Precision farming and climate change adaptation strategies used among cowpea farmers

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Abstract: Climate change will continue to threaten cowpea supply security due to spontaneous global warming. Efforts towards achieving effective climate change adaptation have been hindered by factors that are yet to be investigated. This paper ascertains the factors affecting effective climate change adaptation among cowpea farmers in Ido local government area of Oyo State, Nigeria for cowpea supply security. Following a survey of 108 randomly selected cowpea farmers, descriptive statistical tools were used for data analysis while multiple regression analysis was used to identify factors influencing effective climate change adaptation among cowpea farmers. Adaptation measures adopted by respondents ranged from local (low sophisticated) to high regional (moderate sophisticated) technology. The use of precision farming technology such as variable-rate technology and green seeker were discouraged among farmers. Hence, there is a need to eliminate factors hindering utilisation of modern adaptation measures for better coping mechanism and sustainable cowpea production.

Keywords: precision-farming; climate-change; cowpea-farmers; Oyo State; adaptation-strategy.

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1 Introduction

Climate change is a serious threat to global food security due to changes in water supply and demand by altering the spatial and temporal distribution of rainfall, the availability of water (Nyadzia et al., 2018), and other agricultural production factors (Alcamo et al., 2007; Hanjra and Qureshi, 2010; Muller and Shackleton, 2013; Kang et al., 2017; Baya et al., 2019). Sustainable use of water resources for food production is essential for ensuring rapid social and economic development. Climate crises affect the global agricultural sector, its functions, and the capacity to provide many benefits and services to people, such as the ability of ecosystems to regulate water flows and nutrients cycling (FAO and UNDP, 2020). Climate change is likely to intensify the current challenges of water scarcity in dry-land areas and aggravate competition for water within and between communities. The major consequences of climate change were expressed in terms of increasing water scarcity, drought, torrential flooding, and land degradation (Arimi, 2014; Kang et al., 2017; Fathi and Ezziyyani, 2019; Amede and Whitbread, 2020).

Agricultural production in Nigeria is highly sensitive to climate variability and weather extreme such as droughts, floods and storms (Arimi, 2014; Odozi, 2015). About 90% of Nigeria's population depends on agriculture as a means of livelihood (Murtala and Abaje, 2018). Most of the population lives in rural areas and they depend on cowpea production for sustenance.

Cowpea (*Vigna unguiculata)* is one of the means of livelihoods. It provides income and nutrition for millions of people (Murtala and Abaje, 2018; Ekpoh, 2010; Apata, 2011; Ntombela, 2012). It is the cheapest source of protein, minerals, and vitamins in daily diets. It is common in children and women's diets. Currently, Nigeria is the largest producer and consumer of cowpea in the world. The nation cultivates about 5 million hectares of land and produces over 2 million metric tonnes annually (Murtala and Abaje, 2018). Despite the economic importance of cowpea, the production of cowpea in Nigeria has been greatly affected by climate change. Climate change refers to any variation in climate over time due to natural variability or as a result of human activities (Murtala and Abaje, 2018).

Climate change occurs at a local, regional, and global scale (IPCC, 2014). The main climatic elements, temperature, sunlight, wind, and rainfall are warming of the climate system that is unequivocal evident from observations of increases in global average air and ocean temperatures. Widespread melting of snow and ice and rising sea level consequently lead to increased rainfall, and increased rainfall would lead to frequent floods resulting in variability in crop yields in different ecological systems (Anderson, 2015).

Climatic changes events such as higher temperature, reduced water availability, farmers compete for water during the dry season in Nigeria, thereby limiting their capacity to cultivate a large hectare of land. Dry spell leads to the wilting of seedling and stunted growth of crops planted (Murtala and Abaje, 2018). On the other hand, high rainfall leads to floods that washed away crops planted and disrupted the flowering of the

plants in the field and consequently reduced the cowpea crop yields, net farm revenues, and threaten sustainable cowpea supply in Nigeria (Murtala, and Abaje, 2018). Hence, adaptations to the negative impacts of climate change become imperative.

Adaptation to climate change is a policy response that seeks to reduce the vulnerability of social and biological systems (Arimi, 2014). Thus, the capacity and potential for humans to adapt (called adaptive capacity) to climate change is unevenly distributed across different regions and populations (Adam et al., 2018; Henderson et al, 2017). Adaptation, therefore, means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage it may cause. It also means the act of taking advantage of opportunities that may arise thereafter. Climate change adaptation through the adoption of precision farming system is a better option (Say et al., 2017).

Precision farming is defined as the adoption of the right management practices at the appropriate location and at the right time (Mulla and Miao, 2016). Precision farming is also known as precision agriculture or site-specific crop management. Precision farming started in the mid-1980s to enhance agricultural productivity by improving soil fertility which is a key factor in farming (Divya et al., 2018) and grid soil sampling for delineation of management zones (MZs) (Mulla, 1993). Moreover, precision farming system is focused on observing, measuring and responding to inter and intra-field variability in crops production (Say et al., 2017; Miller et al., 2017; Dang et al., 2019).

Precision farming uses developments in engineering and on-farm technology to open up new dimensions of efficiency and environmental management (Akdemir, 2016; Divya et al., 2018). These technologies include nanotechnology, the use of satellites and drones, and the assessment of tillage systems. Precision technology helps to minimise the depth of tilling the soil to prevent erosion. It ensures good drainage system that reduces the risk of waterlogging and soil salinisation, GPS tools to support more accurate farming systems. Adoption of precision farming technology help farmers to determine long term cropping plans such as erosion controls by taking proactive measure on avoidance of flood-prone area through information or weather forecasting technology available, besides, it helps farmers to target fertiliser where it is most needed rather than applying it uniformly across the whole field, plants receive larger accurately placed doses, but with a lower field-scale application rate overall (Lobell et al., 2009; Say et al., 2017). This in turn reduces costs, boosts yield, and lessens the impact on the environment by reducing the spread of liquid and solid based applications, and thus nitrous oxide emissions into the atmosphere (Bamire, 2017). Development of information technology is crucial in achieving success in precision agriculture.

1.1 Purpose of the study

Agricultural production in Africa, especially in Nigeria encounters immense challenges due to climate variability and its changes caused by anthropogenic greenhouse gas emissions (Murtala and Abaje, 2018). The global temperatures are rising with a change in the water cycle resulting in more erratic precipitation patterns (Taylor et al., 2020). Consequently, both soil and surface water availability is becoming unreliable (IPCC, 2014; Asante and Franklin, 2015; Bello et al., 2013). How to secure sustainable food supply in a continuous environmental changes and limited resources is the most important challenge that has to be overcome (FAO, 2018). Climate is a vital factor in

agricultural production, its changes which result in a dry spell and water shortage has seriously affected Nigeria farming activities.

Despite the importance of cowpea, its production is beset with constraints such as drought, flooding, salt-stress and extreme temperatures, all of which are expected to worsen with ever-changing climate (Bello et al., 2013; IPCC, 2014). Cowpea yield is mainly determined by ecological factors including climate, soil, pests, and diseases. Thus, any changes in these factors of production could lead to changes in harvested yield. To prevent yield loss in Agricultural production, precision farming has been adopted in crops like vegetables, rice, and maize. For instance, in rice production, precision farming has been adopted in Indian and China (Xia et al., 2016; Mulla, 2013). The rates of using or adopting these technologies in precision agriculture vary widely (Whipker and Akridge, 2006). According to Divya et al. (2018) Autosteer (GPS) and yield monitors are widely used while variable rate spreaders are moderately popular. Remote sensing has not been widely adopted for use in precision agriculture, especially in cowpea production (Mulla, 2013) for a reason that has not been scientifically investigated.

Due to the vulnerability of cowpea production to climate change, farmers had adopted some adaptation measures to reduce the negative impact of climate change, including precision farming systems for resilience. Given the aforementioned, this research is conducted to investigate factors influencing effective climate change among the farmers in Ido local government area of Oyo State.

2 Methodology

This study was conducted in Ido local government areas of Oyo State, Nigeria. Its administrative headquarters was located at Ido town. Ido local government area is located between latitude 6° 45° and 9° 45° north of the equator and longitude 2° and 9° east of Greenwich meridian. The local government area is one of the hot-spots for environmental change especially climate change in Nigeria. How to secure sustainable food supply in continuous environmental changes is the most important challenge in the area.

Primary data were used for the study. Data were collected through the survey method. A list of registered farmers in the local government was obtained from the local government headquarters. A simple random technique was employed to elicit information from 38 registered cowpea farmers (20%) out of 190 registered and 70 (20%) out of 350 unregistered cowpea farmers. A total number of 108 farmers were sampled. Information was collected on the effects of climate change on cowpea production, adaptation measures used and the effectiveness of adaptation measures used.

Climate change is already affecting (cowpea) agricultural production in Nigeria (Murtala and Abaje, 2018; Arimi, 2014). Based on this assertion farmers were asked the following questions.

- Do you think that climate change will result in yields reduction or impact your farm yields? If the response is yes, rate the effect of climate change on the reduction of crop yields on your farm. Considering the following options: great effects (big reduction), little effects (small reduction) or no effects (no reduction).
- Do you think that high rainfall due to climate change will increase pest invasion on your farm? If the answer is yes, rank the effects of climate change on pest invasion on your farm? Given the following option great effects, little effects, or no effects.

- Do you think that high rainfall due to climate change will increase disease infestation on your crop? If the answer is yes, rank the effects of high rainfall on disease infestation on your crop farm. Given the following options: great effects, little effects, or no effects.
- Do you think that climate change negative incidence will make you diversify into other livelihood activities? If the answer is yes, rank the effects of climate change on your likelihood of diversification to other livelihoods. Given the following options: great effects, little effects, or no effects.
- Do you think that climate change will increase your cost of production or affect your cost of production? If the answer is yes, rank the effects of climate change on your cost of production. Given the following options: great effects, little effects, or no effects.
- Do you think that climate change will increase land degradation on your farm or affect your farm? If the answer is yes, rank the effects of climate change on land degradation on your farm. Given the following options: great effects, little effects, or no effects.
- Do you think that climate change will result in water deficit or affect your farm? If the answer is Yes, Rank the effects of climate change on water deficit on your farm. Given the following options: Great effects, Little effects, or No effect
- Do you think that increase in temperature due to climate change will increase plant stress or affect your crop? If the answer is yes, rank the effects of climate change on plant stress. Given the following options: great effects, little effects, or no effects.
- Do you think that high rainfall due to climate change will increase flooding on your farm or affect your farm? If the answer is yes, rank the effects of climate change on the flooding of your farm. Given the following options: great effects, little effects, or no effects.

The technology used by the respondents was grouped into three namely; 'local', 'moderately sophisticated' and 'highly sophisticated' (precision technology) based on the availability in the local environment and ease of use or technicality involved. The respondents were asked to indicate the adaptation technology used among the following options; minimum tillage, organic manure, the shift of planting date, planting of cover crop, construction of drainages and mulching and the use of early warning information system.

Effects of climate change on the cowpea were measured by asking the respondents to describe the future effects of climate change on cowpea production in a 3-points scale of 'great effect', 'little effect', and 'no effect'. A score of (0) was assigned to 'no effect'; a score of (1) to 'little effect' and a score of (2) to 'great effect'. Effects index was determined and the mean score was generated to group the responses into the 'low perception of climatic change effects in the future' (those below mean score) while respondents above mean were categorised as having a 'high perception level of climatic change effects'. Climatic change adaptation strategies used were generated and the respondents were asked to rank the effectiveness of adaptation measures used as 'highly effective' (2), 'moderately effective' (1), and 'not effective' (0). The mean score was generated to group the responses into a 'low level of effective adaptation' (those below

mean score) while respondents above mean were categorised as having a 'high level of effective adaptation'.

The instrument for data collection was subjected to a reliability test, a reliability coefficient of 0.75 was obtained. Finally, data were collected and analysed through the regression method. The regression analysis was used to determine factors influencing effective adaptation measures.

The regression model equation is $Y = a + bX + c$.

The dependent variable is Y. While X is the independent variable that is being used to predict Y. a is the Y-intercept of the line, and c is a value called the regression residual. Y is the effective climate change adaptation which was measured as effective = 1, not effective = 0.

The independent variables were measured as follows:

- age: young = 1, otherwise = 0
- gender: male = 1, female = 0
- marital status: married 1, otherwise = 0
- education attainment: years of schooling was considered
- household size: large household size = 1, small household size = 0
- farm size: actual farm size
- monthly income: actual income
- intensity of vulnerability: highly vulnerable = 1, less vulnerable = 0
- types of adaption strategies used: sophisticated = 1, local = 0
- awareness of precision technology: aware = 1, not aware = 0
- variable rate technology: adopted = 1, otherwise = 0
- weed seeker: adopted = 1, otherwise = 0
- insect control technology: adopted = 1, otherwise = 0
- diseases control technology (fluorescence): adopted = 1, otherwise = 0
- crop scouting: adopted = 1, otherwise = 0
- green seeker: adopted = 1, otherwise = 0.

3 Results and discussion

The majority of the respondents experienced and predicted a great decrease in cowpea yield, land degradation, water deficit, and flood in years ahead while less than half predicted an increase in pest invasion and an increase in disease infestation due to climate change (Table 1). As most of the farmers experienced and predicted more negative impacts of climate change on their farms in future which may likely reduce their agricultural productivity, they are also preparing to adapt to the situation. Some respondents experienced increased cost of production and predicted worse situations for

farming business in the future. Due to the challenges of uncertainty in climate change, a large number of the respondents predicted massive diversification into other activities; this may reduce cowpea production, and thereby affect food security in the study area.

Table 1 Farmers' perception of the effects of climate change on cowpea production in the future

Climate change effects	*Great effect*		*Little effect*		*No effect*	
	Frequency	*Percentage*	*Frequency*	*Percentage*	*Frequency*	*Percentage*
A decrease in crop yield	68	63.0	34	31.5	6	5.6
Increase pest due to high rainfall	41	38.0	55	50.9	12	11.1
Disease due to high rainfall	46	42.6	42	38.9	20	18.5
Diversion of livelihood	51	47.2	37	34.3	20	8.5
Increase the cost of production	40	37.0	57	52.8	11	10.2
Increase in land degradation	33	30.6	43	39.8	32	29.6
Water deficit	35	32.4	30	27.8	43	39.8
Water stress due to Increase in temperature	*44*	*40.7*	*34*	*31.5*	*30*	*27.8*
Flood due to high rainfall	50	46.3	29	26.9	29	26.9

Note: N = 108

3.1 Perception levels of the effects of climate change on cowpea production

Most of the respondents (87.1%) experienced and perceived high negative effects of climate change on cowpea production (Table 2). Like most of the respondents experienced a high effect of climate change on cowpea production it is expected that the farmers would seek adaptation strategies to overcome the adverse effect of climate change on their farms.

Table 2 Perception levels of respondents based on the effects of climate change on cowpea production

Levels of effects of climate change	*Frequency*	*Percentage*	*Mean*
Low	14	13.0	
High	94	87.1	*10.9*
Total	108	100	

Table 3 shows that all the respondents (100.0%) used local adaptation technology such as shifting of planting dates (63.0%), planting of cover crops and mulching (75.0%). The reason for this was that most of the materials used for local adaptation were easily accessible and affordable by cowpea farmers, and even among resource-poor farmers.

Interestingly, a large number of the farmers also used moderately sophisticated technology such as water pumping machines (73.1%) and listening to early warning information (87.0%) through various media. However, the use of precision farming technology which has been considered more efficient in reducing climate change impact (Mulla and Miao, 2016) on the farm was not common among these respondents. The reason for this was a lack of awareness and huge capital investment required by most (89.7%) of the farmers in the study area. This had serious implications for sustainable cowpea production under interrupted negative environmental changes.

Table 3 Adaptation strategies used by cowpea farmers in Ido local government of Oyo State

Adaptation strategies used	*Adopted (%)*	*Never used (%)*
Local adaptation technology	100.0	-
Minimum tillage	81.5	18.5
Organic manure	69.4	30.6
Shift of planting date	63.0	37.0
Planting of cover crop	75.0	25.0
Construction of drainages	75.0	25.0
Mulching	60.2	39.8
Moderate sophisticated technology such as,		
Water pumping machine	73.1	26.9
The construction of the dam	83.3	16.7
Early warning information system	87.0	13.0
Awareness of Precision farming technology	Aware	Not aware
	10.3	89.7
Use of precision farming technology	Adopted	Never used
Variable-rate technology (Landsat TM)	1.4	98.6
Crop scouting/weed seeker	2.2	97.8
Green seeker	0.8	99.2

Note: N = 108

Source: Field survey (2019)

3.2 Effective climate change adaptation by the respondents

Effective climate change adaptation is defined as the capacity of adaptation measures used to ensure climate resilience or minimise vulnerability. Table 4 shows the effectiveness of climate change adaptation strategies used by cowpea farmers in the study area. Out of all the respondents that were using local or moderate climate change adaptation technology in table 1.0 only reasonable number (45.3%) of the respondents agreed that planting a cover crop, minimum tillage (47.2%), planting of trees as hedges (45.3%), planting of resistance to disease crop (50.0%), adoption of late or early planting (61.1%), use of pumping machine (49%), device to water storage facilities (51.8%), construction of the local dam (56.6%) were effective in coping with climate change as negative impact continued to increase.

Fifty-one percentage (51%) of the respondents also agreed that minimum tillage, crop rotation (39%), diversification into other crops or livestock (39%), construct water harvester for water storage (56%), increase use of pesticides (59%), increase use of herbicides were highly effective in coping with climate change.

The results showed that some of the farmers were at present moderately contented with the adaptation measures adopted. The findings were in line with Altieri et al. (2015) who observed that cover crops, mulching are important components of sustainable agro-ecological systems of food production which reduces the impact of climate change. Ifejika (2010) also observed that smallholders make use of fertiliser, and improved seed to reduce the impact of climate change. However, as the effects of climate change are intensified in the future current adaptation measures used by farmers are needed to be upgraded to cope with future projected negative impact of climate change that is likely to occur. As some of the respondents were not sure if the current adaptation measure (54.6%) will be effective in mitigating future climate change. This finding is supported by Zemadim et al. (2020) who predicted climate-induced risk problems already faced to be exacerbated in the communities of dryland areas in the future.

Table 4 Distribution of respondents on the effectiveness of climate change adaptation strategies used

Climate change adaptation strategies used	*Levels of effectiveness*					
	Highly effective		*Effective*		*Not effective*	
	Freq	*%*	*Freq*	*%*	*Freq*	*%*
Planting of cover crops	28	25.9	49	45.3	31	28.7
Minimum tillage	51	47.2	41	38.0	16	14.8
Mulching to preserve soil moisture	18	16.7	38	35.2	52	48.1
Crop rotation	39	36.1	36	33.3	33	30.6
Increase use of fertiliser	32	29.6	47	43.5	29	26.9
Planting of trees as hedges	49	45.3	38	35.2	21	19.4
Planting of resistance to diseases crop	54	50	42	38.9	12	11.1
Adoption of late or early planting	66	61.1	30	27.8	12	11.1
Diversification into other crops or livestock	39	36.1	43	39.8	26	24.1
Use of pumping machine for irrigation	53	49	28	25.9	27	25.0
Device water storage facilities or water harvester	56	51.8	23	21.3	28	25.9
Construction of local dam	61	56.5	28	25.9	19	17.6
Increase use of pesticide	59	53.7	40	37.0	9	8.3
Increase use of herbicide	57	52.8	37	34.3	14	13.0
Use of precision farming technology	-	-	28	25.9	79	73.1

Perception of respondents on the future effectiveness of climate change adaptation measures used		
	Freq	*%*
Will be effective	47	43.5
May not be effective	59	54.6
Total	108	100.0

Source: Field survey (2019)

The regression analysis of factors determining effective climate change adaptation strategies used among cowpea farmers.

The R square obtained was 0.86. Independent variables such as age, gender, marital status, education attainment, household size, farm size, monthly income, intensity of vulnerability, and types of adaption strategies used by farmers contributed 88% (Table 5) capacity of farmers to effective climate change adaptation (dependent variable).

Table 5 Regression analysis on the relationship between the dependent variable (effective climate change adaptation among cowpea farmers) and the independent variables as shown below

Variables	*Unstandardised coefficients*		*Standardised coefficients*	*T*	*Sig.*
	B	*Std. error*	*Beta*		
(Constant)	2.72	1.81		1.50	0.14
Age	0.00	0.01	0.00	0.07	0.95
Gender	1.09	0.65	0.07	1.68	0.10
Marital status	0.02	0.37	0.00	0.04	0.97
Educational attainment	–0.59	0.28	–0.10	–2.13	0.04
Household size	–0.27	0.12	–0.11	–2.38	0.02
Farm size	–0.080	0.05	–0.08	–1.50	0.14
Monthly income	6.706E–005	0.00	0.11	2.32	0.02
Intensity of vulnerability	0.01	0.08	0.01	0.16	0.88
Types of adaptation used	0.97	0.05	0.97	20.16	0.00
Awareness	–0.03	0.09	–0.02	–0.38	0.71
Adoption of precision farming					
Variable rate technology	–0.79	0.84	–0.05	–0.93	0.35
Weed seeker	1.23	0.56	0.13	2.19	0.03
Insect control aphid index	–0.66	0.54	–0.07	–1.22	0.23
Disease control/fluorescence	3.90	0.78	0.28	5.01	0.00
Crop scouting/cloud edge	0.83	0.74	0.06	1.12	0.27
Green seeker	1.04	0.70	0.07	1.48	0.14
R = 0.9					
R-square = 0.88					
Adjusted R-square = 0.86					

Notes: *beta (β) is the standard coefficient in the regression equation.
*t-value indicates the directionality of the effect of relationship.

Table 5 shows that the income of the farmers, type of adaptation measure used (local or improved) such as the use of weed seeker and disease control technology contributed positively to effective climate change adaptation. While the low level of education, large household size and small farm size discouraged the use of effective climate change adaptation technology.

The monthly income ($\beta = 0.11$, $t = 2.32$) significantly influenced the use of effective climate change adaptation among cowpea farmers in the study area. This implied that the

more the income of the farmers, the more they would invest in climate change adaptation technology that is more effective to respond to climate changes. This finding was supported by Murtala and Abaje (2018) who observed that farmers' continuous cultivation of cowpea is determined by the amount of yield obtained and the income derived from their production. Moreover, Barnes et al. (2019), Dang et al. (2019) posited that age, income represents a level of affluence for farm households; and also contributed to farmers' willingness to utilise adaptive measures.

3.2.1 Educational attainment of the respondents

There is a significant contribution of farmers' level of education ($\beta = -0.10$; $t = -2.13$) to effective climate change adaptation. This implies that formally-educated farmers commonly source for information that would improve their capacities or skills to cope with climate change issues. This finding is in agreement with Deressa et al. (2011) who posited that educational attainment increases the probability of utilising adaptive measures such as soil conservation and changing planting dates of crops.

3.2.2 Household size

Household size plays an important role in effective climate change adaptation. This finding shows that there was a significant contribution of household size ($\beta = -0.11$; $t = -2.30$) to effective climate change adaptation by cowpea farmers. The finding is also corroborated by Deressa et al. (2009) who observed that the household population affects adaptive behaviour positively.

3.2.3 Types of adaptation strategies used

There is a significant relationship between types of adaptation strategies used by farmers ($\beta = 0.98$; $t = 20.16$) and effective climate change adaptation measures. This implies that the better or sophisticated the adaptation measures adopted by the farmers, the more they will adapt to climate change. This is in line with Adger et al. (2005) who have also argued that adaptation actions can be undertaken by individuals, groups, authorities at different levels, and governments. It can be at local, national, or international scales. One adaptation action might be efficient for this individual, but not for others; or considered successful at this scale, but not at other.

3.2.4 Gender

There is no significant relationship between gender and effective climate change adaptation by cowpea farmers ($\beta = 0.07$, $t = 1.68$). This implied that male and female farmers invested in climate change adaptation technology. Interestingly, this negated Arimi and Rasak (2016) who observed that even though women and men experience climate change, their ability to adapt to its negative impact was different.

3.2.5 Farm size

There is no significant relationship between farm size ($\beta = -0.08$; $t = -1.50$) and effective climate change adaptation by cowpea farmers. This means that both small and large scale farmers invested in climate change adaptation measures. This is in line with Reidsma

et al. (2010, 2015) who observed that farm-size level responses influenced adaptation measures used by farmers. Similarly, there was no significant correlation between marital status (β = 0.00; t = 0.04), intensity of crop vulnerability (β = 0.01; t = 0.16) and effective climate change by cowpea farmers.

3.2.6 Precision farming technology used

Results depicted that weed seeker (β = 0.13; t = 2.19) contributed significantly to effective climate change adaptation among cowpea farmers. Weeds can be identified in the field crop using remote sensing based on their spectral signatures, leaf shapes, and organisation of the weedy plant. Remote sensing with satellites or airplanes is adequate for detecting weeds that occur in large, dense clusters within a crop or in bare crop-free soil (Lopez-Granados, 2011). The same can be considered for disease control technology such as green seeker (NDVI) and fluorescence (β = 0.28; t = 5.00). On the other hand, awareness of precision farming technology (β = 0.02; t = 0.38), variable rate technology (β = –0.05; t = –0.93), crop scouting (β = 0.59; t = 1.12) and green seeker (β = 0.07; t = 1.48) did not significantly contribute to effective climate change adaptation among cowpea farmers in the study area. The reason for this could be because these technologies were unpopular among the potential users.

4 Conclusions, recommendations and major policy implications

As climate change continues to happen, it is plausible to assert the effectiveness of the current adaptation measure used, and prepare for mitigating future threats that may likely be posed by the negative impacts of climate change. Preparedness must go beyond local adaptation measures. Adaptation measures must involve a combination of strategies.

Cowpea production in the study area was vulnerable to climate change. This spurred the farmers to adopt some adaptation measures ranging from local, moderate to highly sophisticated technology. This paper ascertains the effectiveness of the adaptation measure used and factors contributing to the effective adaptation measures. However, the effectiveness of adaptation measures did not cover a much wide range of scenarios as climate change impacts a further increase in the future. Efforts must focus on understanding what to do at extreme climate change events and providing information about the effectiveness of these measures in a wide range of scenarios. At present, the adaptation measures used are moderately effective in mitigating adverse weather events, and adopted adaptation measures depend on farmers' levels of income, education, and household size. Low-income farmers found it difficult to invest in moderate or high sophisticated adaptation measures such as green seeker and variable rate technology due to lack of awareness. Farmers' ability to effectively adapt climate change hinged on the types of adaptation measures adopted. The use of precision farming technology was unpopular among the farmers due to low income and poor awareness of the technology. This has serious implication on effective climate change adaptation and cowpea production in the study area. There was a strong correlation between the use of precision farming and effective climate change adaptation. Therefore, enlightenment campaigns on the potentials of precision farming, investment in weed seeker, and crop scouting technology are essential for effective climate change adaptation and cowpea supply

security. Besides, the adoptions of these techniques require interventions because higher financial support is needed compared to the current local adaptation measures.

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