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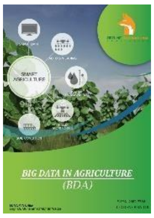

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RESEARCH ARTICLE

ADOPTION OF CLIMATE-SMART AGRICULTURAL PRACTICES: EMPIRICAL EVIDENCE AMONG VEGETABLE FARMERS IN BASSA, NIGERIA

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ABSTRACT

Adoption of climate-smart agricultural practices has several implications and benefits for sustainable agriculture. Therefore, this study analyzed the adoption of climate-smart agricultural practices among vegetable farmers in Bassa, Plateau State, Nigeria. Vegetable farmers were selected using multistage sampling techniques. Primary data collected was analyzed using descriptive statistics, weighted average index and adoption index techniques. The mean age, household size, education (in years), farming experience, farm size were 41 years, 7 people, 7 years, 16 years, and 2ha respectively. Most (88.9%) are male, 82.8% are married, 90.9% had no extension contact; 93.9% have no access to agricultural credit and 92.9% do not belong to any farmer groups or cooperatives. The perceived effects of climate change were indicated by the weighted average index of the following factors: Increased temperature (3.12), irregular rainfall pattern (2.70), incidence of drought (2.37), decline in crop productivity (2.19) and food shortage/insecurity (2.01). Agricultural practices adopted include irrigation facilities (87.8%), improved seed varieties (70.7%), planting date adjustments (63.6%), farm diversification (55.5%) and agro-chemical application (51.5%). Most (68.6%) have low adoption index of ≤0.4.The constraints affecting the adoption of climate-smart agricultural practices among respondents in the study area include inadequate climate information (89.8%), financial constraints (77.7%), cost of agricultural inputs (65.6%), poor access to extension services (58.5%), farm size/tenure status (51.5%). This study recommends: Improved dissemination and awareness of climate information, financial inclusion, extension contact, land policy modification, adequate input supply at subsidized rates and provision of technical support.

KEYWORDS

Adoption index, climate change, farm practices, smallholders, vegetable crops

1. INTRODUCTION

Climate change is a pressing issue that is affecting agriculture worldwide. In Nigeria, vegetable farmers are particularly vulnerable to the impacts of climate change due to their reliance on rain-fed agriculture (Datta, 2013). As a result, there is an urgent need for farmers to adopt climate-smart agricultural practices to mitigate the impact of climate change and ensure food security (Sayemuzzaman et al., 2014). Historically, farmers have always had to adapt to changing environmental conditions. However, the scale and pace of climate change today present unprecedented challenges for agricultural practices. As a result, there is a growing recognition of the need to adopt climate-smart agricultural practices that are sustainable, resilient, and environmentally friendly (IPCC, 2014). These practices aim to increase agricultural productivity, improve livelihoods, and reduce greenhouse gas emissions (Masahumi et al., 2011). The adoption of climate-smart agricultural practices among vegetable farmers is influenced by a variety of socioeconomic factors. One of the key factors is access to information and knowledge about climate-smart practices. Farmers who are aware of the benefits of adopting climate-smart practices are more likely to adopt them. Farmers who had access to extension services and training on climate-smart practices were more likely to adopt these practices compared to those who did not have access to such information (Adesina et al., 2018). Another important factor is the availability of resources and inputs required for implementing climate-smart practices. Climate-smart agriculture often requires farmers to invest in new technologies and inputs, such as drought-resistant seeds, organic fertilizers, and irrigation systems (Adeyemo et al., 2015). Farmers who lack access to these resources may be reluctant to adopt climate-smart practices. Additionally, financial constraints and lack of credit facilities can also hinder farmers from investing in climate-smart technologies (Awotoye and Mathew, 2010). Climate-smart agricultural practices often require upfront investment in new technologies, inputs, and infrastructure (Ayanlade et al., 2010). Farmers who do not have access to credit or financial support may be unable to afford these investments, leading to low adoption rates (Chijioke et al., 2011). Social factors, such as farmers' attitudes and beliefs, can also affect the adoption of climate-smart agricultural practices. Some farmers may be resistant to change and hesitant to adopt new practices, especially if they perceive them as risky or unfamiliar (Codjoe et al., 2011). Cultural norms and traditions can also play a role in shaping farmers' attitudes towards innovation and sustainability (Sarr, 2010). For example, in some societies, traditional farming methods are deeply rooted in cultural practices and beliefs, making it challenging to introduce new technologies or practices. Furthermore, gender dynamics can play a role in determining who makes decisions about farming practices within households. Women, who often play a significant role in vegetable production, may face barriers in adopting climate-smart practices due to limited decision-making power (Kotir, 2011). In addition, market conditions and price volatility can also influence farmers' decisions to adopt climate smart practices (Lee et al., 2012). Farmers who are unable to sell their produce at fair prices may be

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reluctant to invest in new technologies or practices that increase their production costs (Lobell, 2010).

The adoption of climate-smart agricultural practices has several implications for sustainable agriculture and can bring numerous benefits to vegetable farmers in Nigeria (Guodaar, 2015). These practices can improve crop yields, increase resilience to climate change, and reduce the environmental impact of agriculture. In addition, climate smart agriculture can help farmers adapt to changing weather patterns and mitigate the impact of extreme events such as droughts and floods via effective water conservation practices (Bita and Gerats, 2013). By using techniques such as crop rotation, and composting, farmers can improve soil health (Data, 2013). By implementing practices such as crop diversification, mulching, and water harvesting, farmers can improve the resilience of their farming systems to climate change (Garrett et al., 2013). This can help reduce the negative impacts of climate variability, such as droughts and floods, on crop yields and livelihoods. Furthermore, climate-smart agricultural practices can contribute to environmental sustainability by reducing greenhouse gas emissions and promoting the conservation of natural resources (Pinto et al., 2012). For example, the use of organic fertilizers and crop residues can improve soil fertility and reduce the need for chemical inputs, thereby reducing the carbon footprint of agriculture. Additionally, practices such as agroforestry and crop rotation can help restore degraded lands and protect biodiversity (Lee et al., 2012). By promoting the adoption of climate-smart practices, policymakers can help ensure the long-term sustainability of vegetable farming in Nigeria (Ayanlade et al., 2010). Furthermore, the adoption of climate-smart agricultural practices can enhance farmers' income and livelihoods (Kotir, 2011). By increasing productivity and diversifying their crops, farmers can improve their food security and economic stability (Masahumi et al., 2011). They can also access new markets and value chains, generating additional income and creating employment opportunities (Chijioke et al., 2011). Climate smart agriculture can empower farmers to become more self-reliant and resilient in the face of climate change and market fluctuations (Codjoe and Owusu, 2011). The adoption of climate-smart agricultural practices among vegetable farmers in Nigeria is essential for building resilience to climate change and promoting sustainable agriculture.

However, there are also challenges and obstacles to the adoption of climate-smart agricultural practices among vegetable farmers. Access to information, knowledge, and financial resources are critical barriers for many farmers, particularly smallholder farmers in developing countries (IPCC, 2014). Limited access to extension services, training programs, and credit facilities can hinder farmers' ability to adopt climate smart practices (Schlenker and Lobell, 2010). In addition, inadequate infrastructure, such as irrigation systems and storage facilities, can limit farmers' capacity to implement these practices effectively (Awotoye and Mathew, 2010). Furthermore, institutional barriers, such as government policies and regulations, can also impede the adoption of climate-smart agricultural practices (Lobell, 2010). In some cases, policymakers may not prioritize climate change adaptation or sustainable agriculture in their agricultural policies. Subsidies and incentives that promote conventional farming methods or input-intensive practices may discourage farmers from transitioning to climate smart agriculture (Kemausuor et al., 2011). Lack of coordination and collaboration among stakeholders, including government agencies, research institutions, and farmers' organizations, can also slow down the adoption process (Guodaar, 2015).Collaborative initiatives, such as farmer field schools, agricultural cooperatives, and value chain partnerships, can facilitate the adoption of climate smart practices and promote sustainable agriculture (Sayemuzzaman et al., 2014).In conclusion, the adoption of climate-smart agricultural practices among vegetable farmers is influenced by a complex interplay of socioeconomic factors. Access to information, knowledge, financial resources, and social support are crucial determinants that can either facilitate or hinder farmers' adoption of these practices (Garrett et al., 2013). While there are numerous benefits to adopting climate smart agriculture, including increased productivity, resilience, and income, there are also challenges and obstacles that need to be addressed. By addressing these barriers and seizing opportunities for innovation and collaboration, we can promote the widespread adoption of climate-smart agricultural practices and build a more sustainable and resilient food system for the future (Onuwa et al., 2018). Therefore, this study analyzed the adoption of climate-smart agricultural practices among vegetable farmers in Bassa, Plateau State, Nigeria, and specifically aims to:

- Describe the socioeconomic characteristics of the respondents;
- Evaluate the perceived effects of climate change;
- Identify climate-smart agricultural practices adopted;
- Measure the level of adoption of climate-smart agricultural practices; and
- Identify the constraints of adoption of climate-smart agricultural practices in the area.

2. Methodology

2.1 Study area

The study was carried out in Bassa Local Government Area (LGA) of Plateau state, Nigeria. The LGA consists of 9 districts: Kakkek, Buji, Jere, Mafara, Kishika, Amo, Buhit, Miango and Kwall. The LGA has coordinates between latitude $10^0.05^0$N and longitude$8^0.440$E. The LGA has a temperature range between 18^0C-27^oC, with an annual rainfall between1215 mm to 1,500 mm per annum. It covers an area of 1,743km^2 (Onuwa et al., 2018). The inhabitants engage majorly in farming activities and petty trading. The major vegetable crops cultivated include cabbage, lettuce, tomatoes, large pepper, peace, green pepper and pepper; others include rice, maize, hungry rice (Acha), guinea corn and soya beans. The major livestock reared include cattle sheep, goat and poultry (Onuwa et al., 2018).

2.2 Sampling procedure

A multistage sampling technique was employed in selecting the respondent farmers used for the study. In the first stage, two (2) districts, i.e. Miango and Kwall districts were purposively selected, due to the predominance of vegetable farmers in those districts in the study area. In the second stage, three (3) villages were randomly selected from each of the two districts, for the Miango district we have; jebbu- miango, Chovo and Huke and for the Kwall district we have; Ta-agba, Kimakpa and Kpasho. The last stage involved the systematic random selection of farming households within the selected villages using a list of vegetable farmers in the study area, compiled by the staff of Fadama III programme. By applying 20% constant proportionality rule a sample size of 99 respondents was selected from a sample frame of 495 vegetable farmers.

2.3 Method of data collection

Primary data was collected using structured questionnaires designed in line with the objectives of the study.

2.4 Analytical techniques

Descriptive statistics (frequency distribution, percentages and mean) was used to analyze objectives i, iii and v. Weighted Average Index (WAI) was used to analyze objective ii, while the Adoption index was used to measure the level of adoption climate-smart agricultural practices (objective iv).

2.5 Weighted average index

Weighted average index (WAI) analysis is an index ranking method that was used to evaluate the perceived effects of climate change among vegetable farmers in the study area. To determine the weight of each scale, each item was calculated by multiplying the frequency of each response pattern by its appropriate nominal value and dividing the sum by the number of respondents to the items. Responses for the components are rated by using a three-point scale with the scoring order. Given that; 1= Indifferent (I), 2 = Agree (A) and 3 = Strongly Agree (SA). A weighted average index (WAI) analysis was then estimated (Onuwa et al., 2022) and is presented in equations 1 and 2:

$$\sum f_i w_i \div N \quad (1)$$

$$WI \div \quad (2)$$

Where:

$\sum$=Summation; F_i = frequency of 'i' occurrence; W_i = weight of each scale; WI = weighted index; and

N = number of respondents

The benefits were therefore ranked using their average weight. This was estimated in equation (3);

$$\text{Average weight (WA)} = \Sigma s / r \quad (3)$$

Where:

s= scoring order; r = scale rating (3-point scale); and $\sum$=Summation.

$\sum s = 1+2+3=6$

$=6\div 3=2$; thus, weighted average index ≥2 will be considered to be critical.

2.6 Adoption index

The adoption index of climate-smart agricultural practices per vegetable farmer was estimated and presented in equation (1) as adapted from Onuwa and Adedire (2023):

$$B_i = \sum (R_i/R_T) \quad (4)$$

Where:

B_i = Adoption index of climate-smart agricultural practices by i_{th} farmer; R_i = climate-smart agricultural practices adopted by i_{th} vegetable farmer; and R_T = climate-smart agricultural practices available to i_{th} vegetable farmer; and i = (1…………n).

Decision rule: ≤0.4 represents a low adoption index of climate-smart agricultural practices, while ≥0.5 represents a high index of adoption of climate-smart agricultural practices. The common climate-smart agricultural practices in the study area include: (i) Irrigation farming; (ii) use of improved seed varieties; (iii) planting date adjustments; (iv) farm diversification; (v) agro-chemical application; (vi) improved agronomic practices; and (vii) adoption of agro-forestry practices.

3. Result And Discussions

3.1 Socioeconomic variables of the respondents

3.1.1 Age of respondents

Table 1 reveals the distribution of the age differentials of the farmers in the study area. The mean age was 41 years and 48% of the vegetable farmers are between the age brackets of 20 – 39 years, followed by those between the age brackets of 40 – 59 (29.3%). This implies that most of the respondents are within the economically active age bracket and thus, have a relatively greater potential in adopting new agricultural practices. The majority of respondents fall within the age bracket of between 19-40 years, signifying an economically active farming population which has far-reaching effects on their adoption of adaptation practices (Adesina et al., 2018).

Table 1: Distribution of respondents based on their age

Age (years)	Frequency	%
≤19	7	7.1
20 – 39	48	48.5
40 – 59	29	29.3
60 and above	15	15.1
Mean	41	

Source: (Field Survey, 2018)

3.1.2 Gender of the respondents

Table 2 reveals that 88.9% of respondents were males while 11.1% were females. This implies that a greater proportion of the respondents were males, this gives an indication to the fact that heads of farming households in the study area are male dominated. This factor influences the extent of vegetable farmer's access to productive resources such as farmland, capital, etc.

Table 2: Distribution of respondents based on their gender

Gender	Frequency	%
Male	88	88.9
Female	11	11.1

Source: Field Survey (2018)

3.1.3 Marital status of the respondents

The Table 3 reveals that most (82.8%) of the respondents were married, while (17.2%) were single. This implies that most of the respondents had families who eventually assist them in carrying out their various farming activities. Married respondents have readily available labour supply for agricultural production activities (Adeyemo et al., 2015).

Table 3: Distribution of Farmers based on their Marital Status

Marital status	Frequency	%
Married	82	82.8%
Single	17	17.2%

Source: (Field Survey, 2018)

3.1.4 Household Size of the Respondents

Table 4 presents a mean household size of 7 people per household. The result shows that 39.4% of the respondents had household size ranging between 4–6 people, followed by household size ranging between 7-10 people (26.2%). This implies that households in the study area have a relatively large population. Farmers rely heavily on their household size for labour supply to carry out most of their farming activities e.g. mulching, irrigation, agro-chemical application, etc. (Adeyemo et al., 2015).

Table 4: Distribution of Respondents based on their Household Size

Household size	Frequency	%
0 – 3	20	20.2%
4 – 6	39	39.4%
7 – 10	26	26.3%
11 and above	1 4	14.1%
Mean	7	

Source: (Field Survey, 2018)

3.1.5 Educational Level of the Respondents

Table 5 reveals that the mean educational level attained by the respondents is 7years, i.e. primary and post primary education. It is evident that 37.4% of respondents had attained secondary education school, followed by primary education (32.3%). This implies that most of the respondents had basic level of literacy. The level of farmer's education influences their capacity to readily adopt climate-smart agricultural practices in the study area (Pinto et al., 2012).

Table 5: Distribution of Respondents based on their Educational Level

Educational level (years)	Frequency	%
Primary School (1 – 5)	32	32.3
Secondary School (6 – 12)	37	37.4
Tertiary Institution (13 – 16)	10	10.1
Informal Education	20	20.2
Mean	7	

Source: (Field Survey, 2018)

3.1.6 Farming Experience of the Respondents

Table 6 reveals that the mean farming experience of the respondents was 16 years; while 33.33% of the respondents had farming experience ranging between 6-10years, this was followed by those with farming experience of between 11-15 years (23.2%). This implies that most of the respondents had adequate farming experience which influenced their capacity to readily adopt practices in responding to the impact of climate change (Adesina et al., 2018).

Table 6: Distribution of Respondent based on their Farming Experience

Farming experience	Frequency	%
1 – 4 years	14	14.1%
6 – 10 years	33	33.3%
11 – 15 years	23	23.2%
16 – 20 years	14	14.1%
Above 20	15	15.2%
Total	99	100
Mean	16	

Source: (Field Survey, 2018)

3.1.7 Farm Size of the Respondents

Table 7 reveals that the respondents have a mean farm size of 2ha. Most (57.6%) of the respondents has an average farm holding of between 2-4 ha, this was followed by those with farm holding of ≤ 1ha (39.4%). This implies that highest percentages of the respondents are subsistent farmers and hence their adaptive capacities may be influenced by the size of their farm holdings (Adesina et al., 2018).

Table 7: Distribution of Respondents based on their Farm Size

Farm Size (ha)	Frequency	%
≤ 1	39	39.4
2 – 4	57	57.6
5 – 7	2	2
≥ 8	1	1.1
Total Mean	99.2	100

Source: (Field Survey, 2018)

3.2 Access to extension contact

Table 8 shows that a significant percentage (90.9%) of the respondents had no contact with any form of extension or agricultural services, while only (9.1%) of the respondents had access to agricultural extension agent. This implies that majority of the respondent had no extension contact which may have adverse effects on their adaptive capacities; hence they will have less access to climate information and new innovations in adaptation practices (Onuwa et al., 2023).

Table 8: Distribution Based on Access to Extension Contact

Extension contact	Frequency	%
Yes	9	9.1
No	90	90.9

Source: (Field Survey, 2018)

3.3 Access to agricultural credit

Table 9 reveals that most (93.9%) of the respondents do not have access to agricultural credit, while only 6.1% had access to agricultural credit. This implies that most of the respondents will encounter financial constraints in adopting certain climate-smart agricultural practices, due to high cost of these agricultural inputs, e.g. agro-chemicals, irrigation facilities, etc. The high cost of agricultural inputs may mitigate the capacity of rural farmers in adopting new technologies (Adeyemo et al., 2015)

Table 9: Distribution based on Access to Agricultural Credit

Access to credit	Frequency	%
Yes	6	6.1%
No	93	93.9

Source: (Field Survey, 2018)

3.4 Membership of farmer groups or cooperatives

Table 10 reveals that Most (92.9%) of the respondents do not belong to any farmer groups or cooperative association, while only 7.1% of the respondents were members of farmer groups and cooperatives. This implies that non-members of cooperative groups may encounter resource constraints in relation to farm capital, agricultural input supply, etc. that may enhance their adaptive capacity. Also climate information dissemination tends to be faster among farmers who belong to cooperatives. Also, members of cooperatives tend to have more access to a variety of agricultural inputs than non-members of cooperatives (Bita and Gerats, 2013).

Table 10: Distribution based on Membership of Farmer Groups or Cooperatives

Membership	Frequency	%
Yes	7	7.1
No	92	92.9

Source: (Field Survey, 2018)

3.5 Farmers' perception of climate change effects

Table 11 revealed that the perceived effects of climate change among vegetable farmers are very critical determinants of farmer's adoption decision and choices; and are indicated by the weighted average index of the following factors: Increased temperature (3.12), irregular rainfall pattern (2.70), incidence of drought (2.37), decline in crop productivity (2.19), food shortage/insecurity (2.01), incidence of flooding (1.75), pest and disease outbreaks (1.62), loss of soil fertility (1.54) and land degradation (1.41). This result also corresponds with the findings of other researcher where outbreaks, flood, loss of soil fertility, food shortage happened on agricultural technology adoption (Kemausuor et al.,2011).

Table 11: Distribution Based on Perceived Climate Change Effects			
Perceived Effects	**$\sum f_i w_i$**	**WI**	**Rank**
Increased temperature	309	3.12	1st
Irregular rainfall pattern	268	2.70	2nd
Incidence of drought	235	2.37	3rd
Decline in crop productivity	217	2.19	4th
Food shortage/insecurity	199	2.01	5th
Incidence of flooding	174	1.75	6th
Pest & disease outbreaks	161	1.62	7th
Loss of soil fertility	153	1.54	8th
Land degradation	140	1.41	9th

Source: (Field Survey, 2018)

3.6 Adoption of climate-smart agricultural practices

The results presented in Table 12 indicates that most (87.8%) of the respondents adopted irrigation farming, to augment short fall in rains, about 70.7% adopted improved seed varieties (drought tolerant and early maturing crop varieties), 63.6% adjusted their planting dates. also, farm diversification was also practiced by 55.5% of the respondents, to serve as buffers to the adverse effects of climate change. other climate-smart agricultural practices adopted by the respondents in the study area include use of agro-chemicals (51.5%), improved agronomic practices (44.4%), and adoption of agro-forestry practices (32.3%). The adoption of climate-smart agricultural practices has several implications for sustainable agriculture and can bring numerous benefits to vegetable farmers in Nigeria (Guodaar, 2015).

Table 12: Distribution based on the Adoption of Climate-smart agricultural practices		
Agricultural Practices	**Frequency***	**%**
Irrigation farming	87	87.8
Use of improved seed varieties	70	70.7
Planting date adjustment	63	63.6
Farm diversification	55	55.5
Agrochemicals application	51	51.5
Improved agronomic practices	44	44.4
Agro-forestry practices	32	32.3

Source: (Field survey, 2018); * = multiple responses

3.7 Index of adoption of climate-smart agricultural practices

The result in Table 13 reveals that most (68.6%) of the farmers have low adoption index of ≤0.4; while, 31.3% have high adoption index of ≥0.5. Moreover, it was evident that several climate-smart agricultural practices are available to vegetable farmers in the study area; however, the index of adoption of these agricultural practices was very low and not satisfactory. This trend was responsible for the existing low farm productivity of this crop in the area; as observed in previous studies (Mailumo and Onuwa, 2022). It is well known that in sub-Saharan Africa low agricultural productivity by smallholder farmers have been attributed to poor adoption of improved agricultural technologies. Therefore, identification of factors hindering adoption/uptake of improved agricultural practices is pertinent and particularly critical to agrarian communities (Onuwa et al., 2022).

Table 13: Distribution based on the Index of Adoption of Climate-smart agricultural practices		
Adoption index	**Frequency**	**%**
Low adoption index (≤0.4)	68	68.6
High adoption index (≥0.5)	31	31.3

Source: (Field survey, 2018)

3.8 Constraints of Adoption of Climate-smart agricultural practices

Table 14 shows that the major constraints affecting the adoption of climate-smart agricultural practices among vegetable farmers in the study area include inadequate climate information (89.8%), financial constraints (77.7%), high cost of agricultural input (65.6%), poor access to extension services (58.5%), farm size/tenure status (51.5%), poor access to agricultural inputs (43.4%) and limited technical capacity of farmers (36.3%). These constraints identified adversely affected vegetable farmers capacity to fully adopt climate-smart agricultural practices (Onuwa and Folorunsho, 2022).

Table 14: Distribution based on the Constraints of Adoption		
Constraints	**Frequency***	**%**
Inadequate climate information	89	89.8
Financial Constraints	77	77.7
High cost of agricultural input	65	65.6
Poor Access to extension services	58	58.5
Farm size/Tenure status	51	51.5
Poor access to agricultural inputs	43	43.4
Limited technical capacity of farmers	36	36.3

Source: (Field Survey, 2018); * = multiple responses

4. Conclusion And Recommendations

This study analyzed the adoption of climate-smart agricultural practices among vegetable farmers in Bassa, Plateau State, Nigeria. The socioeconomic factors of the vegetable farmers influenced their adoption decisions. The perceived effects of climate change critically affected the production outcomes of the vegetable farmers. Several climate-smart agricultural practices are available to the vegetable farmers in the study area; however, a low adoption index of these practices was reported. The vegetable farmers identified several constraints that adversely affected their capacity to fully adopt climate-smart agricultural practices. Improved dissemination and awareness of climate information, financial inclusion, extension contact, land policy modification, adequate input supply at subsidized rates and provision of technical support are recommended. Based on the findings, the following recommendations are suggested:

i. Effective dissemination of climate information to vegetable farmers via appropriate information channels.

ii. Agricultural policies and programmes should focus on intensifying awareness on climate change.

iii. Improved sensitization and education of vegetable farmers on climate change, its causes, effects, as well as the appropriate mitigation practices to be adopted.

iv. Financial inclusion of vegetable farmers to improve their access to affordable farm capital and agricultural credit.

v. Implementation of policies that improves vegetable farmers' access to extension contact.

vi. Modification of land tenure policies, particularly for agricultural purposes.

vii. Policy formulation that ensures adequate agricultural input supply at subsidized rates.

viii. Agricultural policies and programmes should focus on improving vegetable farmers technical efficiency and productivity.

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