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ARTICLE

Assessing the Contributions of Smallholder Wheat Farming to Livelihood Outcomes in North West, Nigeria

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ABSTRACT

This study investigates the contributions of smallholder wheat farming to rural livelihoods in Nigeria's Sudan Savannah agroecological zone, focusing on food security, income generation, and poverty. The study was conducted across Kano, Jigawa, and Katsina States. We employ descriptive statistics, Endogenous Switching Probit Regression, and Instrumental Variable Quantile Treatment Effects to analyze data from 360 wheat farming households. Results reveal that wheat farming is profitable, and significantly enhances food security and income, particularly at moderate-to-high quantiles (30th–75th). However, 85% of households remain food insecure, with 71–85% facing mild-to-moderate access issues and 19–31% severe conditions, highlighting a disconnect between profitability and food access. Benefits skew toward wealthier farmers, with the most vulnerable (15th quantile) seeing limited

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gains. Wheat farming shows no significant impact on poverty at the 15th (0.0801, $p > 0.05$) and 30th (0.027, $p > 0.05$) quantiles, suggesting that the poorest farmers derive minimal benefits. However, significant positive effects emerge at the 45th (0.3491, $p < 0.01$), 60th (0.1909, $p < 0.01$), and 75th (0.6430, $p < 0.01$) quantiles, with the largest gains observed among wealthier households. These findings indicate that while wheat farming contributes to poverty reduction, its benefits are regressive, disproportionately favoring middle- and upper-income farmers. Our findings suggests improving credit access, irrigation, extension services, and market stability to ensure equitable and sustainable impacts. These findings underscore wheat farming's potential to bolster livelihoods while emphasizing the need for targeted interventions to address systemic barriers and reduce Nigeria's wheat import dependency.

Keywords: Wheat; Livelihood; Income; Food Security; Poverty; Nigeria

1. Introduction

The Agricultural sector is important for most of the developing countries including Nigeria because of its contribution to national economy and food security through overall domestic production, trade and employment [1–6]. This sector is an important sector in improving the lives of poor households and in determining opportunities for escaping poverty. Agriculture is the core sector of less Developed Countries and Sub-Saharan Africa (SSA) in particular [7–9]. Agriculture plays a cardinal role in Nigeria's economy contributing the greatest share to the nation's gross domestic product (GDP) [10–15]. For instance, 2017 agriculture's contribution to total real GDP was 42.07 percent with crop, livestock, forestry and fishery accounting for 37.52, 2.65, 1.37 and 0.53 percent, respectively [16–19]. This implies that the crop sub-sector contributed 91.79 percent of agriculture GDP. Further, agriculture generates employment for over 70 percent of the total labour force, accounts for about 60 percent of the non-oil exports and, perhaps most importantly, provides over 80 percent of the food needs of the country [20, 21]. Nigeria has substantial economic potential in its agricultural sector [22–25]. However, despite the importance of agriculture in terms of employment creation, its potential for contributing to economic growth is far from being fully exploited [26–30].

Wheat has arguably become one of the most important agricultural commodities in Nigeria. This is evident in the country's phenomenal increase in annual consumption rate, which jumped from 1.0 million metric tonnes (MT) in the 1980s' to 4.2 million MT per year [31]. Today, food items made from wheat have gained popularity over traditional staples made from commodities such as maize and wheat. In Nigeria, wheat is used to make local foods such as Taliya, Gurasa, Tuwo, Alkaki, Fura, Algaragis, Alkubus, Danwake, and others [31]. Nigeria is the second largest consumer of wheat in Sub-Saharan Africa behind South Africa [32]. In 2022, the government spends approximately $1.5 billion on wheat imports alone and with the growing demand for non-traditional foods such as pasta, increase in wheat imports will lead to an increase in Nigeria's import bills. While Nigeria produces approximately 300,000 MT of wheat in 2021 worth $12.66 million (0.004% of global production), the demand is much higher at 4.63 mn tons 2020/2021 season [33]. There is therefore a huge demand gap of 4.57 mn tons, making Nigeria the least self-sufficient country in Africa when it comes to meeting its wheat demand.

In an attempt to make Nigeria self-sufficient in Wheat production, several measures were put in place by the Federal Government of Nigeria and other stakeholders in the wheat industry. The measures include launching of several agricultural programmes and establishing several institute aimed at stimulating interest in local production of wheat. Some of these were the Agricultural Transformation Agenda and Anchor Borrower Programmes of the Central Bank of Nigeria which were launched in 2011 and 2015 respectively focused on increased production of specific commodities including wheat. Looking beyond food security, Nigeria policy makers also considered the income-generation potential of wheat production, believing that the higher yields and income will help to eradicate the endemic poverty that characterizes many parts of rural Nigeria.

Regardless of all government efforts, poverty has persisted in Nigeria and the country has experienced a growing rural-urban divide since 1990s [34, 35]. The share of Nigeria 's poor population living in rural areas stands at 84.6% and for a long time, the Northern region (including North Central, North East and North West zones) lead the country as the poorest region where 76.3% of the population live in rural areas [36]. Despite the high level of poverty, progress in reducing poverty remains strong [37–45]. The complexity of rural livelihoods and poverty in the developing world has led to a need for in-depth research into understanding the role that smallholder farming plays in improving the lives of the poor. Livelihoods of poor rural households in Nigeria are known to be diverse and in many of these livelihoods, farming occupies the central stage [46]. The fact that smallholder wheat farming contributed to improved household welfare, therefore is definite. The effectiveness of smallholder wheat farming as poverty-reducing strategies has long been recognized in many developing countries [47–50]. Diversity of the rural livelihoods and the variable importance of farming in the rural livelihoods of poor households have been documented in communities that practiced other cereal farming. However, information on livelihoods and farming households holding plots on smallholder wheat farmers in Nigeria has received inadequate research attention. Therefore, the extent to which smallholder wheat farming contributes to rural livelihoods remain unknown [51]. Furthermore, it is not clear what needs to be done to realize the full potential of smallholder wheat farming to enhance its potential to improve livelihoods. However, study such as role of smallholder farmers in Nigeria's food security by Eldridge et al. [52] have established that, there is positive association between participation in smallholder farming including wheat and improved livelihoods and poverty reduction and food security.

While smallholder farming in Nigeria has been widely studied [53], wheat-specific contributions to livelihoods in the Sudan Savannah are rarely addressed. Most research focuses on staple crops like sorghum or maize, leaving a gap in understanding wheat's role amid Nigeria's agro-ecological diversity. Existing studies on Nigerian smallholder livelihoods often generalize across agro-ecological zones (e.g., humid forest, guinea savannah) without isolating the Sudan Savannah's unique conditions (e.g., semi-arid climate, shorter growing season). This gap is evident when comparing to works like Mgbenka and Mbah [53], which assess irrigation impacts across zones but not wheat-specific outcomes in the Sudan Savannah. Also, the socio-economic contributions of wheat farming (e.g., income generation, food security, and poverty role) to rural livelihoods in this zone remain underexamined. While studies like Umar et al. [54] explore organic farming adoption in southeast Nigeria, similar analyses for wheat in the Sudan Savannah are absent, particularly regarding how it affects poverty alleviation or household resilience. Consequently, to understand the contribution of smallholder wheat farming to the livelihoods of rural poor clearly, it is important to be cognizant of the role of smallholder farming in rural livelihoods and income strategies of the different types of smallholder wheat farmers, with different social and economic statuses, engaged in a wide range of livelihood strategies. This current study will contribute to filling the knowledge gaps. The specific objectives are to examine whether smallholder wheat farming contributes to household food security and examine the distributional impact of wheat farming on food security, income and poverty trends of the wheat farmers in the study region. This study offers valuable, previously unavailable knowledge specific to Nigeria. Given the said investment that has been directed towards smallholder wheat farming, policymakers must be informed of the extent to which that investment has translated to a better quality of life in the Sudan savannah ecological region of Nigeria. Quantifying the relationship between smallholder wheat farming, household income and food security will indicate the extent to which investment in smallholder wheat farming has addressed the country's priority area of reducing rural poverty. Furthermore, the study will inform policymakers on both the potential of smallholder wheat farming and the debate on whether Nigeria should invest more in smallholder wheat farming in pursuit of the country's key strategic objectives of eliminating poverty and reducing inequality.

2. Conceptual Framework

2.1. Understanding Rural Livelihoods

The conceptual framework for this study is depicted in **Figure 1**. Poverty reduction and improved rural household welfare are central to the debate on rural livelihoods. Given that this study is a livelihood-centered evaluation of smallholder wheat farming distribution to rural livelihoods, the Sustainable Livelihoods Framework (SLF) were applied extensively. This approach provides an understanding of the livelihoods of poor people. The SLF presents the main factors that affect people's livelihood and the typical relationship between them. The SLF has been used previously, both in planning new development activities and in assessing the contribution of existing activities to livelihood sustainability. The reference scale of such a framework is always influenced by the uses to which it is put. The same framework can be applied at different scales, including livelihoods of individuals, households, villages, communities, districts or nations, assessing sustainable livelihood outcomes at different levels [55]. Although the framework is not intended to be an exact model of reality, it provides an analytical structure that facilitates a systematic understanding of the various factors that influence livelihood opportunities and shows how the factors relate to one another [56, 57]. The SLF provides an approach that reconciles the contribution made by all the sectors to building up the stocks of assets upon which people draw to sustain their livelihoods [58]. The strengths of the SLF draw from its two key components, which are that it is a systematic view of the factors that cause poverty and that it is a set of principles that guide action to address and overcome poverty. The rationale of the sustainable livelihoods approach is therefore poverty reduction, although it does not lay down any explicit definition of what exactly constitutes poverty, as poverty is context-specific.

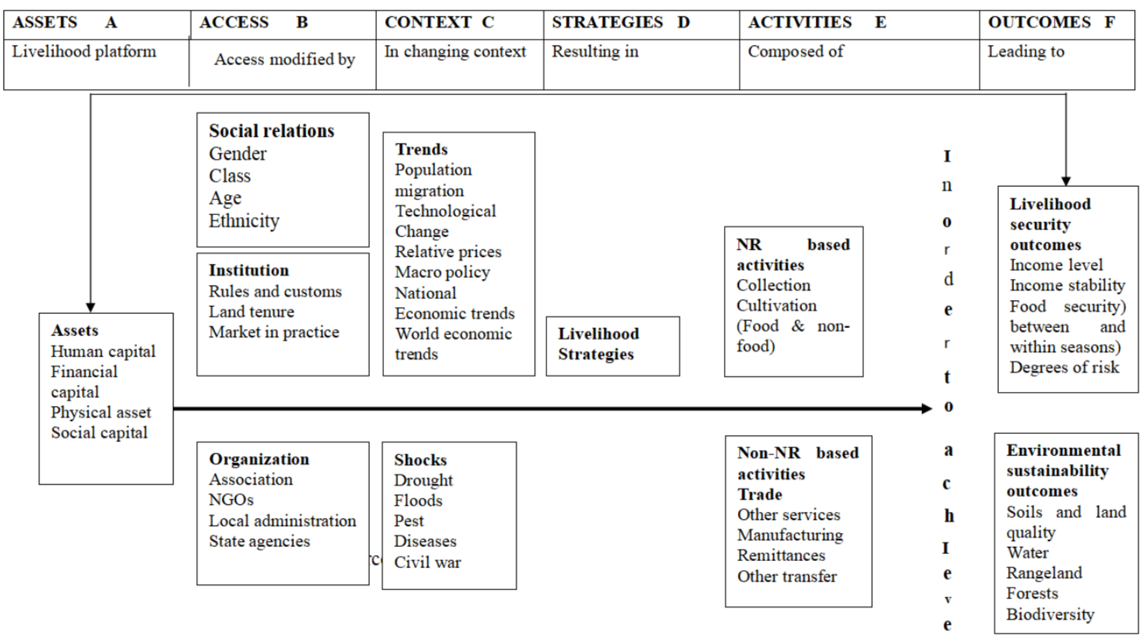

Figure 1. The Sustainable Livelihood Framework.

Source: Krantz [58].

According to Krantz [58], there are insights into poverty that underpin the SLF approach. The First is the realization that while economic growth may be essential for poverty reduction, there is no automatic relationship between the two since it all depends on the capabilities of the poor to take advantage of expanding economic opportunities. Secondly, there is the realization that poverty, as conceived the poor themselves, is not just a question of low income, but also includes other dimensions such as poor health, illiteracy, lack of social services, a state of vulnerability and feelings of powerlessness etc. Furthermore, it is recognized that the poor must be involved in designing projects and policies intended to improve their livelihoods, as they often know their situation and needs best. There are various ways of conceptualizing the components of a livelihood and influences upon it, which led to numerous, slightly different, schematic representations of these variables and their interconnections. **Figure 1** represents a diagrammatic representation adapted from DFID [57]. The arrows within the framework denote different types of dynamic relationships between the variable listed in columns A to F. Starting from D and E, the poor employ a mix of different strategies, given their resources to engage in agricultural, natural resource-based and non-natural resource-based activities. The outcomes of the livelihood strategies include effects on livelihood security and on environmental sustainability. Notable is that income in the livelihood security box does not refer only to monetary income but also to income in kind, such as food produced by the farmer for home consumption.

All livelihood strategies depend upon access to assets (column A). The framework is built around five principal categories of assets. Viewed from a livelihood perspective, smallholder wheat farms are assets. They can be used to increase and diversify the livelihood activity of plant production, resulting in improved livelihood outcomes, either directly in the form of food or income for farming households or indirectly by providing full or partial livelihoods to people who provide goods and services in support of wheat farming. Notably, livelihoods depend on a combination of assets of various kinds and not just from on category. The assets, as identified in the SLF, include human, natural, social, financial and physical capital [58]. A distinction between different types of assets draws attention to the variety of resources, often used in combination, on which people rely to derive a flow of income or consumption and also invest in so as to increase future flows of income or consumption.

Access to assets (Column B) is important, as livelihood strategies may focus on increasing the range of assets to which an individual or household has access in an effort to improve the quality of life. The more assets individual has, the less vulnerable they are to shocks and trends. The effectiveness of an asset in proving livelihood security depends on contextual factors such as social relations, institutions and organizations, which affect ways in which people combine and use their assets to achieve their goals. These are their livelihood strategies employed to achieve their livelihood outcomes [58]. It is noteworthy that assets do not deploy themselves but people do so. Therefore, the effectiveness of an asset will depend on the skills and knowledge possessed by the individual using it, in addition to these to these contextual factors. The extent of people's access to these assets is strongly influenced by their vulnerability context, which entails trends (e.g, population, migration, technological change, economic, e.t.c) and shocks (e.g. epidemic, natural disasters, civil strife). Trends represent gradual change while shocks are sudden changes. Household exposure to trends and shocks can weaken, strengthen or force households into a new direction [58].

People can be poor at any point in time because they possess few assets. They can also be poor because of financial and other constraints that limit their ability to use the assets they have. Given enough time, people can build up additional assets they need; however, within that time, negative shocks may take place that push people further behind. According to Carter and May [59], the dynamics of poverty depend on how these dimensions of time interact and on people's strategic choices, given their awareness of time as both opportunity and vulnerability.

2.2. The Pathways Framework

To determine pathways out of poverty through participation in wheat farming, the pathways framework was applied. **Figure 2** presents a diagrammatic representation of the pathways framework, which illustrates how access to productive and consumptive assets would eventually lead to improved household welfare. The diagram is compiled using various aspects adapted from Gebbisa and Mulatu [60]. The arrows imply certain levels of influence between the variables listed. The framework shows the key interrelated dimensions of the relationship between the access to assets employed and socio-economic uplifting of the poor in rural communities and improved household welfare.

The framework emphasizes the importance of assets in realizing the key benefits through key pathways and eventually reducing the vulnerability of poor people's livelihood and improving welfare. The key pathways through which smallholder wheat farming contributes to improved livelihoods are identified. These comprise food production/productivity, income/consumption, employment, food security, and other social impacts contributing directly or indirectly to overall improved household welfare [61, 62].

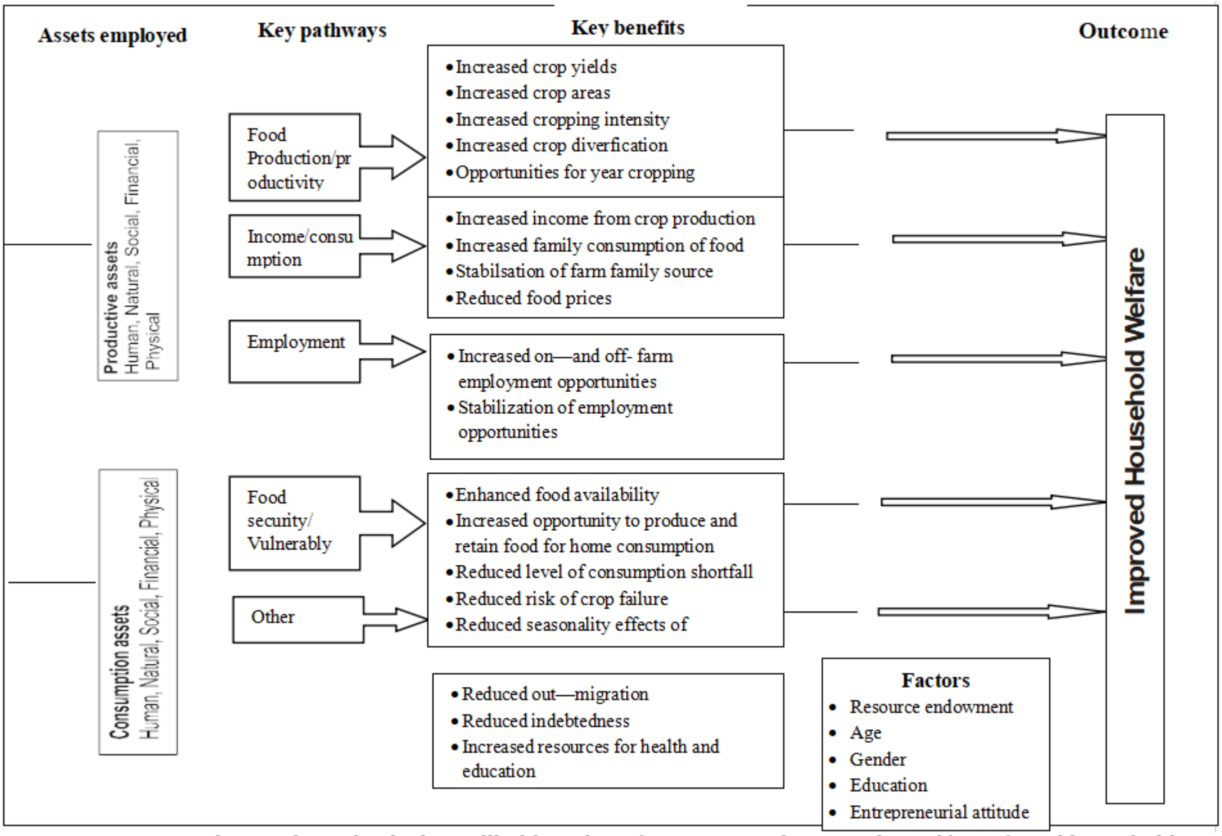

Figure 2. Key pathways through which smallholder wheat farming contributes to the welfare of rural household.

Source: Author compiled with adaptions from Gebbisa and Mulatu [60].

3. Methodology

3.1. Study Area

The study was conducted in Sudan Savannah Agro-Ecological zone of Nigeria (**Figure 3**). Special focus was placed on Kano, Jigawa and Katsina states because the three states are known today as the most irrigated state in the country with more than 3 million hectares of cultivable land [63]. Subsistence and commercial agriculture are mostly practiced in the outlying districts of the states. Kano State is located in the North-Western Nigeria. Kano State had a population totaling 9,383,682. The official language of Kano State is Hausa language, but the Fulani language is commonly spoken. It lies between latitude 130°N in the North and 110°N in the South and longitude 80°W in the West and 100°E in the East. The total land area of Kano State is 20,760 sq kilometers. The temperature of Kano State usually ranges between a maximum of 33 °C and a minimum of 15.8 °C although sometimes during the harmattan it falls down to as low as 10 °C. Kano has two seasonal periods, which consist of four to five months of wet season and long dry season lasting from October to April. Kano is known today as the most irrigated state in the country with more than 3 million hectares of cultivable land. Subsistence and commercial agriculture is mostly practiced in the outlying districts of the state. Some of the food crops cultivated are wheat, millet, cowpeas, sorghum, maize and rice for local consumption while groundnuts and cotton are produced for export and industrial purposes.

On the other hand, Jigawa State is one of thirty-six States that constitute Federal Republic of Nigeria. It is situated in north-western part of the country between Latitudes 11.00˚N to 13.00˚N and Longitudes 8.00˚E to 10.15˚E. The state is divided into twenty seven local government areas with an estimated population of 4,348,649 million and a total of 322,410 sq km land area. Jigawa State is populated mainly by Hausa-Fulani but there are also Manga (a Kanuri dialect) and Badawa, who constitute significant percentages in Birnwa, Guri and Kirikasamma Local Government Areas. The annual mean temperature is about 25˚C but the mean monthly values range between 21˚C in the coolest month and 31˚C in the hottest month. However, the mean daily temperature could be as low as 20˚C during December and January when the cold dry harmattan wind blows from the Sahara Desert. The total annual rainfall ranges from 600 mm in the north to 1000 mm in the southern parts of the state. The people of the state are mainly farmers. Food crops produced include wheat, maize, millet and guinea corn, cash crops like cotton and groundnut are also produced.

Katsina state borders the Republic of Niger to the north for 250 km and the state of Jigawa for 164 km and Kano to the east, Kaduna to the south for 161 km and Zamfara to the west. Katsina state is about 23,938 square kilometers (9243 sq mi). It is situated between latitude 11˚07′49″ and 13˚22′57″N and longitude 6˚52′03″E and 9˚9′02″E. The state is blessed with abundant productive arable land that enables numerous crops to thrive, and thus attract intensive production of both vegetables and arable crop respectively. Major crops grown in the state are wheat, maize, rice, yam, groundnut and soybean. Majority of the farmers in the state produces at subsistence level.

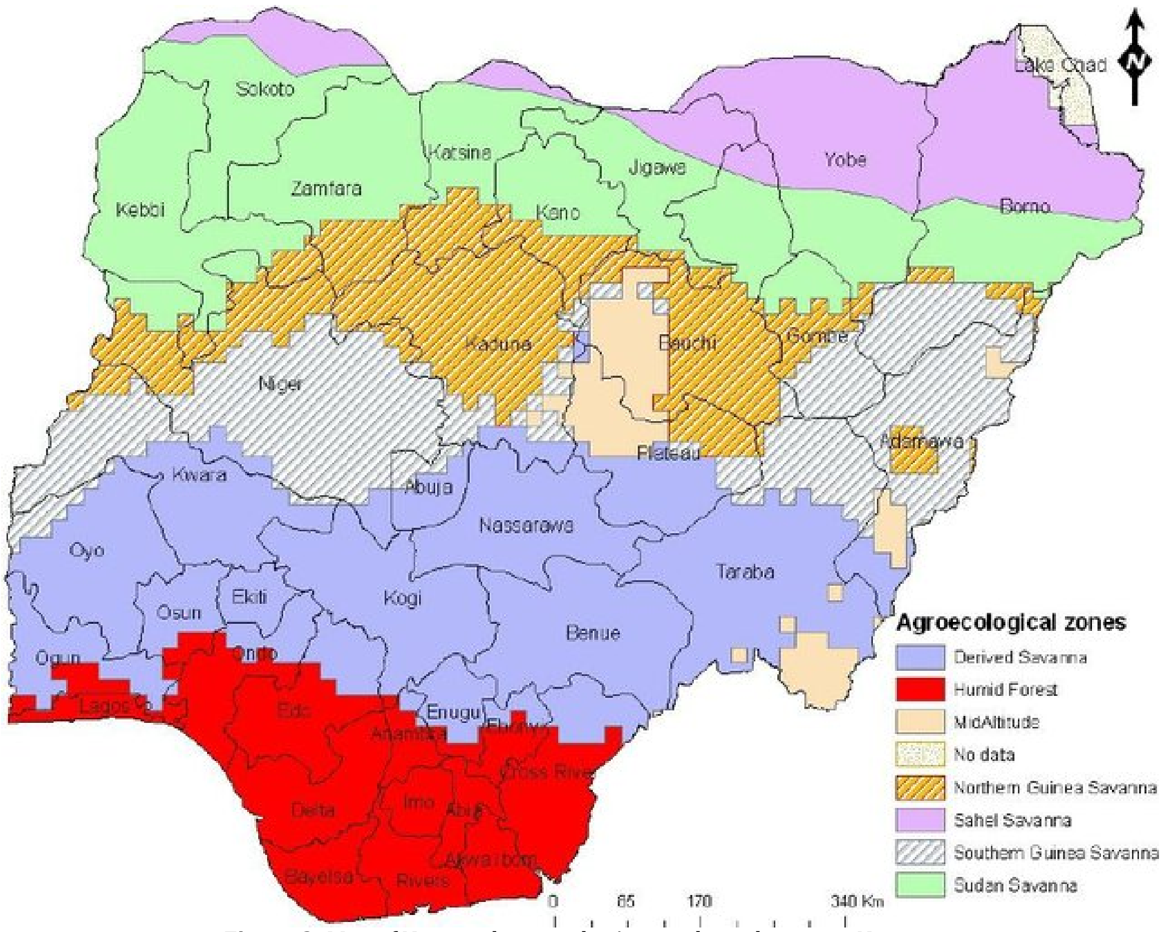

Figure 3. Map of Nigeria showing the Agroecological zones in Nigeria.

3.2. Sampling Method and Sample Size

A multi-stage sampling technique were employed for the study. The first stage was the purposive selection of two (2) Local Government Areas from each state due to the concentration of wheat farmers in the areas[63–65]. For Kano, the local governments are Bagwai, and Wudil, for Jigawa, the local governments are Hadijai and Dutse while for Katsina, the local governments are Bakori and Jibia. The second stage involved random selection of three (3) villages from each of the six Local Government Areas. In the last stage, twenty (20) wheat farmers were selected randomly from each of the villages totaling 360 households to be surveyed. Sampling at the study area involved a census of all registered smallholder wheat farmers. The list of registered farmers was obtained from the Wheat Farmers Association of Nigeria (WFAN) Kano chapter. Furthermore, selected respondents in the study sites were asked for consent to voluntarily participate in the study before the interviews began. Interviews proceeded only when consent was obtained from the respondents. Data were collected by trained enumerators using personal interviews.

Sample size were determined using Cochran's formula for computation of sample size.

$$n = \frac{z2p(1-p)}{d2} \quad (1)$$

where; n = Minimum sample size; z = Constant at 95% confidence interval which is 1.96 for two tailed study; p = Best estimate of population prevalence of 50%; d = Precision, which is at 95% confidence the interval is 5%.

$$\text{n} = \frac{(1.96^2) \times 0.5(1-0.5)}{0.5^2} \quad (2)$$

n = 360 respondents;

This study relied on primary data collected using structured questionnaire. The first phase of the questionnaire involved detailed information on household composition and characteristics, income-generating activities, household expenditure, household well-being, household asset endowment, household savings and loans, and membership of association. The second phase of the questionnaire gathered additional livelihood data on agriculture and entrepreneurship to augment the general livelihood study. Data collected include the availability of and access to farm labour, access to land and water, ownership of agricultural assets, marketing of both livestock and crops, farmer support services, entrepreneurial attitude and attitude to risk. The third phase collected information on food security status through the Household Food Insecurity Access Scale (HFIAS) while the last phase was on household expenditure to ascertain their poverty status. Following table shows the variables that were captured in the questionnaire and their expected relationship with the dependent variables. Variables used are characteristics of the component of the sustainable livelihood framework. In general, given the nature of the variable listed, an increase in the explanatory variable will result in an increase in the dependent variable, and hence more positive relationships are expected.

3.3. Analytical Techniques

Descriptive statistics such as frequencies, percentage, means and standard deviation were used to analyzed the socio-demographic characteristics of farmers with the result presented in **Table 1**.

Results from **Table 1** show that the mean ages of the wheat farmers were 47.69 ± 15.55 years. This result shows that wheat farmers in the study area are in their productive age, and are thus expected to be open to innovations that will help them improve their productivity. The results of this finding agree with[66–71], who all found that wheat farmers are young adults who were mostly in their active age. For wheat production in the study area, both men and women were actively involved in its production as 49.72% of the respondents were male while 50.28% were female. This result might be attributed to the fact that different intervention projects have been implemented in the Sudan savannah agro-ecological zones of Nigeria by the International Center for Agricultural Research In the Dry Areas (ICARDA), International Maize and Wheat Improvement Center (CIMMYT), Institute of Agricultural Research (IAR) and the Lake Chad Research Institute (LCRI) to promote the production of wheat and this projects mostly specifically target women farmers in the region, hence the high rate of female gender in wheat production in the study area. This finding aligns with that of Falola et al., Endalew et al., Dambazau et al., Derso et al., Mwangi et al. and Mohammed et al.[66–71] who all found that wheat was been cultivated by men and women smallholder farmers. The majority (80.28%) were married. This might be because marriage is cherished in these areas and as such women farmers marry early due to their religious tradition. This will however afford them the opportunity for the utilization of family labor on their farms for wheat production. This result agrees with the findings of Falola et al., Endalew et al., Dambazau et al., Derso et al., Mwangi et al. and Mohammed et al.[66–71], who found that majority of wheat farmers in Nigeria were married. The mean household size were 8.41 ± 4.85 members. This result shows that wheat producers in the study area had a relatively medium to large household size. This might be as result of the fact that majority of the respondents were married. Having a large household size can be substituted for hired labor which help to reduce cost of hired labor during wheat production in the study area. This finding agrees with the findings of Reuben et al., Olanrewaju, and Ajadi et al.[72–75], who all found that smallholder farmers in Nigeria had an average household size of 6 members (large household size) in which they utilized for farm production activities. The mean years of farming experience for the wheat farmers were 20.2 ± 13.83 years. This indicates that the respondents had been into wheat production for a longer time and thus had the necessary experience required for efficient wheat production. These findings agrees with that of Reuben et al., Olanrewaju, and Ajadi et al.[72–75] who all found that smallholder farmers involved in wheat production had many years of farming experience. The mean years of education were 7.346 ± 3.21 years. The indication of this result is that the levels of literacy among the wheat farmers were relatively medium to high since many of them attained up to secondary education. The farmers are expected to be able to read and write. This is expected to positively contribute to the likelihood of using wheat technologies that will help improve their production efficiency. These results agrees with the findings of Babatunde et al., Kaguongo et al., Kolapo et al.[76–83], who all found that smallholder farmers has a medium to high literacy in Nigeria. The majority (55.56%) of the wheat farmers were members of farmers association. Being a member of association will afford the farmers the opportunities to have access to current useful information and other inputs that could help them improve their production efficiency and profitability. Being a member of an association can significantly influence wheat production in Northern Nigeria by providing farmers with resources, support systems, and opportunities that enhance their agricultural outcomes. In the context of the study area, where wheat farming is a dry-season, irrigation-dependent activity, associations, such as farmers' cooperatives, agricultural unions, or community-based groups play a key role. The Majority (70.83%) had access to extension services. This result shows that wheat farmers majorly had access to extension services. This might have helped in the popularity of the production of wheat farming among the smallholder farmers in the study area. This is because having access to extension services help the farmers to get access to quality and up to date information which will help increase their profitability and thus enhance the food security and poverty level of the wheat farmers in the study area. In addition, many intervention projects have been implemented in Northern Nigeria by different international and local organizations regarding improving wheat production, this might have influenced the high level of access to extension services in the region. For the wheat farmers, majority (82.22%) were indigene of their communities. This shows that majority of the wheat farmers were indigenous to their communities and are thus expected to have access to resources needed for profitable wheat production in the study area. Being an indigene of a community in Northern Nigeria can significantly influence wheat production through a mix of social, cultural, economic, and practical factors. In Northern Nigeria, land tenure systems often favor indigenes, who typically inherit farmland through family or communal arrangements. Wheat production, which relies heavily on irrigation during the dry season, requires consistent access to fertile land near water sources like rivers or boreholes. Indigenes are more likely to own or control such prime plots, giving them an advantage over non-indigenes, who may have to rent land at higher costs or settle for less productive areas.

Secure land tenure also encourages indigenes to invest in long-term improvements, like irrigation channels or soil management, boosting yields. The mean numbers of years that the wheat farmers had resided inside their communities were 28.78 ± 17.34years. This indicates that the respondents have resided for a longer period of years in their respective communities. The number of years a farmer or farming household has stayed in a community can influence wheat production in Northern Nigeria in several practical ways. First, longer residency often means deeper knowledge of the local environment. Northern Nigeria's wheat belt relies heavily on irrigation and cooler harmattan seasons for wheat, which isn't a natural fit for the region's hot, semi-arid climate. Farmers who've lived in a community for many years likely have a better grip on seasonal quirks, soil conditions, and water availability, like how to time planting with the dry season or manage sandy soils versus vertisols. This experience could lead to smarter decisions, boosting yields compared to newcomers who might still be figuring it out. Second, staying longer builds social ties and access to resources.

Table 1. Summary of Descriptive Statistics.

Variable	Mean	Std. dev.	Max.	Min.
Age (years)	47.69	15.55	18	80
Marital status (married)	0.8028	0.4275	4	1
Gender	0.4972	0.500	1	0
Years of Education	7.346	3.21	8	0
Household size	8.41	4.85	14	1
Farm Experience (years)	20.2	13.83	53	6
Membership of association (%)	0.5556	0.4971	1	0
Access to extension services	0.7083	0.4437	1	0
Frequency of extension contact (#)	6.908	12.592	15	0
Access to credit (yes = 1, no = 0)	0.3083	0.6472	1	0
Indigene of community	0.8222	0.392	1	0
land size cultivated (ha)	1.8716	0.5583	2.937	0.0625
Years stayed in community	28.78	17.34	75	2.2
Access to climate information	0.575	0.4785	1	0
Visits to agricultural field offices	0.5444	0.4710	1	0
Cropping systems	0.5778	0.3176	1	0.1
Willingness to take risk	0.5194	0.2713	1	0
E. Gross Margin			306,401.84	306,401.84
F. Net return			196,828.89	196,828.89
ROI			0.71	0.71
ROI			1.71	1.71

Source: Data Analysis, 2025.

The majority (57.5%) of the respondents had access to climate information. They might have gotten climate information from extension agents that visited them. Access to climate information can play a significant role in shaping wheat production in the Sudan Savannah agro-ecological zones of Nigeria, a region characterized by a semi-arid climate with a short rainy season and a prolonged dry period. Wheat, while not traditionally a dominant crop in this zone due to its preference for cooler conditions, has been increasingly cultivated with irrigation and improved varieties. Having access to reliable climate information, like seasonal rainfall forecasts, temperature trends, or early warnings about extreme weather, helps farmers make informed decisions about when to plant, irrigate, or harvest. Majority (54.44%) had visited the agricultural field office. Field office visits affect wheat production through improved access to information and training. Farmers visiting these offices can learn about modern agronomic practices tailored to wheat, such as optimal irrigation scheduling, soil fertility management, and pest control. Majority (57.78%) intercropped with other crops. In the Sudan Savannah region of Nigeria, wheat production is influenced by a variety of factors, including climate, soil conditions, water availability, and farming practices. The choice between sole cropping and mixed cropping plays a significant role in determining wheat yield, resource use efficiency, and overall farm sustainability. About 51.94% were willing to take risks. The willingness of farmers to take risks plays a significant role in shaping wheat production in the Sudan Savannah region of Nigeria. Farmers' risk-taking behavior influences their decisions about adopting new practices, investing in inputs, and expanding wheat cultivation, all of which directly impact production levels. Farmers who are more willing to take risks are often more likely to experiment with innovative techniques that could enhance wheat yields. About 30.83% had access to credit. This implies that the wheat farmers lack access to financial services. Lack of access to credit can significantly impact wheat production by limiting farmers' ability to invest in essential resources, manage risks, and maintain consistent output. Wheat farming, like most agriculture, requires upfront costs for seeds, fertilizers, pesticides, equipment, and labor. Without credit, farmers, especially smallholders, may struggle to afford high-quality inputs, leading to lower yields or reliance on cheaper, less effective alternatives. Credit also acts as a buffer against unexpected setbacks, droughts, pests, or market slumps. Without it, a single bad season can trap farmers in a cycle of debt or force them to abandon wheat altogether for less capital-intensive crops. These findings agree with the findings of Adeyonu et al., Yusuf et al., and Ahmad et al.[84–86], who all found that smallholder farmers in Nigeria lack access to adequate financial services where they often source from informal sources including from friends, family and relatives and through association membership as an alternative. Total costs (variable + fixed) amount to ₦277,962.66, leaving a gross margin (gross returns minus variable costs) of ₦306,401.84 and a net return (gross returns minus total costs) of ₦196,828.89. These figures suggest profitability. Two ROI values are listed: 0.71 and 1.71. The former represents net return divided by total cost (₦196,828.89 / ₦277,962.66 $\approx$ 0.71), meaning a 71% return per Naira invested. The latter (1.71) is an alternative metric (e.g., gross return/total cost $\approx$ 1.71), implying a 171% return if fixed costs are excluded. An ROI of 0.71 is solid for smallholder farming, where returns often hover below 1.0 due to risks like weather or market volatility[87].

3.4. Household Food Insecurity Access Scale (HFIAS)

To assess the food security of the wheat farming households, the Household Food Insecurity Access Scale (HFIAS) were used following USAID recommendations. The Household Food Insecurity Access Scale (HFIAS) comprises nine (9) generic questions that were asked from the respondents. The responses were calculated and used to classify them into being food secure or food insecure. All of the data were quantified in such a way that if a household responded "not experienced" to a particular condition it received a value of 0 and the frequency of that condition was also denoted as 0. However, if a household did experience a particular condition, it received a value of 1 and the frequency was assigned a value of 1 for "rarely," 2 for "sometimes," and 3 for "often."

3.5. Endogenous Switching Probit Model (ESPM)

This study is also interested in estimating the impact of wheat farming on binary outcomes like the incidence of food insecurity (objective 1). Contrarily, it might be challenging to apply non-linear models for continuous outcome variables when sample selection and endogenous switching are present for binary outcomes[88, 89]. Therefore, two-stage approaches used in evaluations (like Heckman's sample selection model) would produce contradictory results and erroneous inferences. Therefore, the Endogenous Switching Probit (ESPM) framework was used in the present study, which is similar to the endogenous switching regression for continuous outcomes[89, 90]. The ESPM model will be used to demonstrate the impact of wheat farming on the food security status of farm households. This was done in two separate analytical steps. The choice to cultivate wheat was calculated in the first step using a probit model. In the second stage, the study used a probit regression with selectivity correction to investigate the relationship between a set of explanatory variables conditional on the farm households' decision to cultivate wheat and a binary outcome variable (food secure/food insecure). The decisions by farm households to cultivate wheat were represented by the following latent response models:

$$T_i^* = M_i\gamma + \tau_i \tag{3}$$

$$T_i = \begin{cases} 1, \; if \, T_i^* > 0 \\ 0, \; otherwise \end{cases} \tag{4}$$

Where, T_i^* is a continuous latent variables; γ represents parameters to be estimated; τ_i is error term. The binary response, were defined as follows;

$$g_i^* = w_i\lambda + \mu T_i + \tau_i \tag{5}$$

$$g_i = \begin{cases} 1, \; if \, g_i^* > 0 \\ 0, \; otherwise \end{cases} \tag{6}$$

Where, g_i represents most important outcomes variables; g_i^* is a continuous latent variables, λ represents vector of parameter to be estimated; μ represents coefficient of endogenous treatment dummy; τ_i represents residual term. The endogenous switching issues here is that, the response for the i^{th} farm households are not observed always. Asides, g_i is assumed to depends on endogenous dummy, T_i including a vector of the explanatory variable, m_i. The endogenous dummy, $_i$ also depend on vector of explanatory variable, m_i there is possibility that vector, w_i and μ, are correlated. Due to unobserved endogeneity, direct estimation of equation 3a and interpretation as the causative impact would lead to erroneous estimates. By simultaneously estimating the selection and outcome equation with the proper instrumentation of the wheat cultivation decision, the ESPM regression would correct this bias [90]. In a two-stage treatment framework, the ESPM framework models the choice to cultivate wheat and its effect on binary outcomes. A probit model will be used in the first step to model and estimate farm households' decision to cultivate wheat. In the second stage, a probit model with selectivity correction is used to ascertain the association between the binary outcomes, wheat farming, and explanatory variables. The study stated the binary outcomes contingent on the cultivation of wheat as an endogenous switching regime model, following [90]:

$$\begin{gathered} Regime\ 1(wheat\ farming):\ g_{1i}^* = \lambda_1 W_{1i} \\ +\phi_{1i} g_{1i} = 1(g_{1i}^* > 0) \end{gathered} \tag{7}$$

$$\begin{gathered} Regime\ 1(Non-wheat\ farming):\ g_{0i}^* \\ = \lambda_0 W_{0i} + \phi_{1i} g_{0i} = 1\left(g_{0i}^* > 0\right) \end{gathered} \tag{8}$$

Observed $g_i$reflects the latent variables' dichotomous realization and is described as follows:

$$g_i = \begin{cases} g_{1i}, \; if \, T_i = 1 \\ g_{0i}, \; if \, T_i = 0 \end{cases} \tag{9}$$

Where,g_{1i} and g_{0i}, represent latent variable determining observed binary outcome, g_1 and g_0 for $wheat\ farming$ and, non-$wheat\ farming$ respectively; W_1 and W_0 represents vector of weakly exogenous variable; M_i represent vector of variables that determine a switch between regimes; λ_1 and λ_0 represents vector of parameters estimated; ϕ_{1i} and ϕ_{0i} represents error term of outcome equations. In accordance with Lokshin and Sajaia [90], the study will evaluate an endogenous switching Full Information Maximum Likelihood (FIML) probit model to calculate the relevant parameters. By utilizing the analytical framework suggested by Lokshin and Sajaia [90], the study will also estimate the effects of wheat farming on the farmers' food security status. Furthermore, according to Awotide et al. [91], the defined endogenous switching probit model permitted the derivation of probabilities in hypothetical situations. This study calculated the Average Treatment Effect on the Treated (ATET) and the Average Treatment Effect on the Untreated (ATUT) using the following formulas:

$$\begin{gathered} TET_j = pr\left(g_{1j} = 1 | T = 1\right) \\ -pr\left(g_{0j} = 1 | T = 1\right) \end{gathered} \tag{10}$$

$$\begin{gathered} TUT_j = p\tau\left(g_{1j} = 1 | T = 0\right) \\ -pr\left(g_{0j} = 1 | T = 0\right) \end{gathered} \tag{11}$$

3.6. The Instrumental Variable Unconditional Quantile Treatment Effects (IVQTE)

To ascertain the distributional impact of wheat farming on food security, income and poverty trends of the wheat farmers in the study region, instrumental variable unconditional quantile treatment effects (IVQTE) were used. To estimate the distributional or heterogeneous effects of cultivating wheat crop, the study used the IVQTE following Fröolich and Melly [92, 93]. The estimation of quantile treatment effects (QTE) is important to evaluate the effect of a variable on different points of the outcome distribution and therefore allows for the identification of effects even in situations where the mean of the outcome variable remains unchanged. Let y_{1i} and y_{oi} be the continuous potential welfare outcomes of household i. Hence, y_{1i} would be realized if individual i were to cultivate wheat (D = 1), and y_{oi} would be realized otherwise. Following Fröolich and Melly[92, 93], the unconditional QTE (for quantile τ) can generally be given by:

$$\Delta^T = Q^{\tau}_{y1} - Q^{\tau}_{y0} \tag{12}$$

Where Q^{τ}_{y1} is the quantile for y_{1i} and Q^{τ}_{y0} is τthquantile of y_{oi}.

As mentioned earlier, the decision to cultivate wheat is endogenous, hence the identification can only be achieved through an IV, Z. The treatment effects are allowed to be arbitrarily heterogeneous, such that the effects can only be identified for the population that responds to a change in the value of the instrument, i.e. compliers[93]. Therefore, we focus on the QTEs for the compliers:

$$\Delta^T = Q^{\tau}_{y1|c} - Q^{\tau}_{y0|c} \tag{13}$$

The unconditional IVQTE for compliers proposed by Fröolich and Melly[93] can be defined as a bivariate quantile regression estimator with weights:

$$\begin{gathered}\left(\widehat{\alpha}_{IV}, \widehat{\Delta}^{\tau}_{IV}\right) = arg \min_{\varphi\Delta} \\ \sum W_i^{FM} \rho\tau \left(y_i - \alpha - D_i \Delta\right)\end{gathered} \tag{14}$$

Where W_i^{FM} denote the weights proposed by Fröolich and Melly[93]. $\rho\tau = \mu\{(\tau - 1(\mu < 0)\}$, where μ is the asymmetric absolute loss function or check function (Wooldridge, 2010). The weights are defined as:

$$W_i^{FM} = \frac{Z_i - Pr(Z-1|X_i)}{Pr(Z=1|X_i)\left\{1 - Pr\left(Z=1|X_i\right)\right\}} \tag{15}$$

Where Z_i is a binary instrumental variable and Pr$(Z-1|X_i)$ are the propensity scores. (Group membership is used as an identifying IV).

As a key robustness check for the distributional impacts of wheat farming, the study will also estimate treatment heterogeneity by conditioning on a full set of covariates but without controlling for unobserved heterogeneity following Brand and Xie[94]. Besides, the QTEs described above are only valid for continuous outcomes. Following Brand and Xie[94], this study used the SD method to analyze how treatment effects vary with the propensity to cultivate wheat. In summary, the method follows three steps: First, estimate the propensity scores. Second, fit separate, non-parametric regressions of the welfare variables on the propensity score for the wheat farmers and non-wheat farmers. Third, estimate the difference in the non-parametric regression line between the wheat farmers and non-wheat farmersβat different levels of the propensity score. This enables one to obtain a pattern of treatment effect heterogeneity as a function of the propensity score. **Table 2** presents definitions of dependent and explanatory variables in regression models.

Table 2. *A priori* Expectation.

Variable	Description	Expected Sign
Dependent variables		
Household Income	Income realized from cultivation of wheat	
Household food security	Food security status of household (food secured = 1, non-food secured = 0)	
Poverty status	Household poverty status (poor = 0, non-poor = 1)	
Independent variables		
Gender	Gender of HH head (1 = male, 0 = otherwise)	+
Age	Age of HH head (years)	+
Marital status	Marital status measured as dummy (married = 1, otherwise = 0);	+
Education level	1 = no formal education, 2 = primary education, 3 = secondary education, 4 =tertiary education	+
Household size	No of people in household (number)	+
Farming experience	No of years in wheat production (years)	+
Farm size	Area of land located to wheat farming for (ha)	+/−
Risk aversion	HH head's willingness to take risk (1 = willing to take risk; 0=otherwise	+/−
Farmer association	Dummy, =1 if HH head is member of the local farmer association, 0 otherwise	+
Extension access	Dummy, =1 if HH head had access, 0 otherwise	+
Number of years stayed in community	HH head's number of years stayed in community in years	+

Table 2. *Cont.*

Variable	Description	Expected Sign
Independent variables		
Access to climate information	Dummy, =1 if the HH had access to climate informattion, 0 otherwise	+
Labor expenses	Amount spent on loabor use (Naira)	+/−
Fertilizer qty	Quantity of fertilizer applied (kg)	+/−

4. Results and Discussion

4.1. Wheat Farming's Contribution to Household Food Security (Food Security Status)

This study assessed household food insecurity, including prevalence, food insecurity access scale scores, household food insecurity access-related circumstances, and food insecurity access-related domains. The findings collectively characterize the homes under study's level of food insecurity.

Table 3 presents data on food insecurity access-related conditions among wheat farming households, based on the Household Food Insecurity Access Scale (HFIAS). The table captures two metrics: the percentage of households experiencing each condition at least once in the past four weeks (recall period prevalence) and the percentage experiencing it "often" (frequency). **Table 3** lists nine HFIAS questions, ranging from mild food insecurity (e.g., worrying about food sufficiency) to severe (e.g., going a whole day without eating). The HFIAS, developed by Coates et al.[95], is a validated tool for assessing food access, with higher prevalence and frequency indicating greater insecurity. The data reveals a spectrum of experiences among wheat farming households, suggesting varying degrees of vulnerability.

4.1.1. Prevalence of Conditions (Any Time in the Past Four Weeks)

High Prevalence (71–85%): The most common conditions include: Inability to eat preferred foods (85.29%), Eating a limited variety of foods (74.11%), Eating unwanted foods (75.37%), Eating smaller meals (77.18%), Eating fewer meals (71.38%), and worrying about food sufficiency (78.45%). **Moderate Prevalence (31%):** No food of any kind in the household (31.39%); and **Lower Prevalence (19–20%):** Going to sleep hungry (19.47%) or fasting a whole day (20.18%).

4.1.2. Frequency of Conditions (Experienced "Often")

Moderate Frequency (33–49%): Frequent occurrences include: Eating unwanted foods (49.47%), Inability to eat preferred foods (46.28%), Worrying about food (39.47%), Limited variety (38.51%) and smaller meals (33.29%). **Low Frequency (1–20%):** Less frequent severe conditions: Fewer meals (20.57%), No food at all (11.56%), Sleeping hungry (7.47%), and full-day fasting (1.74%). The high prevalence (71–85%) across the first six conditions indicates that most wheat farming households face mild to moderate food insecurity. Worrying about food (78.45%) and compromising on food quality or quantity (e.g., 85.29% unable to eat preferred foods) are nearly ubiquitous. This aligns with the HFIAS framework, where such conditions reflect anxiety and reduced dietary diversity, early stages of food insecurity[95]. The frequency data (33–49% "often") suggests these aren't sporadic issues but recurring challenges, pointing to chronic resource constraints.

A clear gradient emerges: milder conditions (e.g., worrying, limited variety) are more prevalent and frequent than severe ones (e.g., no food, fasting). For instance, while 78.45% worried about food at least once, only 20.18% went a full day without eating, and just 1.74% did so "often." This suggests that while most households experience food access stress, extreme hunger is less common, possibly due to coping mechanisms like reducing meal size (77.18%) or eating unwanted foods (75.37%). Coates et al.[95] note that households often employ such strategies to buffer against severe outcomes, a pattern evident here.

Despite being wheat producers, these households exhibit significant food insecurity. **Table 1** showed a net return of ₦196,828.89 and an ROI of 0.71, indicating profitability. Yet, 85.29% couldn't afford preferred foods, and 31.39% faced total food depletion. This paradox aligns with findings by Coates et al.[95], who argues that smallholder farmers often sell cash crops to meet financial needs, leaving insufficient resources for household consumption, a phenomenon termed the "sell-to-survive" trap. The drop from prevalence to frequency is stark for severe conditions. For example, 31.39% experienced no food at all, but only 11.56% did so "often," and full-day fasting fell from 20.18% to 1.74%. This suggests episodic rather than persistent severe insecurity, possibly tied to seasonal income or harvest cycles. Literature on agricultural households [96] highlights how income shocks or market access issues can cause temporary food shortages, mitigated over time by savings or aid.

Table 3. Food insecurity access-related condition of the studied wheat farming households.

HFIAS Questions	Households Experienced the Condition at any Time During the Recall Period (%)	Households Experienced the Condition (Often) at a Given Frequency (%)
Worry that your household would not have enough food	78.45	39.47
You or any household member not able to eat the kinds of foods you preferred because of a lack of resources	85.29	46.28
You or any household member have to eat a limited variety of foods due to a lack of resources	74.11	38.51
You or any household member have to eat some foods that you really did not want to eat because of a lack of resources	75.37	49.47
You or any household member have to eat a smaller meal than you felt you needed because there was not enough food	77.18	33.29
You or any household member have to eat fewer meals in a day because there was not enough food	71.38	20.57
Was there ever no food of any kind to eat in your household because of lack of resources to get food	31.39	11.56
You or any household member go to sleep at night hungry because there was not enough food	19.47	7.47
You or any household member go a whole day and night without eating anything because there was not enough food	20.18	1.74

Source: Data Analysis, 2025.

The profitability in **Table 1** contrasts with the food insecurity in **Table 3**, implying that income doesn't translate directly to food access. High variable costs and reliance on labor may drain resources, leaving little for food purchases. Fafchamps [96] notes that market-oriented smallholders often prioritize cash over subsistence, exacerbating food insecurity despite income gains. In addition, frequent compromises on food variety (38.51%) and quality (46.28%) signal potential nutritional deficiencies. Studies like Maxwell et al. [97] link dietary diversity loss to malnutrition, particularly in rural farming communities, suggesting long-term health risks for these households, especially children. The result underscores a need for targeted support including income diversification, food access and coping capacity. In conclusion, **Table 3** reveals pervasive mild to moderate food insecurity among wheat farming households, with 71–85% facing access issues and 33–49% doing so frequently, alongside less common but notable severe conditions (19–31% prevalence, 1–11% frequent). This suggests chronic resource strain tempered by coping mechanisms, yet a disconnect persists between farming profits and food security. Implications include nutritional risks, policy needs for stability, and a call for deeper causal analysis. Supported by literature [97, 98], these findings highlight the complex interplay of production, income, and access in agricultural livelihoods.

4.2. Determinants of the Risk Factors of Food Insecurity

We investigated the risk variables for families' food insecurity status after measuring the prevalence of household food insecurity access. The entire sample of households was split into two groups: food secure (15% of the households) and food insecure (85% of the households) (calculated from **Table 3**). Families classified as mildly, moderately, or severely food insecure were considered the insecure group. Without exact overlap data, the percentage of food secure households is the complement of those experiencing at least one condition. If 85.29% is the highest single prevalence, the upper bound of food secure households is 14.71%, but this overestimates, as other conditions likely capture additional households. A more realistic estimate comes from assuming near-universal overlap across the 71–85% range for milder conditions. If we take the lowest prevalence of a less severe condition (e.g., 71.38% ate fewer meals) and assume it captures most insecure households, about 28.62% (100%−71.38%) might be food secure. However, the true figure is likely lower, given the cumulative effect of multiple conditions. The "often" column (1.74%–49.47%) reflects chronicity, not total prevalence, so it's less relevant for a binary categorization but confirms that insecurity is persistent for many (e.g., 49.47% often ate unwanted foods).

Based on the prevalence data: Food Secure: Households experiencing none of the nine conditions. Approximately 15%. This conservative assumes 85% of households experienced at least one condition, factoring in overlap of the 71–85% prevalence rates. The upper bound (15%) aligns with 100%−85.29%, adjusted downward for multiple conditions. Food Insecure: Households experiencing at least one condition, approximately 85%. This reflects the high prevalence across multiple questions, with 85.29% as the minimum and likely higher due to cumulative effects. We used the Endogenous Switching Probit Model (ESPM) to investigate the risk variables of food insecurity in the families under study because the exploratory variable is binary.

Table 4 presents parameter estimates from an Endogenous Switching Probit Regression (ESPR) examining the determinants of risk factors for food insecurity among wheat farming households, split into "food secured" and "non-food secured" groups. The ESPR is a sophisticated econometric approach that accounts for endogeneity and sample selection bias by modeling two regimes (food secure vs. non-food secure) and their switching mechanism. The ESPR assumes that households self-select into food security states based on unobservable factors (e.g., motivation, risk preferences), which may correlate with observed variables, necessitating correction for endogeneity. The table reports coefficients and standard errors for each regime, with significance levels (*10%, **5%, ***1%), correlation parameters (rho1, rho0), and a likelihood ratio test (LR chi^2). The significant LR chi^2 (218.47, $p < 0.0000$) indicates the model fits the data well, rejecting the null of no joint significance. The /athrho1, /athrho0 indicate the Arctangent of correlation coefficients (rho1, rho0) between the error terms of the selection equation and regime equations, indicating endogeneity. rho1, rho0**:** Significant rho1 (−0.002**) suggests mild endogeneity in the food secure regime; rho0 (−0.044*) hints at it in the non-food secure regime.

Table 4. Parameter estimates of the Endogenous Switching Probit Regression.

Variable	Food Secured		Non-Food Secured	
	Coefficient	Std. Err	Coefficient	Std. Err
Age	−0.004*	0.002	0.053**	0.022
Gender	0.000	0.002	−0.010	0.014
Education	0.001	0.000	−0.032	0.032
Marital status	−0.002	0.000	0.206	0.032
Household size	0.000	0.000	−0.003	0.025
Farming experience	−0.001***	0.000	0.580	0. 361
Access to climate information	−0.044*	0.024	−0.333	0.418
Membership of association	0.004	0.002	−0.038	0.054
Access to credit	−0.004***	0.001	0.050	0.053
Risk willingness	0.004***	0.001	1.280**	0.634
Access to extension contacts	−0.229***	0.059	0.061	0.450
No. of years stayed in comm.	0.0082	0.0110	−0.467	1.451
Constant	0.0088***	0.0020	5.7808**	2.754
/athrho1	0.0094***	0.0043		
/athrho0	0.203	0.296		
rho1	−0.002**	0.000		
rho0	−0.044*	0.024		
LR chi^2 *(12)*	218.47			
Prob > chi2	0.0000			

Note: ***,**&* represent significance 1eve1 at 1%, 5% & 10%, respective1y.

In the Food Secured Regime, the coefficient of age was negative and statistically significant at 10% probability level. A negative coefficient at 10% significance suggests that older household heads in food secure households face slightly lower risk of food insecurity. A one-year increase in age reduces the probability of risk factors by 0.004 (probit scale). This could reflect accumulated farming knowledge or wealth mitigating risks. Barrett[98] finds older farmers often leverage experience to stabilize food access, though diminishing physical capacity can offset this in insecure contexts. The coefficient of farming experience was negative and statistically significant at 1%. Highly significant (1%) and negative, indicate that each additional year of experience reduces risk factors by 0.001. Experienced farmers likely optimize resources (e.g., wheat yields from **Table 1**) or adopt better coping strategies, enhancing food security. Dercon [99] notes farming experience reduces vulnerability to shocks, supporting this protective effect.

Furthermore, access to climate information negatively and statistically significantly influenced food security among food-secured households. Access to climate data lowers risk by 0.044. This suggests informed decision-making (e.g., planting timing) helps secure food access, critical for wheat's climate sensitivity. Bryan et al. [100] show climate information reduces agricultural risk in rain-fed systems, consistent with this finding. For access to credit, highly significant (1%), credit access reduces risk by 0.004. Credit likely enables input purchases (e.g., fertilizer) or buffers income shocks, stabilizing food security. Zeller et al. [101] link credit access to improved food security via investment and consumption smoothing. Risk Willingness was positive and statistically significant at 1%. The positive and significant (1%) indicate that a unit increase in risk willingness raises risk factors by 0.004. Among food-secure households, risk-taking (e.g., investing in new methods) might expose them to volatility, though they remain secure overall. Moscardi and Janvry [102] suggest risk-averse farmers prioritize stability, implying risk-willingness could destabilize secure households if unsuccessful. Likewise, the coefficient of access to extension contacts is negatively and statistically significant at 1% probability level. This implies that extension contact reduces risk by 0.229, the largest effect. Extension services likely provide technical advice (e.g., pest management), boosting yields and security. Bjornlund et al. [103] confirm extension services enhance productivity and resilience, aligning with this result.

With regards to the Non-Food Secured Regime, the coefficient of Age is positive and significant at 5%, indicating that a one-year age increase raises risk by 0.053, opposite to the food secure group. Older heads in insecure households may face physical or economic constraints, exacerbating vulnerability. Devereux [104] notes aging can worsen food insecurity in resource-poor settings due to reduced labor capacity. Risk Willingness was positive and significant at 5%, with a large coefficient, risk willingness increases risk by 1.280. In insecure households, risk-taking (e.g., borrowing heavily) might amplify exposure to failure, deepening insecurity. Frelat [105] finds risk-taking in vulnerable households often backfires without safety nets, supporting this effect.

4.3. Distributional Impact of Wheat Farming on Food Security, Income and Poverty

Table 5 presents the distributional impact of wheat farming on food security (measured by the Household Food Insecurity Access Scale (HFIAS), income (measured in Naira per hectare) and poverty (measured by household expenditures) (**Table 6**). The results are disaggregated across quantiles (15th, 30th, 45th, 60th, and 75th), allowing for an analysis of heterogeneity in effects across different levels of food security, income and poverty.

Table 5. Parameter estimates of Instrumental Variable Unconditional Quantile Treatment Effects (IVQTE) showing the Distributional impact of wheat farming on food security and income.

	Selected Quantiles (Dependent Variable = Hfias Score)					Selected Quantiles (Dependent Variable = Net Farm Income)				
	Food Security (HFIAS)					Income (Naira/ha)				
	15th	**30th**	**45th**	**60th**	**75th**	**15th**	**30th**	**45th**	**60th**	**75th**
	0.395 (0.095)	0.280*** (0.149)	0.0689*** (0.0002)	0.799*** (0.004)	0.236*** (0.047)	0.221*** (0.059)	0.403 (0.123)	0.514 (0.434)	0.403*** (0.123)	0.647*** (0.094)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.237*** (0.081)	2.390*** (0.114)	5.553*** (0.756)	3.323** (1.716)	8.890*** (1.332)	2.401*** (0.986)	3.592*** (0.693)	2.067** (0.986)	4.147*** (1.39)	11.088*** (2.443)

Table 5. *Cont.*

	Selected Quantiles (Dependent Variable = Hfias Score)					Selected Quantiles (Dependent Variable = Net Farm Income)				
	Food Security (HFIAS)					Income (Naira/ha)				
	15th	30th	45th	60th	75th	15th	30th	45th	60th	75th
Observation	360	360	360	360	360	360	360	360	360	360

Note: Robust standard errors in parentheses. ** $p < 0.05$. *** $p < 0.01$.

Table 6. Parameter estimates of IVQTE showing the Distributional impact of wheat farming on poverty.

	Selected Quantiles (Dependent Variable = Household Expenditures)				
	Poverty Status (Household Expenditures)				
	15th	30th	45th	60th	75th
	0.0801 (1.282)	0.027 (1.232)	0.3491*** (0.093)	0.1909*** (0.0894)	0.6430*** (0.2213)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	0.1051*** (0.031)	0.312*** (0.083)	0.7381*** (0.094)	0.1909*** (0.0894)	5.1262*** (2.0091)
Observation	360	360	360	360	360

Note: Robust standard errors in parentheses. ** $p < 0.05$. *** $p < 0.01$.

4.3.1. Food Security (HFIAS Score) across Quantiles

The coefficients represent the estimated IVQTE at each quantile, indicating the effect of wheat farming on food security across different levels of household food insecurity. At the 15th quantile, the coefficient (0.395) is positive but not statistically significant, suggesting that wheat farming does not significantly improve food security for the most food-insecure households. At the 30th quantile, the coefficient (0.280) is significant at $p < 0.01$, indicating that wheat farming has a positive and statistically significant impact on food security for households with moderate levels of food insecurity. The effect remains significant at the 45th quantile (0.0689***), though the coefficient is smaller, suggesting a diminishing impact as food security improves. At the 60th and 75th quantiles, the effects increase again (0.799*** and 0.236***, respectively), showing that wheat farming positively influences food security at these levels. The significant effects at the 30th, 45th, and 75th quantiles indicate that wheat farming contributes to reducing food insecurity, particularly for households with moderate to high levels of food security. However, the lack of significance at the 15th quantile suggests that wheat farming alone may not be sufficient to improve food security for the most vulnerable households. Structural barriers such as land access, input costs, or market integration may limit the benefits for the most food-insecure farmers [106]. The increasing impact at higher quantiles suggests that better-off farming households benefit more, aligning with findings on agricultural commercialization and food security dynamics [107].

4.3.2. Income Effects across Quantiles

The second part of **Table 5** examines the impact of wheat farming on farm income (Naira/ha) across quantiles. At the 15th quantile, the coefficient (0.221***) is significant, indicating that even the lowest-income farmers experience a significant income boost from wheat farming. At the 30th quantile, the effect increases to 0.403, though it is not statistically significant, suggesting variability in income effects at lower-middle income levels. At the 45th quantile, the effect is 0.514 but remains statistically insignificant, possibly due to heterogeneity in farm size, productivity, or market conditions. At the 60th and 75th quantiles, the effects become significant (0.403*** and 0.647***), indicating that wheat farming generates higher income benefits for wealthier farmers. The positive and significant effects at the 15th quantile suggest that even small-scale wheat farmers benefit financially, aligning with findings on the pro-poor potential of high-value crops [108]. The higher significance at the 60th and 75th quantiles suggests that wealthier farmers capture the largest income gains, potentially due to economies of scale, better access to inputs, and higher market participation [109]. The insignificance at the 45th quantile could indicate that some midincome farmers face productivity constraints, such as high input costs or climate-related risks, limiting their ability to maximize returns [110].

Table 5 demonstrates that wheat farming significantly enhances food security and income, but the effects vary across income and food security distributions. Higher-income farmers benefit more, raising concerns about equity in agricultural transformation. Addressing smallholder constraints through policy interventions, gender-sensitive investments, and climate-smart practices could enhance the inclusivity of wheat farming's benefits.

4.3.3. Poverty Effect across Quantiles

Table 6 presents the results of IVQTE analysis, examining the distributional impact of wheat farming on poverty, with household expenditures serving as the dependent variable and proxy for poverty status. This method is particularly valuable because it goes beyond average effects to explore how wheat farming influences poverty across different quantiles of the expenditure distribution, specifically the 15th, 30th, 45th, 60th, and 75th percentiles. This allows us to assess whether wheat farming disproportionately benefits poorer or wealthier households. The IVQTE approach addresses endogeneity (e.g., the possibility that wealthier farmers grow more wheat) by using instrumental variables, ensuring causal inference. The dependent variable, household expenditures, is a common proxy for poverty status: higher expenditures typically indicate lower poverty levels. The table reports coefficients for wheat farming's impact at various quantiles, with robust standard errors in parentheses and significance denoted as ** ($p < 0.05$) and *** ($p < 0.01$). Control variables are included but not detailed, and the sample size is 360 observations.

At the 15th and 30th quantiles, representing the poorest households, wheat farming shows no significant effect on household expenditures (coefficients: 0.0801 and 0.027, with *t*-values of 1.282 and 1.232, respectively). These *t*-values fall short of the 1.96 threshold for significance at $p < 0.05$, indicating that wheat farming does not measurably reduce poverty for the most impoverished farmers. The poorest households, likely characterized by limited land, capital, or market access, do not experience a poverty-reducing benefit from wheat farming. This could be due to insufficient scale (small wheat plots yielding marginal income), high input costs (e.g., seeds, fertilizers) that offset gains, or barriers to selling surplus wheat at profitable prices. Kolawole and Ojo [111] argues that agricultural interventions often fail to uplift the poorest farmers without complementary support like credit or infrastructure. Similarly, Kolawole and Ojo [111] notes that the benefits of crop production tend to bypass the bottom quantiles unless targeted policies address structural constraints.

Wheat farming significantly increases household expenditures at the 45th (0.3491***), 60th (0.1909***), and 75th (0.6430***) quantiles, with effects growing stronger as we move up the distribution. At the 45th Quantile (Coefficient = 0.3491, $p < 0.01$): A unit increase in wheat farming (likely wheat area or intensity) raises expenditures by 34.91% for households at this quantile. This suggests a moderate poverty-reducing effect for lower-middle-income farmers. At the 60th Quantile (Coefficient = 0.1909, $p < 0.01$): The effect weakens slightly to 19.09%, indicating a still-positive but less pronounced impact on middle-income households. At the 75th Quantile (Coefficient = 0.6430, $p < 0.01$): The largest effect occurs here, with a 64.30% increase in expenditures, showing that wheat farming disproportionately benefits wealthier farmers.

Wheat farming reduces poverty more effectively for farmers who are already better off (middle to upper quantiles). This distributional pattern suggests that the income generated from wheat, likely through higher yields or better market access, accrues to households with greater resources, such as larger landholdings, education, or equipment. The increasing coefficients across quantiles (0.3491 to 0.6430) indicate a regressive impact: wealthier farmers reap greater absolute benefits, potentially widening inequality. This aligns with Kolawole and Ojo [111], who find that agricultural growth often favors households above the poverty line due to their ability to invest in productive assets. Likewise Kolawole and Ojo [111] note that staple crop farming (e.g., wheat) benefits farmers with sufficient land and inputs, while the poorest, constrained by these factors, see limited gains.

The IVQTE results reveal a clear heterogeneity in wheat farming's poverty-reducing potential. The insignificant effects at the 15th and 30th quantiles suggest that wheat farming alone is not a silver bullet for extreme poverty. The poorest farmers may lack the scale or resources to translate wheat production into meaningful expenditure gains. The significant, increasing effects from the 45th to 75th quantiles indicate that wheat farming is most effective for farmers who are moderately poor or near-poor, with the wealthiest benefiting most. This could reflect economies of scale, better access to markets, or the ability to adopt modern farming techniques. In addition, the regressive pattern, larger benefits at higher quantiles, raises equity issues. While wheat farming reduces poverty overall, it may widen expenditure gaps between the poorest and less-poor farmers. These findings resonate with broader literature. The World Bank[112] highlights that agricultural growth reduces poverty but often unevenly, favoring farmers with land and capital. Similarly, a study by Jayne et al.[109] shows that staple crop interventions (like wheat) tend to benefit smallholders with moderate assets more than the landless or ultra-poor.

In conclusion, wheat farming has a significant distributional impact on poverty status, as measured by household expenditures, but this impact is uneven. It does not significantly alleviate poverty for the poorest farmers (15th and 30th quantiles), suggesting barriers like limited land or resources. However, it markedly boosts expenditures for middle and upper quantiles (45th, 60th, and 75th), with the wealthiest farmers gaining the most (up to 64.30% at the 75th quantile). This regressive pattern aligns with literature showing that agricultural gains often favor better-resourced households. While wheat farming contributes to poverty reduction overall, its benefits are skewed, necessitating targeted interventions to ensure the poorest farmers are not left behind.

5. Conclusion

The study provides a robust examination of the role of smallholder wheat farming in enhancing rural livelihoods within Nigeria's Sudan Savannah agro-ecological zone, offering valuable insights into its contributions to food security, and income generation. The study uncovers a stark paradox: despite profitability, 85% of wheat farming households remain food insecure, with 71–85% experiencing mild-to-moderate access issues (e.g., limited variety, smaller meals) and 19–31% facing severe conditions (e.g., no food at all). This disconnect suggests that income from wheat does not seamlessly translate into improved food access, potentially due to the "sell-to-survive" dynamic where farmers prioritize cash earnings over subsistence needs. The distributional analysis further reveals inequities, as the most food-insecure (15th quantile) see no significant improvement, and wealthier farmers (higher quantiles) capture greater income benefits. This disparity points to structural barriers, such as limited asset endowments, market access, and resource constraints, that hinder the poorest households from fully leveraging wheat farming's potential. While wheat farming contributes to poverty reduction overall, its benefits are regressive, favoring middle- and upper-income farmers over the poorest. This distributional disparity highlights the need for targeted interventions, such as improved access to land, inputs, or markets, to ensure that the poverty-alleviating potential of wheat farming extends to the most vulnerable households. In conclusion, smallholder wheat farming in the Sudan Savannah offers a promising avenue for improving rural livelihoods, evidenced by its profitability and contributions to income and food security. However, its transformative potential remains curtailed by unequal benefit distribution and entrenched constraints. The study underscores the necessity of a multi-faceted policy approach to maximize its impact: enhancing credit access, expanding irrigation infrastructure, strengthening extension services, stabilizing markets, and promoting climate-smart practices. Such measures could ensure that wheat farming not only boosts household welfare but also addresses Nigeria's broader goals of ensuring food security, narrowing inequality, and achieving wheat self-sufficiency. By filling a critical knowledge gap, this research provides a foundation for evidence-based strategies to support smallholder farmers, urging stakeholders to prioritize inclusivity and resilience in the pursuit of sustainable agricultural development.

5.1. Policy Recommendation

To maximize the benefits of wheat farming and address the identified constraints, the following actionable recommendations are proposed for policymakers, agricultural institutions, development partners, and local stakeholders: Introduce targeted subsidies for critical inputs like seeds and fertilizers. Linking subsidies to cooperative membership could streamline distribution and reduce financial burdens. With drought affecting the farmers and irrigation rent being a major fixed cost, public-private partnerships should develop affordable, community-managed irrigation schemes (e.g., solar-powered boreholes, small dams) to ensure consistent water access during the dry season, critical for wheat's viability. There is a need to expand access to climate information, which reduces food insecurity risks while also partnering with extension services and mobile networks to deliver timely weather forecasts, enabling farmers to optimize planting and irrigation schedules. There is a need to promote drought-tolerant varieties by collaborating with research institutes like ICARDA and LCRI to distribute heat- and drought-tolerant wheat varieties, addressing those who find the lack of improved planting materials severe, thereby boosting yields beyond the current yield. There is a need to strengthen farmer associations as platforms for knowledge sharing, input distribution, and collective bargaining, addressing labor shortages through communal labor pools and reducing reliance on hired labor.

5.2. Suggested Areas for Further Research

The study provides a comprehensive analysis of smallholder wheat farming's contributions to rural livelihoods in Nigeria's Sudan Savannah agro-ecological zone, yet several knowledge gaps and emerging questions warrant further investigation. The following areas are proposed to deepen understanding, address limitations, and inform policy and practice: Despite profitability, 85% of wheat farming households remain food insecure, suggesting a disconnect between income and food access. The study hints at the "sell-to-survive" trap but lacks detailed causal analysis. First, there is a need to investigate why income from wheat sales does not translate into improved household food security. Exploring factors such as market dependence, consumption patterns, intra-household resource allocation, and the role of cash crop prioritization over subsistence needs using qualitative methods (e.g., interviews) alongside quantitative data. Second, this study is specific to the Sudan Savannah, but wheat farming occurs in other Nigerian zones (e.g., Guinea Savannah), and findings may not be generalized. Future studies can conduct a comparative study of wheat farming's livelihood impacts across Nigeria's agro-ecological zones. Examine how environmental, socio-economic, and policy factors vary, informing a national strategy for wheat self-sufficiency.

Author Contributions

Conceptualization, A.J.K.; methodology, A.J.K.; software, A.K.; validation, A.J.K., S.A.I, F.O.B and M.H.F.; formal analysis, A.J.K., A.K.; investigation, A.J.K.; resources, A.J.K.; data curation, A.J.K, A.K.; writing—original draft preparation, A.J.K, A.K.; writing—review and editing, A.J.K., A.K., S.S.; visualization, A.J.K., A.K.; supervision, S.A.I., F.O.B., M.H.F.; project administration, A.J.K, A.K.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Afe Babalola University (22/PGC/SCI07/003 and 20/08/2024)

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study

Data Availability Statement

The data supporting the reported results in this study are available upon request from the corresponding author. The datasets analyzed or generated during the study are not publicly available due to privacy and ethical restrictions. However, data can be made available for academic research purposes upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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