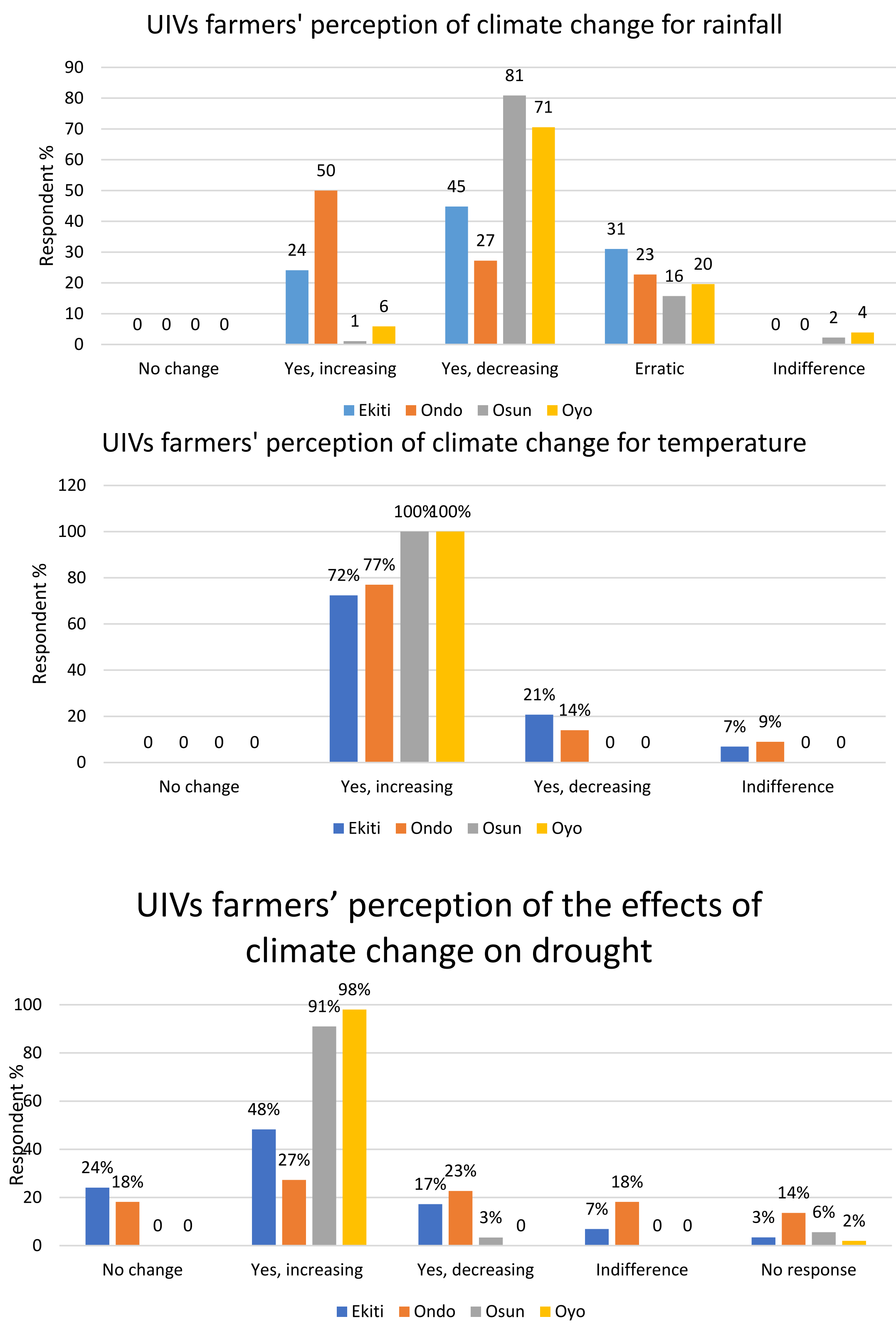

Fig. 4. (a–f) UIVs Farmers' perceptions of climate change in study area of Southwest, Nigeria.

production during the off season, meanwhile, this study sampled both derived savannah and rainforest areas and as such some farmers may not see any reason to adopt adaptation strategy. Further, from the discussion with the farmers, it was gathered that the most important adaptation strategies adopted by UIVs farmers over the years was to cultivate UIVs along the river bank during the dry season and use upland during the wet season to reduce the incident of diseases and flood from excessive high rainfall. About 98% adopted this strategy. The information gathered further revealed that about 63% of UIVs producers diversified from agriculture to non-agricultural related businesses

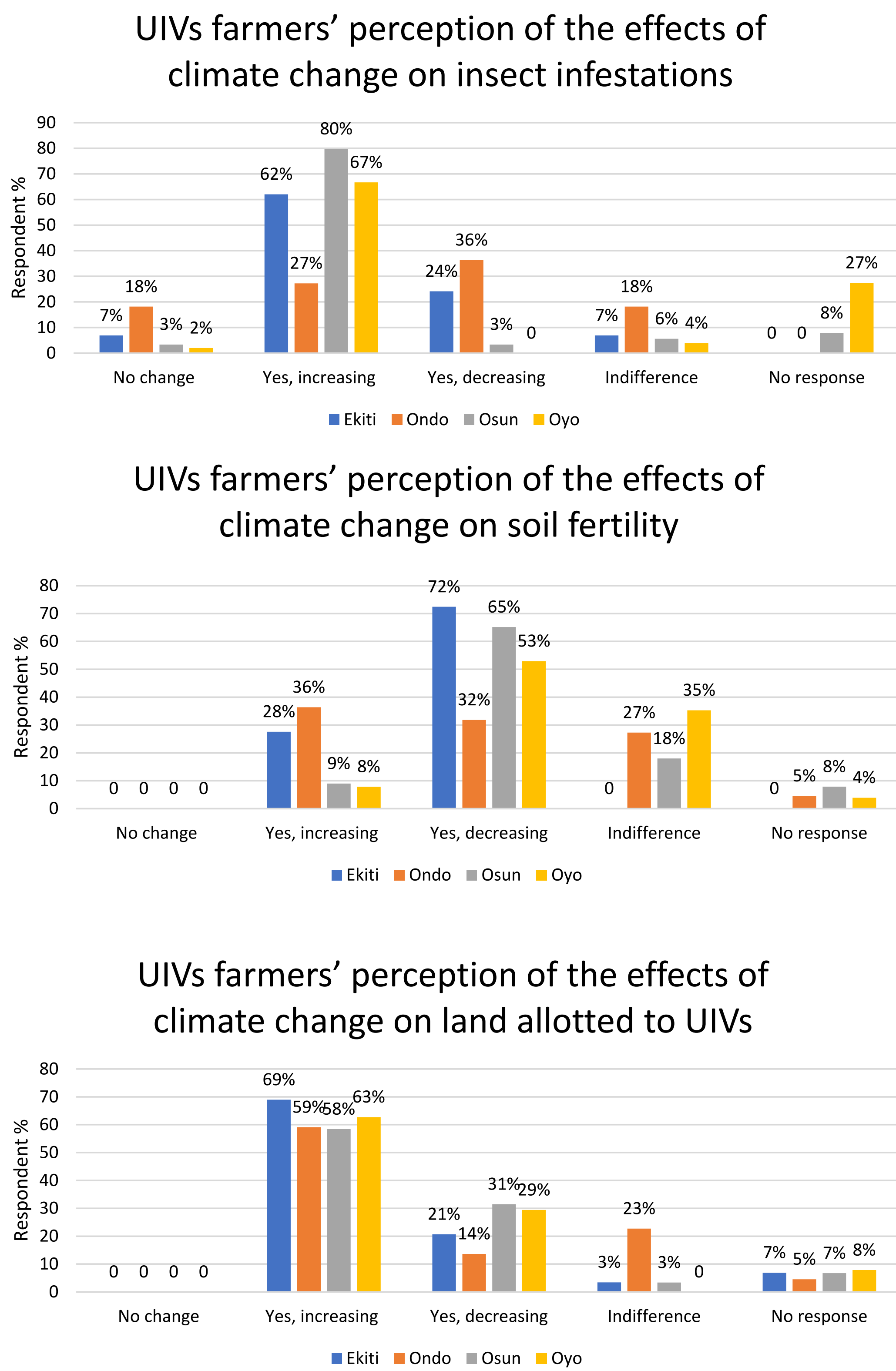

Fig. 4. (*continued*).

as a result of their unpalatable experiences in farming. Some of the excerpts from the FGDs show that many farmers were discouraged as a result of their experiences. The third popular adaptation strategy option was crop diversification. About 27% of the respondents indicated crop diversification as adaptation strategy they have adopted. An excerpt from the FGD in Ile-Ife, Osun State showed this:

> *... that was why I changed to okra plantation. When I tried it and it performed better, I decided to change to okra cultivation*
>
> [*FGD with farmers in Ile-Ife, Osun State*]

Also, 23.56% changed time of planting, about 23% also adopted agricultural good practices such as mulching, crop rotation and mixed cropping. About 21% adopted irrigation, but the excerpts from the FGD

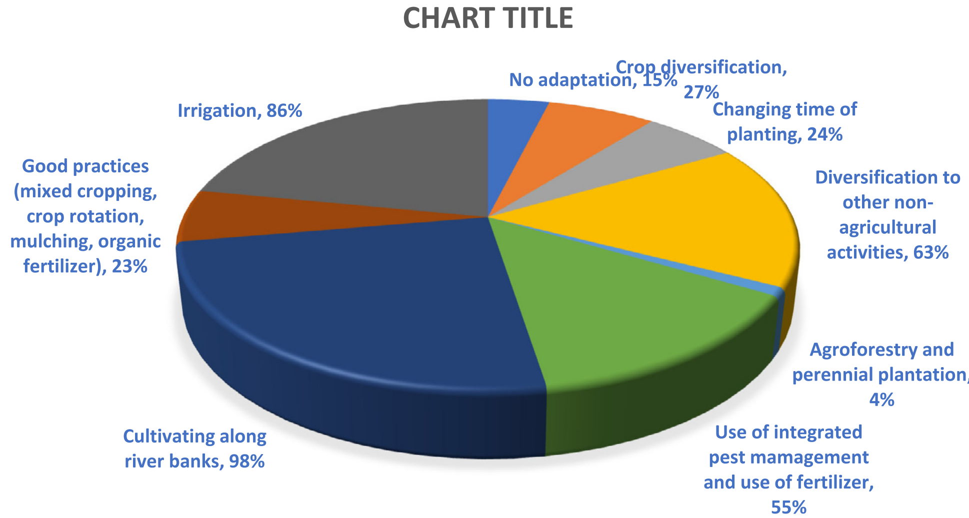

Fig. 5. Adaptation strategies adopted by the UIVs Farmers (multiple responses).

showed that where rain failed, some adopted irrigation system and it led to outbreak of insect infestations which pesticide could not handle. The excerpt from the FGD in Osun State reveals this thus:

> *The first step we took when the rain did not fall was to use irrigation. Different pests and insect infestations showed up. We used different insecticides to kill the insects, but chemical compositions were no longer effective like before.*
>
> [*FGD with farmers in Ilesha, Osun State*]

It was noteworthy that the least (3.66%) adaptation strategy adopted by the UIVs farmers was agroforestry and perennial plantation.

3.9. Adaptation measures adopted by farmers across study area in South-west, Nigeria

Fig. 6 presents the adaptation measures adopted by UIVs farmers across the four states that the study covered. About 18%, 18%, 13% and 16% of the sample respondents from Ekiti, Ondo, Osun and Oyo States, respectively did not adopt any climate adaptation strategy. Adaptation measures adopted by UIVs farmers varied across the four States. In Ekiti State, major adaptation strategy adopted by UIVs farmers include cultivating along river banks (96%), the use of irrigation (89%) and the use of integrated pest management and fertiliser (61%). In Ondo State, the main adaptation measure adopted by UIVs farmers include cultivating along the river bank (92%), the use of irrigation facilities (82%) and diversification to other non-agricultural activities (64%). In Osun State, the primary adaptation strategies adopted include cultivating along river banks (98%), the use of irrigation facilities (85%) and diversification to non-agricultural activities (64%). In Oyo State, the mostly adopted adaptation strategies are cultivating along river banks (94%), the use of irrigation facilities (90%) and diversification to non-agricultural activities (74%). The reason for cultivating along the river bank may be due to dependence of farmers on ground water and easy access to water from river for irrigation in the case of prolonged drought. This result is similar to Abid et al. (2015) who also found that the adopted adaptation measure was premised on the fact that farmers depend on ground water for their production activities. Also, it is noteworthy that diversification to other non-agricultural related businesses is a big threat to the food production, food security and economy, of Nigeria. About 74%, 64%, 63% and 46% UIVs producers from Oyo, Ondo, Osun and Ekiti States, respectively indicate diversification, to non-agricultural related businesses is the strategy adopted to mitigate the negative effect of climate change. Steps must be taken in the right direction to reverse this.

3.10. Adaptation strategy adopted across study area based on UIVs net revenue

Climate change is expected to have significant impact on the revenue of farmers, hence, suitable adaptation strategies are adopted to mitigate the impact (Abid et al., 2015). Fig. 7 presents graphically the adaptation strategies adopted by UIVs farmers and the net revenue across the study area. The results show that in Ekiti State, the largest percentage (43%) of UIVs farmers realised net revenue more than ₦ 1,000,000 ($3,300) annually. It is worthy of note that UIVs farmers that adopted Agroforestry and Agricultural good practices did not experience loss in UIVs production. The highest percentage (59%) of UIVs farmers that realised more than ₦ 1,000,000 net revenue are from Ondo State and the adaptation strategy adopted is cultivating along river banks. No farmer in Ondo State that adopted agricultural good practices made loss in UIVs production. In Osun State, the largest percentages (53 and 52%) of UIVs farmers cultivated along the river banks and used irrigation, respectively. The result from Oyo State is similar to Osun State, about 65% (each) UIVs farmers that cultivated along the river banks and used irrigation, realised more than ₦ 1,000,000 during the production year.

3.11. Results of endogenous switching regression model

A binary probit model was used in the first stage to model the adoption behaviour, and in the second stage, separate regression models were used to model UIVs net revenue function conditional on a specified criterion function. The results are shown in Table 5. The likelihood of adopting climate adaptation strategies was determined by years of experience in UIVs production, access to climate information and the agro ecological zone. An additional increase in the years of experience of UIVs farmers increased the likelihood of adopting adaptation strategy by 3%. Also, the likelihood of adaptation strategy adoption increased by 79% whenever their access to information on climate change is enhanced or increased. The result also revealed that whether or not a UIVs farmer will adopt adaptation strategy is premised on the agro ecological zone he is located. This is logical, because both rain and sunshine distribution vary across the agro ecological zones.

To establish the difference between the determinants of net revenue from UIVs production in the study area for the adopters and non-adapters of adaptation strategy, the endogenous switching regression model using full information maximum likelihood estimation technique was estimated. The parameters for adopters and non-adapters had positive sign and were significant in the equations. The implication of this is that both adopters and non-adopters significantly increased

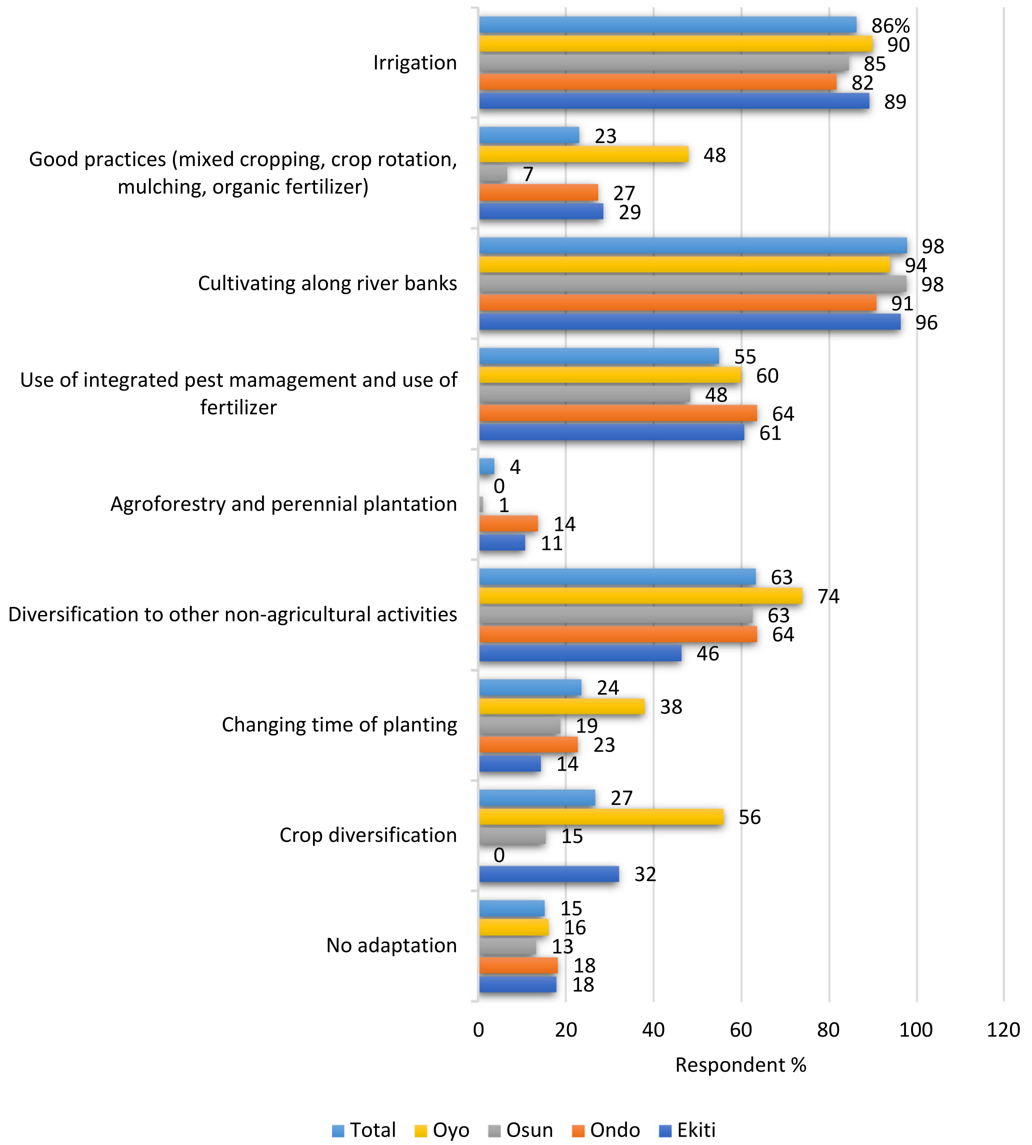

Fig. 6. Adaptation measures adopted by farmers across four States in Southwest, Nigeria (multiple responses).

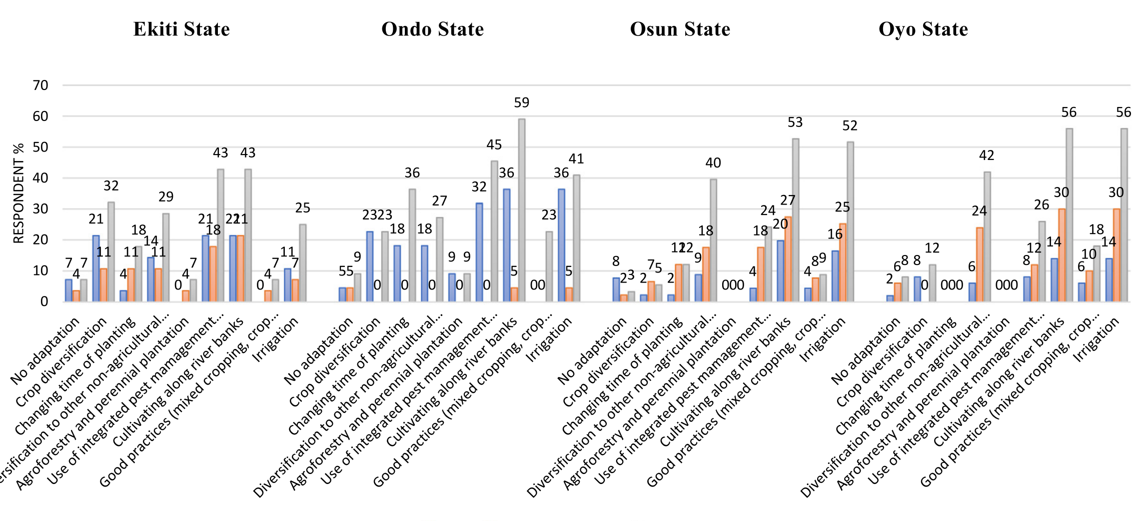

Fig. 7. Adaptation strategy adopted across study area based on UIVs net revenue.

Table 5
Full information maximum likelihood estimate of the endogenous switching regression model.

Dependent variables	(1) Adoption (1/0)	(2) Adopters Ln Net revenue	(3) pNon-adopters Ln Net revenue
Age of respondent	−0.0263 (0.0172)	−0.0021 (0.0051)	0.1261 (0.0764)*
Years of formal education	−0.0123 (0.0452)	−0.0086 (0.0135)	0.0687 (0.1980)
Years of UIVs production experience	0.0335 (0.0209)*	0.0019 (0.0072)	−0.0775 (0.1503)
UIVs Land area	0.7349 (1.6079)	0.0253 (0.1203)	−4.8662 (8.2882)
Access to climate information (1/0)	0.7895 (0.4465)*	0.2428 (0.1329)*	−2.0523 (2.0250)
Agro ecological zone	0.7880 (0.4862)*	0.1846 (0.1726)	4.2682 (2.3488)*
Off farm income (Ln)	0.2749 (0.1765)	0.6526 (0.0497)***	−1.1765 (0.5264)**
Average monthly temperature	−0.6454 (0.3573)	0.3469 (0.6405)	0.1984 (0.0971)
Average monthly precipitation	0.0082 (0.0090)	0.0045 (0.0025)*	0.0307 (0.153)
Average monthly temperature sq	0.0116 (0.0014)	−0.0052 (0.0102)	0.0017 (0.0056)
Average monthly precipitation sq	−0.00004 (0.00003)	−0.00002 (0.00001)*	0.0001 (0.0004)***
Location Ekiti state	−0.3339 (0.7536)	0.0245 (0.1836)	1.6228 (2.9697)
Location Ondo state	−0.3322 (0.6503)	0.4470 (0.2185)**	2.1668 (2.8218)
Location Oyo state	0.1849 (0.5718)	0.0356 (0.1444)	−1.2275 (2.2566)
Farm distance from home	−0.0170 0.0409		
Farm distance from market	0.0228 0.0975		
Σ		−1.3384 (0.5068)***	−10.7082 (16.5395)
P		0.2611 (0.1251)**	2.3567 (0.3132)***
Likelihood ratio (LR) test of independent equations: chi2(2) = −89.99 Prob > chi2 = 1.0000			

***, **, * Significant at 1%, 5% and 10%, respectively.

revenue from UIVs cultivation, that is with or without adaptation strategy adoption, the production UIVs was significantly profitable. So, UIVs farmers can cultivate UIVs without incurring extra cost of adopting adaptation strategies in the study area.

Further, socioeconomic and farm related factors that were significant determinants of UIVs revenue were age, agro ecological zone and off-farm income for non-adopters, access to information on climate and off-farm income for adopters. An increase in the age of UIVs non-adopter farmers will increase the net revenue form UIVs production significantly. Also, agro ecological zone that non-adopters belong was a significant variable that contributed positively to the production of UIVs in the study area. This result corroborates Seo et al. (2009) who opined that while humid savannah agro ecological zones are more vulnerable to climate change, humid forest zones become more productive in the future. While increase in off-farm income increased the UIVs net revenue for adopters, reverse was the case for non-adopters. This suggests that the off farm income that is generated by the adopters are probably invested into the UIVs business while non-adopters channelled the income to other businesses. Increase in access to information on climate change increased the revenue from UIVs significantly. This implies that those farmers that have access to information on climate change are more likely to adopt climate adaptation strategies thereby increase their revenue.

More so, average temperature and rainfall with their respective squares were included because both are expected to have non-linear effect on the net revenue from UIVs. The climate change variables that were significant determinants of UIVs net revenue for adopters include monthly average precipitation and its square. A unit's increase in average rainfall increased the adopters' net revenue from UIVs but after some point, net revenue tends to decrease for adopters when the rainfall increases as shown by the negative sign of rainfall square. In contrast, one-unit increase in rainfall square increases the net revenue of non-adopters. This suggests that most of the UIVs farmers that were non-adopters are from the savannah agro ecological zone where rainfall is lower, this is deduced from the mean difference in rainfall that is presented in Table 1. The mean rainfall in the adopters' location was significantly higher in quantity than that in non-adopters' location. Also, Table 1 shows that there is no difference in the mean monthly temperature of adopters' and non-adopters' location and hence, there is no significant effect of temperature on the revenue generation from UIVs. The implication of this result is that effect of temperature is not significant on the selected UIVs and this buttressed the fact that UIVs are tolerant to high temperature. Also, moderate rain is adequate for the production of the selected UIVs because increased rainfall, especially in the agro ecological zone with high rainfall reduced revenue significantly but increased revenue in the agro ecological zone with low rainfall. This result is partly similar to Asmare et al. (2019), where the study found that increased rainfall reduced farm income significantly. Lastly, Ondo location contributed significantly to the revenue from UIVs. This is in agreement with the result in Fig. 5, which shows that the largest percentage of farmers who earn more than ₦ 1,000,000 from UIVs production are from Ondo State.

4. Conclusion and recommendations

This paper presented a micro-level study on the adaptation strategies adopted by the farmers to cope with the adverse effects of climate change. The novelty of the study is that it combined both quantitative and qualitative data to examine the impact of climate adaptation strategies on the net farm revenue of UIVs production in southwest Nigeria. Specifically, the study profiled the UIVs that are cultivated, survey the perception of UIVs farmers to climate change and its effects on their production activities and also looked at various adaptation strategies adopted by farmers and factors determining the adoption of the strategies. The study also established the factors that determine UIVs net revenue of adopters and non-adopters in the study area. To this end, data set from plot level survey of 191 UIVs farm was used which include, UIVs production activities, adaptation strategies information and meteorological data. The study found that of 13 UIVs cultivated in the study area, only about 50% is found across the area. Further, the perception of UIVs farmers across the states differ because of the different agro ecological zone in which the states are located, hence, the adaptation strategy adopted by UIVs farmers differ across the states. The study also found that prolonged drought, increased insect infestations and reduction in soil fertility are the aftermath effects of climate change in the study area. Also, it was found that only farmers who adopted Agroforestry and perennial plantation and Good agricultural practices did not have negative net revenue but these are the strategies that are least patronised by the UIVs farmers. Also the determinants of whether a farmer will adopt climate change adaptation strategies were years of experience in UIVs production, access to climate information and agro ecological zone. Further, factors that determine the UIVs net revenue for adopters were access to information on climate change, off-farm income, precipitation, precipitation square and Ondo location. Age, agro ecological zone, off-farm income and precipitation square determined the UIVs revenue for non-adopters.

The study therefore, concluded that the selected Underutilised Indigenous Vegetables were not vulnerable to increased temperature but increased rainfall reduced revenue generation from them. Also, UIVs' farmers may need not adopt any adaptation strategy for some selected UIVs depending on the agro ecological zone they belong to since agro ecological zone determined the likelihood of adopting climate change adaptation strategy. Also, access to regular and up-to-date information on climate change by farmers enhanced their net revenue from UIVs business and the likelihood of adopting climate change strategies. From the conclusion, the following recommendations were made

- In the era of climate change where many crops are failing, future policies measure that will promote the production, marketing and consumption of underutilised crops should be put in place.
- Agricultural research institutes should develop improved varieties of UIVs that are more tolerance to increased rainfall.
- Nongovernmental and government extension agents should make information on climate change available and accessible to farmers.
- Farmers should be trained on the right adaptation strategy to adopt considering the type of crop they cultivate and the peculiarity of their agro ecological zone.
- Vegetables' Farmers should be encouraged to adopt Agroforestry & perennial plantation and agricultural good practices to increase income.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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