Optimizing the Comparative Advantage of Agricultural Products in the Three Senatorial Zones of Kaduna State to Enhance Food Security in Response to Global Climate Changes

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Abstract
This research focuses on optimizing the comparative advantage of agricultural products across Kaduna State's three senatorial zones to enhance food security in response to global climate change. A descriptive survey research design was employed to guide the study, with stratified sampling comprises of 18 (6 local government areas from each zone) randomly selected from the 23 local government areas in the state. A sample size of approximately 2,556 farmers was selected using the Yaro Yamane formula for determining the sample size. Through a combination of quantitative and qualitative methodologies, including Geographic Information System (GIS) mapping, econometric modeling, stakeholder interviews, and field observations, the study comprehensively analyzed the agricultural landscapes, products endowments, and climate patterns of the selected local government areas and access the current agricultural practices, productivity and challenges faced by farmers in each senatorial zone to achieve its goals. Four research questions and a hypothesis were used in the study. A 100-item, five-point likert scale questionnaire, validated with a reliability index of 0.865, was adjudged as reliable instrument and usable for the study. Mean and standard deviation were used to answer the research questions while multi-regression analysis was applied to test the null hypotheses at 0.05 significance level. The result showed significance difference in crop yield between comparative advantage crops and other cultural agricultural practices yield with a calculated value of 4.26 was greater than the regression valued of 1.74. Based on the findings the North Senatorial Zone should focus on Millet, Sorghum, Groundnuts, Cowpea, and Sesame; the Central Senatorial Zone on Maize, Soybeans, Rice, Tomatoes, and Cotton; while the South Senatorial Zone on ginger, Yam, Cassava, Plantain/Bananas. The study also recommended strategies for improving agricultural productivity by ways of improving access to irrigation systems, modern farming techniques, storage and marketing which could further enhance productivity, partnership, stimulating

economic growth, job creation, poverty reduction, reduce product wastage and dumping and infrastructural development. It also emphasized the need for targeted policies, infrastructure developments, research and technology transfer, community engagement, and stakeholder collaboration to maximize the agricultural potentials.

Keywords: *Optimization, Comparative Advantage, Agricultural Products, Senatorial Zones, Food Security, Climate Changes.*

Introduction

The escalating concern over global climate change (Schneider, 2018), necessitate imperative innovative approaches to safeguard food security and promote sustainable development strategies on the vast agricultural resources in Kaduna state. Optimizing the flow of comparative advantage products in the three Senatorial Zones of the State for national development involves the strategic utilization of each zone's unique strengths of crop production in the agricultural sector to contribute to both regional and national economic growth. Kaduna State, located in northern Nigeria is renowned for its agricultural diversity and potential due to its varied climate, fertile soil, and abundant water resources. The state is divided into three Senatorial Zones-Kaduna North, Kaduna Central, and Kaduna South, each characterized by distinct agro-ecological conditions that offer unique opportunities for agricultural development to specialized, (Yusuf, 2012 and Philip, 2006). However, these opportunities remain underutilized, with suboptimal crop specialization and inefficiencies in resource management.

David Ricardo's theory of comparative advantage forms the theoretical basis of this subject matter. Its suggests that different regions or zones should focus on producing goods or services that they can produce more efficiently or at a lower opportunity cost compared to others. By aligning agricultural practices with each zone's unique strengths climate suitability, soil types, water availability, and local expertise, Kaduna State can increase productivity, improve food security, and contribute significantly to national economic growth by trading with other regions (Jhingan, 2012). This specialization could lead to higher productivity, increased incomes for farmers, job creation, and improved food security within the state and contribute to national development objectives. This includes bolstering economic growth, reducing poverty and unemployment, enhancing food self-sufficiency, and generating export earnings. Furthermore, the strategic development of the agricultural sector could lead to improved rural livelihoods, infrastructure development, and sustainable practices that benefit both local communities and the broader nation, (Paul 2004 & Andrew 2012).

Food insecurity entails a lack of consistent access to enough nutritious food for a healthy and active life. This can result from various factors such as poverty, insufficient resources, climate changes and disruption in food supply chain. According to Victor (2015), this has grave effects causing malnutrition, compromised physical and mental health, developmental issues (especially in children), reduced productivity, and increased susceptibility to diseases. Additionally, food security often contributes to a cycle of poverty and could have broader social and economic implications. This research therefore recognizes the need for effective policies, infrastructure investments, research and technology transfer, community engagement, and stakeholder

collaboration to ensure the successful implementation of comparative advantage principles in the State's agricultural sector. By aligning the utilization of products with each zone's strengths and fostering cooperation among zones, the state can position itself as a model for regional and national development through agricultural optimization.

The comparative advantage has several benefits for both the state and for national development. Anyanwuocha (2008), agreed to include increased agricultural productivity, employment generation, economic growth, infrastructure development, export, opportunities, diversification, technology transfer, regional collaboration, rural development and national food security that would lead to a well-rounded and sustainable development strategy that benefits both the state and national development goals. Paul (2012), envisaged could have several negative consequences on both the state and national development such as missed economic opportunities, inefficient resource use, limited growth dependency on imports, uneven development underutilized resources, reduced agricultural resilience, limited infrastructure development, decreased export competitiveness, loss of knowledge and skills and food insecurity, if neglected. These could lead to impeding economic growth, hinder agricultural development, and create a range of challenges for both Kaduna State and national development efforts, (Ewa and Agu, 2004),

Statement of the Problem

Agriculture is the backbone of Kaduna State's economy, with a majority of the population depending on it for their livelihood. Despite its agricultural potential, the state faces several challenges that hinder optimal productivity and food security including global climate changes, poor infrastructures, and inadequate access to resources. Climate change has resulted to unpredictable weather patterns, decreased rainfall, and increased incidences of droughts and floods. Each of Kaduna's three senatorial zones (Northern, Central, and Southern), has distinct climatic conditions, soil types, and agricultural practices, but there is a lack of tailored strategies that leverage the comparative advantages to maximize agricultural output and ensure food security. As a result, many farmers often struggle with poor yields, inadequate storage facilities, post-harvest losses, and limited markets access, which contribute to food insecurity and economic instability in the region. Moreover, the current farming practices in the state also, do not fully account for the varying water availability and soil suitability across the zones. This mismatch between crop selection and environmental conditions often leads to inefficient use of resources, further exacerbating the effects of climate change on agricultural productivity. Additionally, absence of efficient processing and value addition strategies means that many agricultural products are sold in their raw form, reducing their market value and the income potential for farmers and the lack of modern storage facilities leads to significant post-harvest losses, particularly for perishable crops, thereby threatening food security.

Given these challenges, there is an urgent need to develop and implement strategies that optimize the comparative advantage of zonal agricultural products in the State. This requires a comprehensive understanding of the specific climatic, soil, and water conditions in each zone, as well as the development of effective storage, processing, and market access solutions. Without addressing these issues, the state may continue to experience food insecurity, economic hardship for its farmers, and vulnerability to the adverse effects of climate change. When agricultural practices in each zone do not align with their respective comparative advantages, it often result in

inefficient resource utilization and missed economic opportunities. Similarly, the absence of a coordinated policy framework to encourage the specialization of agricultural activities based on comparative advantage may hinder the development of the sector. The impact of climate change further exacerbates these challenges, necessitating a comprehensive understanding of how to strategically harness agricultural product to mitigate food insecurity, of which the study aimed at addressing. Common products produced in the region such as tomatoes, rice, beans, yam, cassava, millet, maize, sorghum, ginger, cotton, pepper, and groundnuts in the current agricultural practices are not optimally produced due to the ignorance of the soil and climatic requirement needed on them. Improved agricultural practices involving advanced technology, improved inputs may not be applicable in all zones without sorting out which zones should harbor which agricultural practice that adapt to the climate change, hence this research.

Aim of the Research

The aim of this study is to identify the agricultural products across Kaduna's three senatorial zones and evaluate their comparative advantage in terms of their value chain associated with the potential economic impact, and to recommend policies for practical participation of stakeholders and sustainability. The research will developed and provide framework for agricultural development that enhance food security, monitoring and evaluating the implementation of the proposed strategies over time to mitigate the effect of climate change in Kaduna state.

Research Questions

The research questions are designed to guide the researchers in addressing the key challenges related to the study.

i. How do the specific climatic condition in each of the three senatorial zones affect the suitability of different crops?
ii. How can the comparative advantages of the agricultural products in the zones be optimized to enhance overall agricultural productivity and food security in Kaduna State?
iii. How can agricultural practices in Kaduna State be adapted to mitigate the impacts of global climate changes while ensuring sustainable food production and security?
iv. How can the annual yield of agricultural products in each senatorial zones be optimized to enhance overall agricultural productivity and food security in Kaduna State?

Research Hypotheses

H_0: There is no statistical significant relationship between the sample mean of climatic conditions of the three senatorial zones and the suitability of different crops for production.

Theoretical Frameworks

In this study, several theoretical frameworks have been drowned and applied to guide and help the researchers establish the underlying principles and concepts that inform the study's approach and analysis. The *Comparative Advantage Theory* developed by David Ricardo in the early 19th century, argued that regions or countries benefit from specializing in the production of goods and services they can produce most efficiently and for which they have a lower opportunity cost (Costinot & Donaldson, 2012).. The study applies this theory to agricultural production in Kaduna State by identifying which crops each senatorial zone can produce most efficiently, given its unique climate, soil, and water resources as comparative advantages leading to increased

productivity and food security in the state. The *Climate-Smart Agriculture (CSA) Framework* promoted by the Food and Agriculture Organization (FAO), aims to achieve increasing agricultural productivity, enhancing resilience (adaptation) to climate change, and reducing greenhouse gas emissions (mitigation) where possible (Adger, et al, 2005). The CSA framework guides the study in exploring ways to adapt agricultural practices in Kaduna State to climate change.
The *Food Security Framework* is widely used in food security research and is based on availability, access, utilization, and stability (Coxhead, 2007). The framework guides the study in analyzing how optimizing agricultural production in the State's different zones affects these pillars. The framework helps in understanding how increasing agricultural productivity in each zone contributes to food availability and stability, thereby reducing overall food insecurity. *Innovation Diffusion Theory:* Developed by Everett Rogers in 1962, this theory explains how, why, and at what rate new ideas and technology spread within a society, (Costinot & Donaldson 2012). This theory can be applied to explore how new agricultural practices, technologies, and strategies can be disseminated and adopted by farmers in the different zones of Kaduna State. It helps in understanding the factors that influence the adoption of innovations that can enhance agricultural productivity and food security in the face of climate change. While the *Agricultural Development Theory* encompasses various approaches to understanding how agricultural sectors develop within broader economic and social contexts (Coxhead, 2007 and Lundquist, 2019). The study also used agricultural development theory to examine the pathways through which agricultural production can be improved in Kaduna State, focusing on structural changes, policy interventions, and resource allocation that can enhance food security.

Methodology

A descriptive survey research design (Aloysius, 2011), was suitable and used in the study, involving stratified sampling of 18 (6 from each zone) randomly selected from the 23 local government areas in Kaduna state. A sample size of 2,556 farmers was selected using the Yaro Yamane formula for determining the sample size. Through a combination of quantitative and qualitative methodologies, including Geographic Information System (GIS) mapping, econometric modeling, stakeholder interviews, and field observations, the study comprehensively analyzed the agricultural landscapes, products endowments, and climate patterns of the selected local government areas and reviewed the current agricultural practices, productivity and challenges faced by farmers in each senatorial zone to achieve its goals. Three research questions and a hypothesis were used to guide the study. Data were collected using a 100-item, five-point likert scale questionnaire, developed and validated with a reliability index of 0.865. The research questions were analyzed using mean and standard deviation, while multi- regression analysis tested the null hypothesis at a 0.05 significant level.

Result: the following results were obtained from the data collected and presented thus:
Research Question One: How does the specific climatic condition in each of the three senatorial zones, affect the suitability of different crops?

Table 1. Mean and S.D of the climatic condition affecting the suitability of different crops in each senatorial zones.

S/N	Statement Item	Mean	S.D	Remark
1	Climatic conditions in Kaduna North favorable for the cultivation of drought-resistant crops (millet, sorghum, groundnuts and cowpea).	3.05	2.60	Accept
2	Kaduna Central's moderate climate suits crops like maize, rice, groundnuts and soya beans	3.13	2.80	Accept
3	Higher rainfall in Kaduna South IS suitable for ginger, yam, cassava, and sugar cane	3.12	2.76	Accept
4	Temperature variation across the zones affect crop productivity.	3.07	2.55	Accept
5	Kaduna North's sandy and loamy soil are ideal for legumes.	3.11	2.65	Accept
6	Kaduna Central's clay soils suits rice farming with proper nutrient management	3.14	2.89	Accept
7	Fertile soils in Kaduna South offer advantage for root crops like cassava and sweet potatoes.	3.09	2.62	Accept
8	Soil degradation and erosion in parts of Kaduna North negatively impact the suitability of certain crops.	2.43	2.19	Reject
9	The availability of water resources in Kaduna Central provides significant opportunities for irrigation-based farming.	3.07	2.55	Accept
10	The relative scarcity of water sources in Kaduna North poses a challenge for growing water-intensive crops like rice and sugarcane.	3.14	2.89	Accept
	Average Total	2.75	2.36	

From table 1, the average mean of 2.75 (SD=2.36) suggests that most of the factors listed were considered relevant climatic conditions affecting crop suitability in the senatorial zones, except for item 8, which did not meet the 2.50 threshold This also implies that the climatic conditions in Kaduna North are favorable for the cultivation of drought-resistant crops (millet, sorghum, groundnuts and cowpea). Kaduna Central's moderate climate is well-suited for growing staple crops like maize, rice, groundnuts and soya beans while the higher rainfall in Kaduna South makes it more suitable for cultivating crops like ginger, yam, cassava, and sugar cane.

Research Question Two: How can the comparative advantages of the agricultural products in the zones be optimized to enhance overall agricultural productivity and food security in Kaduna State?

Table 2: mean and Standard Deviation of comparative advantage agricultural products in the various zones of Kaduna State to enhance overall productivity and food security

S/N	Statement/Item	Mean	S.D	Remark
1	Promoting crop specialization based on the comparative advantages of different zones (e.g., millet in Kaduna North, rice in Kaduna Central, and yams in Kaduna South) will enhance overall productivity.	3.41	2.95	Accept
2	Enhancing transportation and logistics between zones will optimize the comparative advantage and improve food distribution	3.38	2.87	Accept

3	Providing access to improved seeds and inputs tailored to the zone's crops will boost productivity	3.48	2.99	Accept
4	Strengthening irrigation systems in water scarce areas like Kaduna North, will maximize drought-resistant crops potential.	3.47		
5	Encouraging inter-zone trade among producers will optimize the distribution and contribute to food security.	3.48	2.97 2.99	Accept Accept
6	Supporting cooperative farming models will maximize the comparative advantage of each zone.	3.58	2.86	Accept
7	Developing value-added processing industries in each zone will reduce post-harvest losses.	3.41	2.94	Accept
8	Investment in research and development to improve crop varieties will enhance productivity.	3.48	2.98	Accept
9	Strengthening agricultural extension will improve farmers' capacity to maximize their products comparative advantage.	3.64	3.00	Accept
10	Government policies focusing on zone-based agricultural development will improve resource utilization and food security.	3.47	2.97	Accept
	Average Total	3.78	2.86	

From table 2, all factors listed were accepted as important for comparative advantage in agricultural products to enhance overall productivity and food security Kaduna State, with an average mean of 3.78 and Standard Deviation of 2.65. This also implies that Promoting crop specialization based on the comparative advantages of different will significantly enhance overall agricultural productivity; Supporting cooperative farming models and partnerships among farmers in different zones will maximize the comparative advantage of each zone and developing value-added processing industries in each zone based on its agricultural strengths will enhance productivity and reduce post-harvest losses.

Research Question 3: How can agricultural practices in Kaduna State be adapted to mitigate the impacts of global climate changes while ensuring sustainable food production and security?

Table 3: Mean and Standard Deviation of Adopted strategies to mitigate the impact of global climate changes while ensuring sustainable food production and security.

S/N	Statement/ Items	Mean	S.D	Remark
1	Promoting drought-resistant crops such as grains in Kaduna North is an effective strategy to mitigate the effects of climate change.	3.47	2.97	Accept
2	Adopting climate-smart agricultural practices, such as crop rotation and conservation agriculture, can improve food security across all three senatorial zones.	2.44	2.23	Reject
3	The use of improved seed varieties adapted to changing climate conditions is essential for sustaining food production in Kaduna Central.	3.32	2.82	Accept

4	Investing in irrigation systems in areas prone to drought in Kaduna North will help mitigate climate change impacts on agricultural productivity.	3.21	2.62	Accept
5	Diversifying crop production in Kaduna South, especially with crops that are more resilient to extreme weather conditions, will enhance food security.	3.09	2.58	Accept
6	Agroforestry practices in Kaduna Central can reduce the negative effects of climate change while promoting sustainable food production.	2.99	2.56	Accept
7	Training farmers in the three zones on climate-resilient farming techniques will help mitigate the impact of climate change and maintain productivity.	2.99	2.57	Accept
8	Enhancing soil conservation efforts in Kaduna South, where rainfall patterns are shifting, is key to ensuring long-term agricultural sustainability.	2.44	2.25	Reject
9	The adoption of early warning systems for climate-related risks in Kaduna State can help farmers make informed decisions to protect their crops.	2.98	2.59	Accept
10	Government policies that promote the cultivation of climate-resilient crops in all three zones will be crucial for ensuring food security in the face of global climate change.	3.18	2.60	Accept
	Average Total	2.79	2.13	

From table 3, except item 2 and 8, all strategies had mean rating of 2.50 and above indicating that these strategies were considered effective for mitigating climate change impacts and ensuring food security in Kaduna State. The adoption of climate smart agriculture practices and government policies that promote climate resilient crops are vital for long-tern security. This however implies that adopting climate-smart agricultural practices, such as crop rotation and conservation agriculture, can improve food security across all three senatorial zones and government policies that promote the cultivation of climate-resilient crops in all three zones will be crucial for ensuring food security in the face of global climate change.

Research Question 4. What is the annual yield of agricultural products in your senatorial zones?
Table 4: Mean and Standard Deviation of annual yield of agricultural products in three senatorial zones to ensure sustainable food production and security.

S/N	Statement/ Items	Mean	S.D	Remark
1	Promoting drought-resistant crops such as millet and sorghum in Kaduna North is an effective strategy to increase annual yield.	3.47	2.97	Accept
2	Adopting climate-smart agricultural practices, such as crop rotation and conservation agriculture, can improve food security across all three senatorial zones.	2.94	2.63	Reject
3		3.32	2.82	Accept

4	The use of improved seed varieties adapted to changing climate conditions is essential for sustaining high yield production in Kaduna Central.	3.21	2.62	Accept
5	Investing in irrigation systems in areas prone to drought in Kaduna North will help mitigate climate change impacts on agricultural yield productivity.	3.09	2.58	Accept
6	Diversifying crop production in Kaduna South, especially with crops that are more resilient to extreme weather conditions, will enhance high yield.	2.99	2.56	Accept
7	Agroforestry practices in Kaduna Central can reduce the negative effects of climate change while promoting sustainable high yield production.	2.99	2.57	Accept
8	Training farmers in the three zones on climate-resilient farming techniques will help mitigate the impact of climate change and maintain high yield productivity.	2.75	2.35	Accept
9	Enhancing soil conservation efforts in Kaduna South, where rainfall patterns are shifting, is key to ensuring long-term agricultural sustainability.	2.98	2.59	Accept
10	The adoption of early warning systems for climate-related risks in Kaduna State can help farmers make informed decisions to protect their crops yield.	3.18	2.60	Accept
	Government policies that promote the cultivation of climate-resilient crops in all three zones will be crucial for ensuring high yield in the face of global climate change.	2.97	2.41	
	Average Total			

From table 4, all the ten questions were accepted by the respondents supporting the high annual yield of agricultural products in Kaduna State's three senatorial zones as crucial for sustainable food production and security, with an average mean value of 2.97 and Standard Deviation of 2.41.

Testing of the Hypothesis

Hypothesis one (HO_1): There is no statistical significant relationship between the sample mean of climatic conditions of the three senatorial zones and the suit ability of different crops for production.

Table 4: Regression analysis of crop yield in the three senatorial zones based on comparative advantages, climatic conditions and policies.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X201	4.357538	2.304664	2.807008	0.0208
X2	3.300043	1.887612	2.464652	0.0193
X3	1.830407	1.294937	1.103096	0.0212

C	15.56272	5.025650	3.096659	0.0112

R-squared	0.906868	Mean dependent var	3.192000
Adjusted R-squared	0.560303	S.D. dependent var	3.330985
S.E. of regression	0.284666	Akaike info criterion	0.614173
Sum squared resid	0.486208	Schwarz criterion	0.735207
Log likelihood	0.929134	Hannan-Quinn criter.	0.481399
F-statistic	1.005713	Durbin-Watson stat	1.741634
Prob(F-statistic)	0.001667		

INTERPRETATION OF RESULT

X_I (Climate Conditions) has a coefficient of 4.357538 which shows that it has a positive relationship with crop yield (Y), with a probability value of 0.0208. This means that, if X_1 increases by one unit, it will lead to an increase of the Dependent Variable Y, by 4.357538 and the probability value is 0.0208 which is less than 0.05.meaning that it is very significance in showing the changes in Y.

X_2 (Comparative Advantage) also shows a positive relationship with Y, with a coefficient of 3.300043 and a probability value of 0.0193. This means that, if X_2 increases by one unit, it will lead to an increase of the Dependent Variable Y by 3.300043. The probability value of 0.0193 is significance in explaining the changes in Y too.

X_3 (Government Policies) has a smaller but still a positive coefficient of 1.830407 with a probability value of 0.0212. Although the positive relationship is not too strong, it means that if X_3 increases by one unit, it will lead to an increase to the Dependent Variable Y, by 1.830407. This variable is also significant in explaining the variation in Y. Its probability value of 0.0212 indicates that it is very significant in explaining the variation in Y as it is less than 0.05 level of significance.

The R^2 value of 0.906868 indicates that about 90% of the explanatory variables affecting crop yield are included in the Model, only about 10% are explained by other variables outside the model. The Prob(F-statistics) of 0.007667 shows the variables are significance in explaining the changes in Y. Durbin Watson statistic of 1.741634 is within 1.5 – 2.5 shows that there is no autocorrelation in the model. The value of Standard Deviation is greater than the Mean which means that the analysis is correct

Discussion

In respect of the climatic condition as its affect the suitability of different crops in each senatorial zones table 1, item 8 had mean rating of 2.43 but all items had mean rating of 2.5 and above. This implies that those items were considered necessary climatic conditions in each of the three senatorial zones of the state affecting the suitability of different crops. The item with less than 2.50 implies that it is not considered as a necessary factor. This also implies that the climatic conditions in Kaduna North are favorable for the cultivation of drought-resistant crops (millet, sorghum, g/nuts and cowpea). Kaduna Central's moderate climate is well-suited for growing staple crops like maize, rice, g/nuts and soya beans while the higher rainfall in Kaduna South makes it more

suitable for cultivating crops like ginger, yam, cassava, and sugar cane. The Average mean value was 2.75 with a standard deviation of 2.36

In respect to comparative advantage agricultural products in the various zones of Kaduna State to enhance overall productivity and food security table 2, all the ten items were accepted as of factors for comparative advantage of agricultural products in the various zones of Kaduna State to enhance overall productivity and food security. All have mean rating above 2.50 with the average calculated mean value of 3.78 and Standard Deviation of 2.65. This also implies that Promoting crop specialization based on the comparative advantages of different will significantly enhance overall agricultural productivity; Supporting cooperative farming models and partnerships among farmers in different zones will maximize the comparative advantage of each zone and developing value-added processing industries in each zone based on its agricultural strengths will enhance productivity and reduce post-harvest losses.

In respect to adopting strategies to mitigate the impact of global climate changes while ensuring sustainable food production and security table 3, all items except item 2 and 8 had mean rating 2.50 and above. This indicate that adopting the strategies of comparative advantage on agricultural production and policies will mitigate the impact of global climate changes while ensuring sustainable food production and security. This also implies that items 2 and 8 which did not meet the mean rating disagreed with the strategies. This however implies that adopting climate-smart agricultural practices, such as crop rotation and conservation agriculture, can improve food security across all three senatorial zones and government policies that promote the cultivation of climate-resilient crops in all three zones will be crucial for ensuring food security in the face of global climate change.

In respect to annual yield of agricultural products in three senatorial zones to ensuring sustainable food production and security table 4, all the ten questions were accepted by the respondents to support annual yield of agricultural products in the three senatorial zones to ensuring sustainable food production and security since they all have mean value of 2.50 and above. The average Mean and Standard Deviation value is 2.97 and 2.41 respectively.

Conclusion

The study confirms that adapting agricultural practices to specific climatic conditions and leveraging the comparative advantages of each senatorial zones in Kaduna State can significantly improve food production. The Northern Senatorial Zone is ideal for drought resistance products of like, Sorghum, Millet, Groundnuts, Livestock (cattle, goats, sheep using by-products), while the Central Senatorial Zone are suited for a mix of staple and high-value products like maize, rice, cotton, vegetables (tomatoes, onions, peppers) and Livestock (poultry, cattle using by-products) and the key agricultural products for South Senatorial Zone to achieve similar purpose should be ginger, yam, cassava, sugarcane, fruits (mangoes, oranges), and livestock (poultry, goats using by-products).

This will give an annual crop and livestock production of approximately ₦10-12 billion annually, employing about 50,000 people annually for Northern Senatorial Zones and crop and livestock production of approximately ₦7-9 billion and ₦11-13 billion annually employing about 50,000 people annually for Central and Southern Senatorial Zones respectively (KADP, 2020). Therefore,

an increase in any unit of the independent variables (X_1, X_2 and X_3) will lead to a corresponding increase in the dependent variable (Y) as explained in the regression analysis.

Suggestion

Given the varying rainfall patterns across the three senatorial zones of Kaduna State, Northern Kaduna Zone should practice irrigation due to its semi-arid climate with lower and less reliable rainfall, this zone has the highest need for irrigation to support crop production, particularly during the dry season. Surface irrigation systems are suitable due to their water efficiency, particularly for crops like groundnuts, millet, and vegetables and could utilization of groundwater through boreholes and the construction of small dams or reservoirs can provide reliable water sources for irrigation. Central Kaduna Zone receives moderate rainfall, supplemental irrigation is beneficial, especially for high-value crops like vegetables, maize, and rice. Surface irrigation techniques, such as furrow and basin irrigation, are common, but there is also potential to introduce more efficient methods like drip irrigation. The zone's rivers and streams can be harnessed for irrigation, alongside rainwater harvesting and the development of small-scale irrigation schemes. While, Southern Kaduna Zone has higher and more reliable rainfall, irrigation is less critical but still valuable for dry-season farming and enhancing productivity of crops like ginger, cassava, and plantains. Surface irrigation and sprinkler systems can be used, especially in horticultural practices and for tree crops. Rain-fed agriculture predominates, but irrigation can be supported by rivers and small dams, especially in drier areas or for offseason crops.

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