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Economic Viability of Smallholder Agriculture in the Savannah and Transitional Zones of Ghana: Implications of Farm Output Commercialization and Farm Diversification

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Abstract: Smallholder agriculture remains the heart of Ghana's food crop production and crucial to meet the zero-hunger target. Unfortunately, rural households continue to see no significant improvement in their livelihoods, as poverty and food insecurity remain high in these areas. This has raised concerns about the economic viability of smallholder agriculture in Ghana. We estimated propensity score matching on a sample of 581 farmers to determine the economic viability of the smallholder farmers and the impact of farm output commercialization and off-farm diversification on their food security and welfare status. Large-scale (>2 ha) maize production led to 8% more yield and 96% more income than small-scale (≤2 ha) production. At observed mean levels, large-scale farmers performed better in most of the livelihood outcomes. The impact of diversification and commercialization on livelihood outcomes was mixed, based on the scale of production. For small-scale farmers, diversification reduced per capita consumption expenditure, while commercialization improved food security, consumption expenditure, and income. For large-scale farmers, diversification improved yield and food security, while commercialization improved fertilizer application rate and income but reduced yield. Although small-scale farmers are not necessarily doomed, the heterogeneity of farmers' production scale should be considered in the design of rural agricultural policies.

Keywords: commercialization; economic viability; fertilization; off-farm diversification; smallholder agriculture

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1. Introduction

Food security is a major common denominator of sustainable development. Progress toward achieving the zero-hunger objective by the end of 2030 has been rather slow due to climate change, as well as the recent COVID-19 pandemic [1] and the Russia-Ukraine war. About 768 million people (9.9% of the global population) were hungry in 2020, and almost 660 million people (7.7% of the global population) are expected to be hungry in 2030 [1]. Ahead of the United Nation's 2030 deadline for meeting the Sustainable Development Goals, the African Union (AU), through its Malabo Declaration, envisages ending hunger by 2025. Unfortunately, progress is slow, and the level of food insecurity in sub-Saharan Africa (SSA) remains serious, as 24.1% (264.2 million) of the population was undernourished and 29.5% (323.2 million) was severely food-insecure in 2020 [1].

Agriculture is an important engine for the transformation of SSA, since it provides food, and its advancement is more effective in reducing poverty than other sectors of the economy [2]. Driven by alarming rates of population growth, there is growing food demand in SSA, especially in urban areas (at a rate of 4% per year), relative to the rural areas (1%) [3]. The world's food has largely been supplied by smallholder farmers who cultivate less than 2 hectares (ha). For instance, in SSA, smallholders provide about 80% of food and occupy about 60% of the land [4]. Nonetheless, evidence shows that the economic, environmental, and societal sustainability of farms is influenced by farm size [5]. Unlike medium- to large-scale farms that operate at economies of scale with relative ease of accessing agricultural input, output, and financial markets, smallholder farmers lack these market linkages; they also operate under weak institutional support and become locked into a low-equilibrium poverty trap. Smallholder farmers, therefore, face significant challenges in raising their farm productivity, which explains their inability to attain food security and escape poverty [4,6]. For instance, Ref. [3] indicated that potential pro-poor agricultural growth must be found through financial support and an enabling policy environment to make smallholder agriculture viable in SSA. Effective market linkages, improved infrastructure development, and efficient knowledge and technology transfer are also necessary to ensure agriculture delivers on its role in improving the livelihoods of farm households.

In a case study on farming in six SSA countries, Ref. [7] concluded that farm size is a major driver of food self-sufficiency and poverty reduction and that small farms are not economically viable. Additionally, evidence shows that increasing farm size had a positive effect on food self-sufficiency and poverty reduction, suggesting that farm size of smallholders may have to grow to allow them to escape poverty and food insecurity [8]. For [9], the best and shortest pathway to addressing rural poverty in SSA is by improving the productivity of its smallholder farmers. Therefore, the ultimate empirical question is whether smallholder agriculture can be an economically viable venture and lift rural areas out of poverty. Or, can smallholder farmers in Ghana, therefore, "step-up", or should avenues for "stepping-out" production be seriously considered for development of the rural areas? Addressing these questions is important, considering that [7] argued that even when productivity gaps are closed, most smallholder farming households cannot achieve a living income. Ghana is also behind in achieving the zero food insecurity target, as about 12% of the population is either severely or moderately food-insecure [10]. Many of the food-insecure households are located in rural areas, where smallholder crop production is the major or only economic activity [11]. The high food insecurity among smallholder farmers is due to a combination of factors, including weak land tenure systems, unsustainable farming systems, climate change, inadequate markets, low access to finance, high post-harvest losses, and poor infrastructure [11,12].

For many, off-farm diversification and commercialization are critical for improving income and food security among farm households [7,13,14]. Households cannot rely solely on crop production because crops cannot be produced in the dry season in northern Ghana, hence, income from off-farm activities becomes important to the farmer's survival. Over-commercialization also negatively affects smallholder farmers if there are inefficient food markets and if they do not engage in off-farm diversification [15]. It is unclear whether such strategies can address the income and food challenges of smallholder farmers or if this can only be achieved through opportunities to make large-scale production more viable. Given these uncertainties, this study addressed two concerns.

First, the study analyzed the impact of the scale of production on the livelihood outcomes of the farmers—fertilizer use, yield, food consumption score (FCS), income, and per capita consumption expenditure. This provided a comprehensive understanding of the role of the scale of production in the livelihoods of rural households. Second, the impact of commercialization and off-farm activities on the livelihoods of small- and large-scale farmers was analyzed separately. The two hypotheses tested were:

1. The scale of production has no significant impact on the livelihood outcomes of farmers in the Guinea savannah and Transitional zones of Ghana.
2. Output commercialization and off-farm diversification have no significant impacts on livelihood outcomes based on the scale of production.

Addressing these hypotheses would help move away from the blanket recommendation of these strategies as ways of improving the food and cash resources (welfare) of rural farm households without giving recognition to the diverse characteristics differentiating small- and large-scale farmers. The findings of this study are expected to help the Ministry of Food and Agriculture (MoFA) and other stakeholders within the agriculture sector better appreciate the livelihood conditions of smallholder farmers and understand how to reshape policies to improve the wellbeing of farmers.

2. Materials and Methods

2.1. Study Location

The study was conducted in the Savannah (Guinea and Sudan) and Transitional zones of Ghana. These are predominantly agrarian regions where the major staple food crops of Ghana, including maize, are produced. The two zones are climatologically distinct; the Savannah zones have unimodal rainfall; the Transitional zone has bimodal rainfall with higher mean annual rainfall than the Savannah zones. In addition to staple food crops, farmers in the Transitional zone cultivate tree crops, such as cocoa and cashew. About 62.3% of households in the Transitional zone and 78.1% of households in the Savannah zone own or operate a farm [16]. The high involvement of households in agriculture in these zones means that improving the livelihoods of these farmers will have major implications for food security in Ghana. The study was conducted in these zones because over 91% of agricultural households here engage in arable crop production [17] and because several agricultural development programs have been implemented in these zones. Currently, Fertilizer Research and Responsible Implementation (FERARI), a program led by the International Fertilizer Development Center (IFDC), is being implemented in these zones with the objective of improving sustainable intensification, as well as food and nutritional security and reducing poverty. Research to provide empirical information to the program is crucial for its effective implementation. Figure 1 shows the location of the sampled farmers categorized based on the scale of production and fertilizer use.

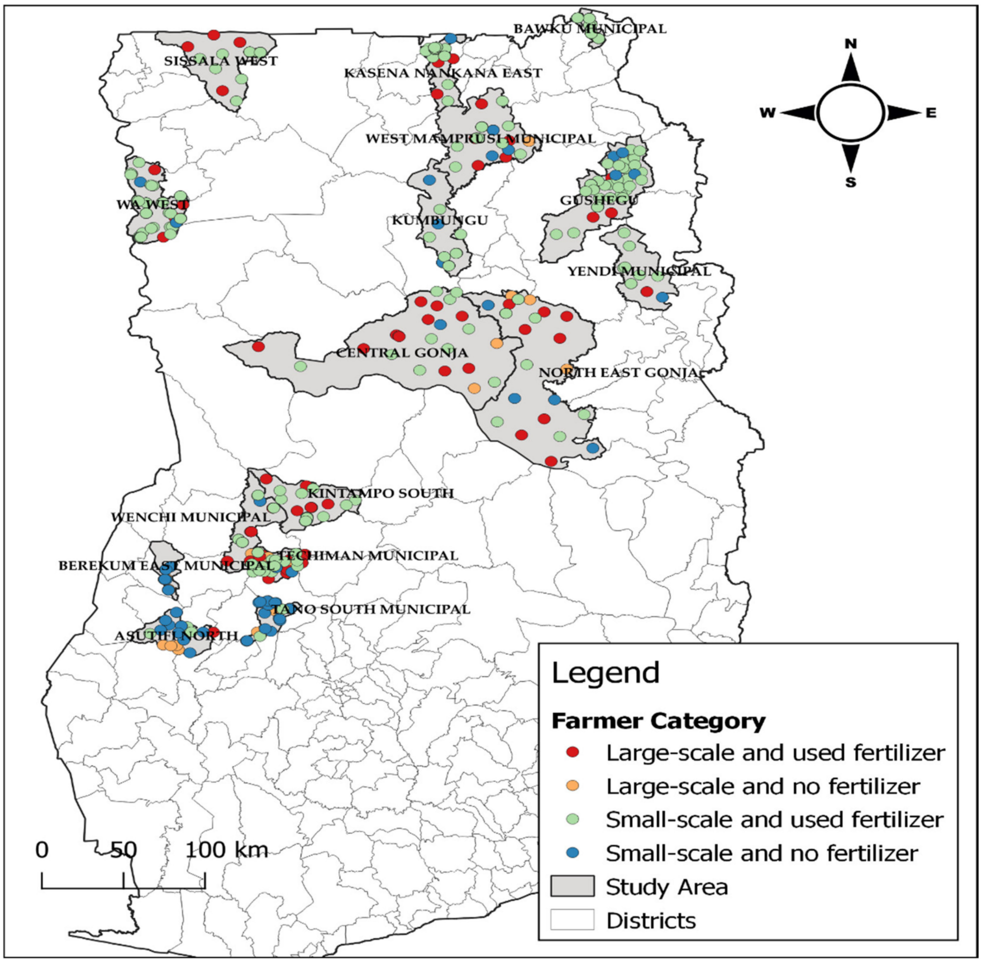

Figure 1. Farmers' locations based on their scale of production and fertilizer use.

2.2. Sampling, Data Collection, and Data Description

The minimum sample for the study was obtained using the Yamen's sample formula:

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

where n is the expected sample, N is the population and e is the margin of error. Using the agricultural household population [17] and a 5% margin of error, n is given as:

$$n = \frac{902,186}{1 + 902,186(0.05)^2} = 399.8 \tag{2}$$

Therefore, a minimum of 400 farm households was adequate for the study. However, since higher values of N have no impact on n and considering that the sampling unit is farmers and not households, the estimated sample was adjusted upward to 748 farmers. A multistage sampling procedure was used in the selection of farmers for the study.

First, purposive sampling was used in the selection of two districts in each of the eight regions in the Savannah and Transitional zones. These districts were selected based on the predominance of agricultural activities and the implementation of activities by the FERARI program in these districts. Because of the prevalence of FERARI activities in the Northern Region, three districts were selected there. In the second stage, simple random sampling was used to select four farming communities in each of these districts. This gave a total of 68 communities (44 in the Savannah zones and 28 in the Transitional zone). Simple random sampling was used in the third stage to select 11 farmers in each selected community. This gave a total of 748 farmers. However, based on the availability of the sampled farmers, the final sample per community varied, and data were valid for 745 farmers. For this study, 587 farmers who cultivated at least maize were sorted from the dataset, but six were dropped for having extreme and unrealistic farm sizes. Therefore, a total of 581 farmers were included in the analysis.

The data were collected through face-to-face interviews using a questionnaire that was computerized to minimize data collection and data entry errors. Experienced research assistants were trained on the objectives of the study, the questions in the questionnaire, and the computerized system to ensure quality data collection. About 66.6% of the interviewed farmers were men, and about 25.5% were youths (using the less than 35 years of age classification in Ghana [16]). The low female representation in the sample is because there was no deliberate attempt in the sampling to capture the gender differences in farm ownership. Only 44.8%, 55.9%, and 42.2% belonged to a farmer-based organization, received an extension service, or benefitted from an agricultural development project in the past, respectively. The level of education among the farmers was also low, considering that the average education was 4.5 years, but the level of experience in farming was high, as farmers had been involved in farming for about 15 years on average.

2.3. Data Analysis

The data were analyzed using the theory of utility maximization. The utility maximization theory is based on the assumption that individual decisionmakers make decisions that give them the highest level of utility. This means that when farmers are faced with two alternatives, for instance, to commercialize or not to commercialize, they will choose the alternative that has the highest utility. Thus, the utility function is given as:

$$U_j^* = X_j' \delta + \varepsilon_i \tag{3}$$

where U_j^* is the expected utility of observation j, X_j' is a vector of characteristics of observation j, δ is a vector of parameter estimates, and ε_i is an error term. Then, the individual j would make a particular decision if and only if $U_{jt}^* > U_{jnt}^*$, where U_{jt}^* is the utility from accepting a condition, and U_{jnt}^* is the utility from rejecting that condition.

In this study, farmers' decisions on the scale of production (small-scale versus medium- to large-scale production), commercialization (commercialized versus non-commercialized), and diversification (off-farm diversification versus no off-farm diversification) were compared. Utility was defined as having an improved livelihood that is measured by the fertilizer quantity used, yield, FCS, income, and per capita consumption expenditure. Depending on the expectations of individual farmers toward any of these utility indicators and based on the characteristics of the individual farmer, he or she makes a particular decision on the scale of production, commercialization, and diversification. The decisions of farmers on the scale of production, commercialization, and diversification can simply be modified using a binary response model such as probit/logit or a seemingly unrelated bivariate probit regression. However, the prime focus of this study instead was on the impact of such decisions on the farmer's livelihood. We could simply estimate the impact of these decisions on the utility indicators (livelihood outcomes) directly using an average response model, such as the ordinary least square (OLS). This would be problematic because the decisions are not exogenous, and the decisions are also not randomly assigned to them. Therefore, it is important to address the self-selection bias when estimating the impact of the decisions on the utility indicators. This study applied propensity score matching to the dataset, which helped resolve the self-selection limitations. Propensity score matching has largely been applied in adoption studies, especially in agriculture.

Propensity score matching involves two stages. In the first stage, the decisions of farmers are modeled using binary (logit in this study) regression, which allows the propensity scores for the individual farmers to be estimated. This is given as:

$$D_i = X_i\gamma + \varepsilon_i \tag{4}$$

where D_i is the decision variable, defined as 1 for small-scale, commercialized, and diversified farmers and 0 for medium- to large-scale, non-commercialized, and non-diversified farmers. X_i are the characteristics of the farmers, while γ are the parameter estimates on each characteristic.

In the second stage, the average treatment effect on the treated (ATT) was estimated based on the propensity scores estimated from the first stage. This involves matching treatment farmers with control farmers based on the similarity of their characteristics. The matching was performed using the propensity score matching technique that chooses a case in the control group that is nearest to each case in the treatment group. Therefore, the ATT is the net impact of the decisions on the utility indicators (outcomes) of the farmers. Following studies such as [18,19], the ATT can be estimated as:

$$\text{ATT} = E(y_{1i} - y_{0i}|D_i) = E(y_{1i}|D_{i=1}) - E(y_{0i}|D_{i=1}) \tag{5}$$

where $E(\cdot)$ is the expectation, y is the outcome, and D is the decision variable. Because propensity score matching using Equation (3) provides unbiased estimates under conditional independence and the ATT is defined only within the region of common support, we proceeded with its estimation. This approach has been used extensively according to the literature [20–23]. For brevity, the results of the selection models are not presented but will be made available on request.

2.4. Measurement of Outcome Variables

The food security level of farmers was determined using the food consumption score. This is a score calculated based on the frequency of consumption of eight different food groups within the 7 days preceding the date of data collection. Each food group was multiplied by a standard weight, and the results were summed to obtain the FCS of the household. The food groups and associated weights included cereals and tubers (2), pulses and nuts (3), vegetables (1), fruit (1), meat/fish (4), milk (4), sugar (0.5), and oil (0.5). The FCS is thus an indicator of dietary diversity and frequency of consumption, a proxy for a household's caloric availability. The FCS ranges from 0 to 112, and the approach has been used extensively in the literature [11,24] and by the World Food Programme for its Comprehensive Food Security and Vulnerability Analysis (CFSVA). The income level of the farmers is the total sum of annual income from farming maize and other crops, livestock, non-farm employment, sale of personal assets, remittances, and any other activities identified by the farmer. The data show that, on average, the revenue from maize production accounted for about 47.6% of the income of farmers within the sample, with no more than 1% from the sale of personal assets and other income sources. The per capita consumption expenditure of farmers was determined from the sum of a household's total expenses for food and non-food items, weighted by the square root of the household size. Farmers were also classified into two groups based on the total area of maize cultivation. Those who cultivated 2 ha or less were classified as small-scale farmers, while those who cultivated more than 2 ha were classified as large-scale farmers. This classification is based on the general definition of a small-scale farm as a cultivated area of not more than 2 ha [17]. Diversification was defined as binary for farmers who engaged in any other economic activity in addition to maize production and those who did not. Similarly, commercialization was binary for farmers who sold part of their harvested maize produce and those who did not sell any portion of their harvested produce.

3. Results

3.1. Mean Statistics of Farmers' Livelihood Outcomes Based on Scale of Production

The data show that 70.7% of the sampled farmers cultivated not more than 2 ha of farmland in maize, while the remaining 29.3% cultivated more than 2 ha to about 8.5 ha (Table 1). From the Ghana Statistical Service [25], about 68% of Ghanaian farmers cultivate starchy staples on not more than 2 ha of land. The average maize farm size of the sampled farmers was 1.6 ha, with a statistical difference between small-scale (0.9 ha) and large-scale (3.4 ha) farmers. Of the small-scale farmers, 77.4% used fertilizers and applied an average fertilizer quantity of 223.1 kg per hectare (kg/ha); of the large-scale farmers, 72.4% used fertilizers and applied an average fertilizer quantity of 181.5 kg/ha. The observed difference in fertilizer quantity used was statistically significant. Although the mean values for both were below the recommended rate of 350–500 kg/ha for a 5 metric ton per hectare (mt/ha) yield target [26,27], the relatively low fertilizer application rates among the large-scale farmers were because they applied the quantities bought on their larger farms. The inability of farmers to apply fertilizers at recommended rates was largely due to financial difficulties [28]. More small-scale farmers (71.8%) than large-scale farmers (65.1%) also mentioned soil degradation as having a high impact on their maize production, which could underscore the relatively high fertilizer application rate among small-scale farmers. There was no significant difference in yield between the small-scale (1489.3 kg/ha) and the large-scale (1543.5 kg/ha) farmers, which could perhaps be the main reason for the insignificant difference in the FCS between the farmers. The insignificant difference in yield implies that large-scale farmers had a higher fertilizer use efficiency than the small-scale farmers. This is important for improving soil health and ensuring a sustainable increase in crop yields. Generally, the low yields despite the observed fertilizer application rates are an indication that other covariates, including the socioeconomic conditions of the farmers, should be considered in determining fertilizer recommendations.

Large-scale farmers have significantly better welfare than the small-scale farmers, as their income and consumption expenditure are higher. Overall, the observed mean per capita consumption expenditures are consistent with national data, as the average for the regions considered in this study ranged from GHS 1588 to GHS 3353 [29]. The data also showed that the large-scale farmers saved about 73% more of their income than the small-scale farmers. Figure 2 shows that income had a positive association with other indicators, suggesting that an increase in the income of the farmers would likely result in an improvement in the other indicators. Farm size also positively correlated with yield, income, and per capita consumption expenditure. The negative correlation of farm size with fertilizer application rate is justifiable since farmers often lack the financial resources for investing in the purchase of large quantities of fertilizers. Where the farms are small, the fertilizer quantity required is low, and it is possible that farmers may be able and willing to buy adequate quantities. However, the reason for the negative correlation between farm size and FCS is unclear, since [7] concluded that farm size is a major determinant of food self-sufficiency.

Table 1. Mean statistics of livelihood outcomes.

Factor	Small-Scale	Large-Scale	T-Value
Farm size (ha)	0.9	3.4	29.08 ***
Fertilizer (kg/ha)	223.1	181.5	−2.44 **
Yield (kg/ha)	1489.3	1543.5	1.17
Income (GHS/year)	4791.2	10,935.6	7.96 ***
Per capita consumption expenditure (GHS/year)	2222.5	2793.5	3.17 ***
FCS	72.2	70.2	−1.16

*** and ** indicate significance at 1% and 5%, respectively.

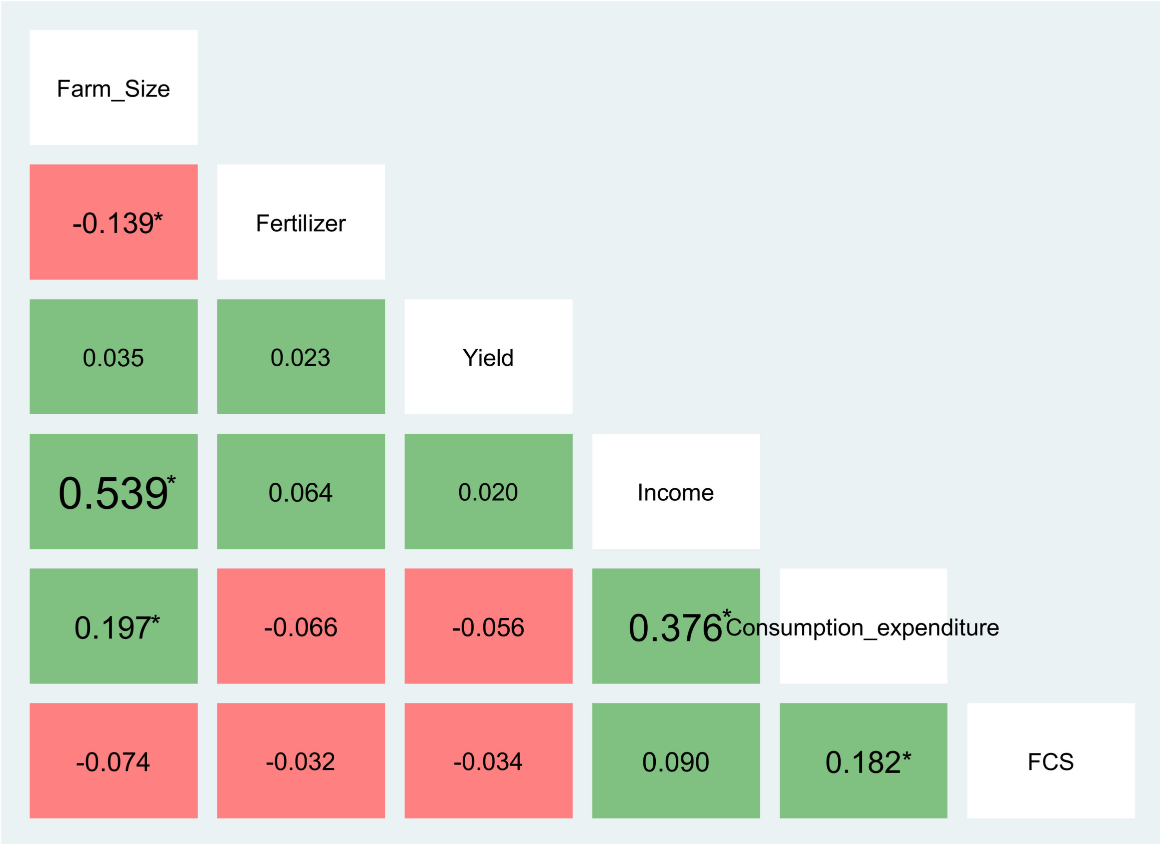

Figure 2. Correlation matrix on livelihood outcomes. Red and green colors indicate negative and positive correlation, respectively. * indicates significance of correlation coefficient at 5%.

As indicated in the Data Analysis section, the observed mean differences in Table 1 were estimated from a self-selected (non-random) sample; hence, farmers who chose to cultivate on a large-scale may have had characteristics that were distinct from those who chose to cultivate on a small scale. These unique characteristics correlate with the livelihood outcomes in Table 1. Therefore, further statistical analyses on these indicators were subsequently conducted. These were estimated using comparable subsamples of small-scale and large-scale farmers. Therefore, the subsequent average treatment estimates should not be confused with the observed mean estimates in Table 1.

3.2. Impact of Scale of Production on Livelihood Outcomes

Unobserved factors also influence the effect a farmer's decision will have on the scale of production. Therefore, it is appropriate to correct for such unobserved effects and to match the samples based on similar observed characteristics. This was achieved through propensity score matching. Thus, given a set of covariates, the model identifies farmers within a common support (sufficient overlap in the characteristics between the treated and control to identity adequate match) and compares the performance of matched large-scale farmers with that of small-scale farmers. The estimates show that although the small-scale farmers performed better on all the indicators except yield and income, the differences were statistically insignificant (Table 2). However, the differences in yield and income, for which the large-scale farmers performed better, were statistically significant. Therefore, improving the incomes of farming households is a viable factor for improving the livelihoods of farmers, which can be achieved through large-scale maize production, complemented by other income sources. Two such complementary income sources are off-farm diversification and farm commercialization. Giller et al. [7] argued that off-farm employment is mandatory if farm households are to be food-secure and obtain a higher income, and the authors further recognized the important role of market access in improving farmers' livelihoods. Farm commercialization intensifies social stratification by increasing the income of the commercial farmers, who intend to invest such increased incomes in cultivating more land [30]. Recognizing this evidence, the impacts of commercialization and off-farm diversification on the livelihood of small-scale and large-scale farmers were examined separately. This is important in determining how these strategies best suit the diversity among the farmers.

Table 2. Average treatment effect of scale of production on livelihood outcomes based on a matched sample.

Indicator	Treated (Large-Scale)	Control (Small-Scale)	Difference	Change (%)	T-Value
Fertilizer (kg/ha)	181.6	201.9	−20.3	−10.0	−0.8
Yield (kg/ha)	1543.5	1428.9	114.6	8.0	1.85 *
Per capita consumption expenditure (GHS/year)	2793.5	2859.8	−66.3	−2.3	−0.23
Income (GHS/year)	10,935.6	5580.7	5354.9	96.0	4.43 ***
FCS	70.2	70.6	−0.5	−0.7	−0.18

* and *** indicate significance at 10% and 1%, respectively.

3.3. Difference in Scale of Production by Diversification or Commercialization

The cultivated farm size was analyzed by classifying farmers based on their application of fertilizers, engagement in commercialization of output, and participation in off-farm economic activity (Figure 3). Small-scale farmers, whether or not they used fertilizer, cultivated the same average farm area, but medium- to large-scale farmers who used fertilizers cultivated 0.3 ha less than those who did not, although the difference was not significant. About 60.4% of maize farmers commercialized their output. Commercialization was significantly higher among large-scale farmers (82.9%) than small-scale farmers (51.1%). Although the small-scale and large-scale commercial farmers cultivated more farmland on average than the non-commercial farmers, the difference was significantly higher among large-scale farmers. This suggests that farmers who cultivated larger farmlands obtain higher outputs beyond subsistence and will sell portions of the output. The promotion of large-scale maize production must, therefore, take into consideration the market opportunities for the farmers. Considering that maize is the number one staple of the country, with high industrial demand as well as export potential, market opportunities do exist. Therefore, regulatory policies and infrastructural development to connect the farmers to these market opportunities are necessary. As explained by [30], commercialization results in improved incomes that can be reinvested into cultivation of larger farm areas.

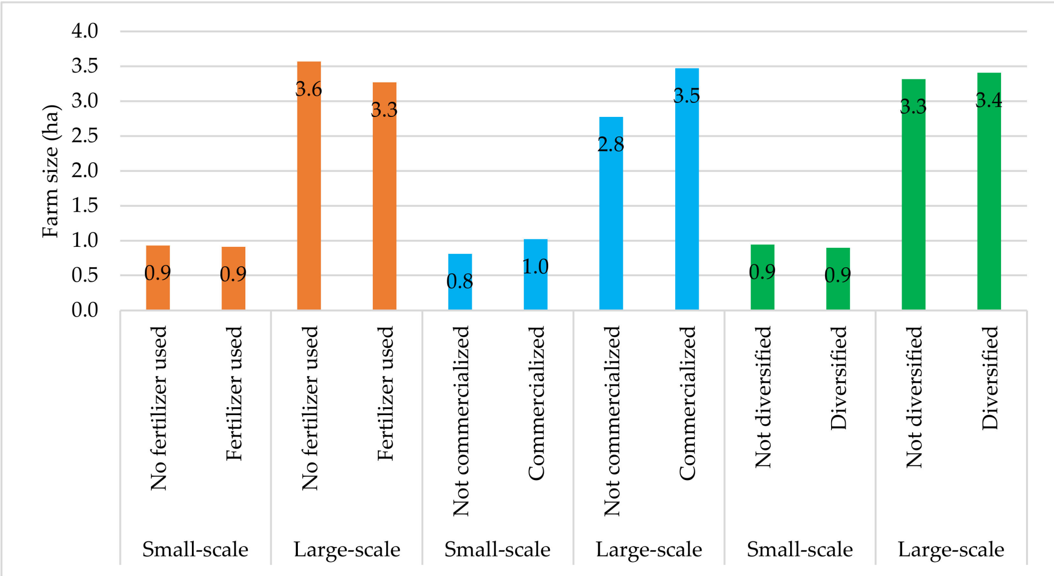

Figure 3. Mean cultivated area (ha) of unmatched sample by category of farmer.

Although off-farm diversification has been widely considered in the literature [21], there is no understanding of how its impact could vary based on the farmers' scale of production. About 49.9% of farmers engaged in off-farm diversification, but this was higher among small-scale farmers (53.8%) than large-scale farmers (40.6%). No difference was observed in the cultivated area of farmers who participated in off-farm diversification. Participation in off-farm activities generates additional income and, therefore, is considered a risk management strategy among farmers [31]. Johnston et al. [32] explained that diversification not only provides economic and agronomic gains, but also social benefits. Although the additional income was expected to be invested in increasing the cultivated area, that was not the case in this study. It is possible that farmers reinvest income from non-farm activities into similar activities and not their farms. Distribution of the cultivated area was normal, irrespective of the factor used in the classification (Figure A1).

3.4. Difference in Fertilizer Application Rate and Yield by Scale of Production with Diversification and Commercialization

Figure 4 explains the variation in the influence of commercialization and diversification on the fertilizer application rate among small-scale and large-scale farmers. While large-scale commercial farmers used more fertilizers than their non-commercial counterparts, no difference was seen in the fertilizer application rate among the commercial and non-commercial small-scale farmers. This implies that although the fertilizer application rate is low among large-scale farmers, it is higher for the commercial ones. Although the observed yield was slightly higher for the small-scale commercial farmers than their non-commercial counterparts, the difference was insignificant. The large-scale commercial farmers had a lower yield, suggesting a lower fertilizer use efficiency for these farmers than for the large-scale non-commercial farmers. Considering [28] estimated fertilizer use efficiency to be low among farmers in the study regions, the better performance of large-scale farmers in this study provides a case study for promoting large-scale crop production. Consistent with the insignificant yield difference between small-scale and large-scale farmers (Table 1), the result suggests commercialization had no significant effect on the yield within the scale of production.

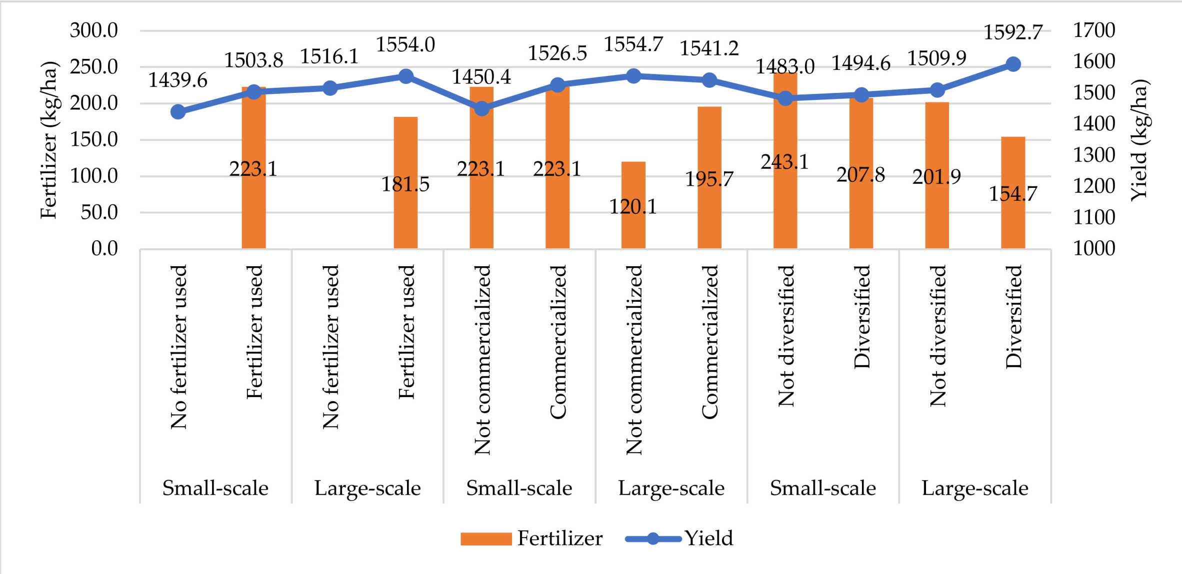

Figure 4. Mean statistics of fertilizer application rate and yield among an unmatched sample.

Non-diversified farmers used more fertilizers but had lower yields than the diversified farmers. This implies that although diversification into off-farm activities causes farmers to use lower quantities of fertilizer, they are able to maximize the efficiency of fertilizer and other inputs to obtain a higher yield. The difference in yield between diversified and non-diversified large-scale farmers was significant. The lower fertilizer application rate among diversified farmers contradicts [33], who explained that off-farm activities lead to an improved investment in productivity-enhancing inputs, such as fertilizer and pesticides. There is a right-tailed distribution in the fertilizer application rate by the farmers (Figure A2), suggesting that most farmers applied lower quantities of fertilizer and only a few applied larger quantities. For yield, there was generally a normal distribution among the farmers (Figure A3).

Tables 3 and 4 show the treatment effect results of the matched samples. Table 3 shows that diversification had a significant impact on only the yield of large-scale farmers. The causal effect of diversification was a yield increase of 13.9% among diversified large-scale farmers over that of non-diversified large-scale farmers. Although insignificant, diversification led to a reduction in crop yield among small-scale farmers. Moreover, while commercialization had an insignificant impact on the fertilizer use and yield of small-scale farmers, it increased the fertilizer use and reduced the yield among large-scale farmers (Table 4). The general conclusion that diversification and commercialization improve yield must be made within the context of the scale of production. Otherwise, such blanket recommendations will produce both negative and positive impacts, and the net impact may be a low yield in the region.

Table 3. Impact of diversification on fertilizer application and yield by scale of production based on a matched sample.

Outcome	Treated (Diversified)	Control (Non-Diversified)	ATT	Change (%)	T-Value
		Small-scale farmers			
Fertilizer (kg/ha)	212.9	259.5	−46.6	−18.0	−1.57
Yield (kg/ha)	1491.8	1506.5	−14.7	−1.0	−0.21
		Large-scale farmers			
Fertilizer (kg/ha)	158.0	181.2	−23.2	−12.8	−0.34
Yield (kg/ha)	1587.8	1394.6	193.2	13.9	1.6 *

* indicates significance at 10%.

Table 4. Impact of commercialization on fertilizer application and yield by scale of production based on a matched sample.

Outcome	Treated (Commercialized)	Control (Non-Commercialized)	ATT	Change (%)	T-Value
		Small-scale farmers			
Fertilizer (kg/ha)	232.8	223.6	9.3	4.1	0.35
Yield (kg/ha)	1518.9	1452.5	66.4	4.6	0.89
		Large-scale farmers			
Fertilizer (kg/ha)	223.4	81.1	142.3	175.4	3.57 ***
Yield (kg/ha)	1527.0	1739.8	−212.8	−12.2	−1.65 *

* and *** indicate significance at 10% and 1%, respectively.

3.5. Difference in Food Security by Scale of Production and Fertilizer Use with Diversification or Commercialization

The mean distribution of the FCS shows small-scale farmers who applied fertilizer had a higher FCS, while large-scale farmers who applied fertilizer had a lower FCS. Commercial farmers had a lower FCS than non-commercial farmers, and the difference was significant for large-scale farmers. While small-scale diversified farmers had a higher FCS than their non-diversified counterparts, the large-scale diversified farmers had a lower FCS than their non-diversified counterparts (Figure 5). This implies that there is a mixed effect of diversification on the food security of farm households based on their scale of crop production. The distribution of FCSs (Figure A4) shows that most of the farmers were centered around the estimated means.

The estimates of the impact of diversification and commercialization on food security based on matched samples show that diversification and commercialization can lead to improved food security (Table 5). However, the significant relevance of these strategies varied by the scale of production. For instance, diversification significantly improved the food security level among large-scale farmers, while commercialization improved the food security among small-scale farmers. These results help delineate the type of strategy that should be adopted by small-scale and large-scale farmers to reach the goal of improved food security. Empirically, Ref. [22] argued that there is little evidence that commercialization leads to improved nutrition, while [34] explained that although diversification is necessary, it is not enough to improve the food security of some households. Owusu et al. [35] also noted that engaging in non-farm activities improved the food security among farm households. For [36,37], improving market conditions were found to be important for improving dietary diversity among smallholder farmers. Justus et al. [14] argued that commercialization improves the dietary diversity of farmers and reduces the number of food shortage coping strategies adopted by farmers. Such findings may have been masked by the scale of production, which may partly explain the reason for the mixed results obtained by previous studies. While the conclusion that off-farm employment must be pursued alongside farming to improve food security [7] was confirmed in this study, the impact was only significant for large-scale farmers.

Table 5. Impact of diversification and commercialization on food consumption score based on a matched sample.

Factor	Farmer Group	Treated	Control	ATT	Change (%)	T-Value
Diversification	Small-scale	75.0	72.3	2.8	3.8	0.96
	Large-scale	72.1	62.6	9.5	15.2	1.80 *
Commercialization	Small-scale	71.4	65.5	5.8	8.9	1.83 *
	Large-scale	70.1	74.0	−3.9	−5.3	−0.56

Note: * indicates significant at 10%. Treated is diversified or commercialized farmers and control is non-diversified or non-commercialized farmers.

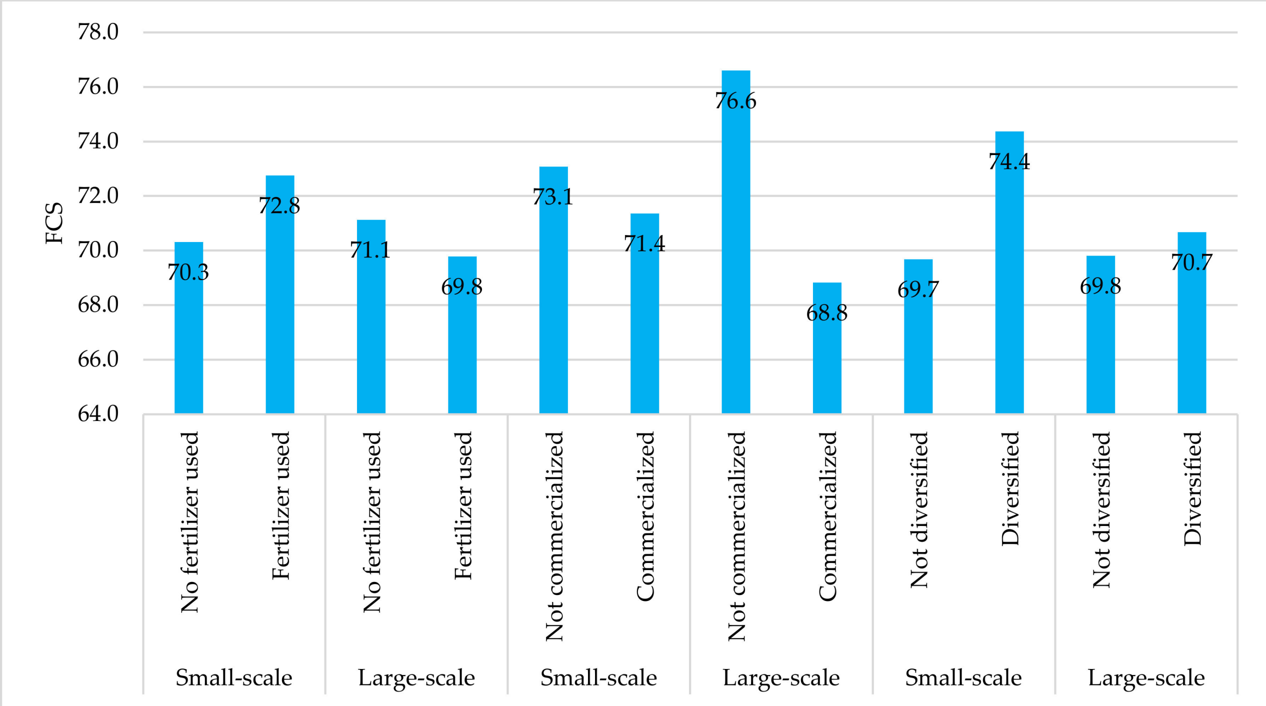

Figure 5. Food consumption score by scale of production and fertilizer use with diversification or commercialization of an unmatched sample.

3.6. Difference in Income and per Capita Consumption Expenditure by Scale of Production with Diversification or Commercialization

Diversification and commercialization had an influence on the income and per capita consumption expenditure of small-scale and large-scale farmers (Figure 6). Irrespective of the scale of production, there was a positive relationship between the income and per capita consumption expenditure of the farmers. Commercial and diversified small-scale farmers had higher income and per capita consumption expenditure. While commercialization influenced a rise in the income and per capita expenditure of the large-scale farmers, diversification increased the income but reduced the per capita consumption expenditure. The distributions of income and per capita consumption expenditure are shown in Figures A5 and A6, respectively.

The estimates of causality show that diversification led to a 25.1% and 40.7% increase in the per capita consumption expenditure and income of small-scale farmers, respectively (Table 6). For large-scale farmers, diversification led to an improvement in income and reduction in per capita consumption expenditure, although the impact was not significant. This means diversification is an essential strategy for improving the standard of living among small-scale farmers and is also a necessary tool for the large-scale farmers. This provides further clarity on the type of farmer to target with off-farm opportunities, considering that empirical studies (e.g., Ref. [21] have concluded that off-farm diversification improves income and welfare. For [7], off-farm diversification is a "must" for farm households. Mahama and Nkegbe [13] also concluded that livelihood diversification improves the per capita consumption expenditure of Ghanaian households in the short term and asset accumulation in the long term. Juxtaposing these conclusions with the present study suggests that small-scale farmers are the appropriate target for off-farm opportunities.

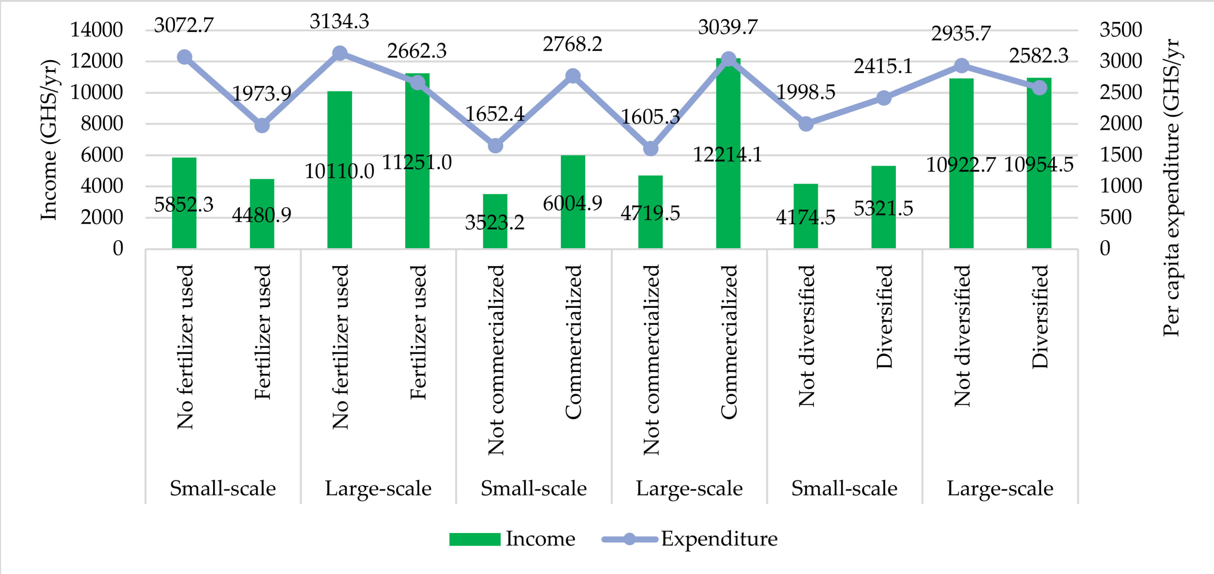

Figure 6. Income and per capita consumption expenditure by scale of production and fertilizer use with diversification or commercialization of an unmatched sample.

Table 6. Impact of diversification and commercialization on income and per capita consumption expenditure based on a matched sample.

Outcome	Treated (Diversified)	Control (Non-Diversified)	ATT	Change (%)	T-Value
		Small-scale farmers			
Consumption expenditure (GHS/year)	2507.6	2005.0	502.6	25.1	2.00 **
Income (GHS/year)	5476.8	3892.6	1584.1	40.7	2.39 **
		Large-scale farmers			
Consumption expenditure (GHS/year)	2622.4	3189.7	−567.3	−17.8	−0.93
Income (GHS/year)	11,113.3	10,516.8	596.5	5.7	0.16

** indicates significance at 5%.

Commercialization had a positive impact on the income and per capita consumption expenditure of both small-scale and large-scale farmers (Table 7). However, the impact on per capita consumption expenditure among large-scale farmers was statistically insignificant. With improved commercialization of output, farmers can generate the needed income to meet their household needs. Therefore, improving market access and market conditions can be an important way of incentivizing farmers to commercialize. The results also suggest that commercialization can be a strategy for developing rural areas and for reducing poverty among farmers. The percentage change due to commercialization was higher for large-scale farmers than small-scale farmers. The implication is that providing equal market opportunities to both small-scale and large-scale farmers results in more gains in the livelihoods of the latter group of farmers. This calls for a reassessment of more efficient ways of improving the livelihoods of small-scale farmers.

Table 7. Impact of commercialization on income and per capita consumption expenditure based on a matched sample.

Outcome	Treated (Commercialized)	Control (Non-Commercialized)	ATT	Change (%)	T-Value
		Small-scale farmers			
Consumption expenditure (GHS/year)	2705.6	2121.5	584.1	27.5	2.11 **
Income (GHS/year)	6099.6	3784.4	2315.2	61.2	2.68 ***
		Large-scale farmers			
Consumption expenditure (GHS/year)	2942.9	2262.1	680.8	30.1	1.18
Income (GHS/year)	13,473.3	4364.0	9109.3	208.7	4.06 ***

** and *** indicate significance at 5% and 1%, respectively.

3.7. Difference in Poverty Status by Scale of Production, Diversification, Commercialization and Fertilizer Use

Due to the unexpected insignificant impact of commercialization and diversification on the consumption expenditure of large-scale farmers, further descriptive distribution was estimated (Figure 7). Farmers were further classified into three poverty groups based on their per capita consumption expenditure. Following [29], farmers with a per capita expenditure below GHS 792.05 were considered extremely poor, as they could not meet their nutritional needs (2900 calories per adult equivalent per day) even if all consumption expenditure were allocated to food; those with a per capita expenditure above GHS 1314 were considered rich, because they could meet their food and non-food needs; and those with a per capita expenditure of GHS 792.05–1314 were considered poor, as they could only meet their food needs. About 23.1% of the farmers were extremely poor, with almost twice as many small-scale farmers (26.5%) in that category compared to large-scale farmers (14.7%) (Figure 7). This is comparable to the 15.6% level of extreme poverty among rural Ghanaian households [29]. Giller et al. [7] found that, at best, only one-third of farming households in SSA were non-poor and argued that farm size is a crucial driver of farm income among farming households.

Most of the small-scale farmers who either used fertilizers, engaged in off-farm activity, or were commercialized lived above the poverty line. Most of the large-scale farmers who either used fertilizers, were commercialized, or did not engage in off-farm activities lived above the poverty line. The non-use of fertilizers placed most of both the small- and large-scale farmers in extreme poverty, where they were unable to meet their food needs. The lack of commercialization also played a significant role in limiting the ability of both small- and large-scale farmers to meet their household food needs because they were unable to generate the income needed to purchase food items beyond their production. Although more diversified large-scale farmers than their non-diversified counterparts lived below the poverty line, the proportion was still better than that observed for the diversified and non-diversified small-scale farmers. The chi-square estimates showed a significant difference in the observed poverty distribution based on the specific indicators. Generally, the results suggest that fertilizer use pushes more small-scale farmers above the poverty line than commercialization or diversification, while commercialization pushes more large-scale farmers above the poverty line than the use of fertilizer or diversification. Although these strategies cannot be substituted for each other, it is important that blanket recommendations not be offered toward poverty reduction among large- and small-scale farmers.

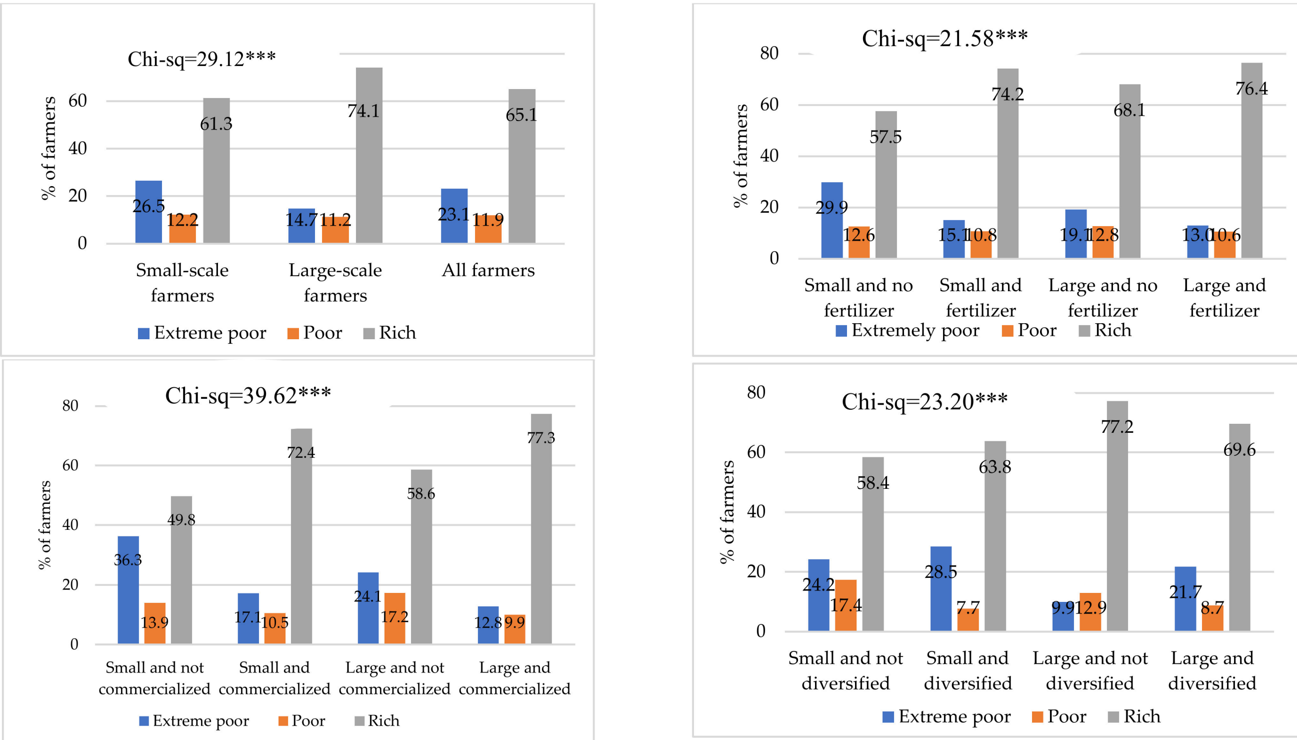

Figure 7. Difference in poverty status by scale of production, diversification, commercialization and fertilizer use. *** indicates significance at 1%.

4. Conclusions

Smallholder farmers remain at the heart of Ghana's agriculture and rural development. However, poverty among the rural population increased from 37.9% in 2012/13 to 39.5% in 2016/17 [29], while rural households constituted 78% of Ghana's 3.6 million food-insecure households [10]. Thus, concern has been raised about the economic viability of rural smallholder agriculture. This study provided an empirical analysis of the impacts of smallholder agriculture on household livelihoods and addressed the strong recommendations for commercialization and off-farm diversification for improving food security and household welfare. Further, the different impacts of these strategies on the farmers' livelihoods were analyzed based on the scale of crop production. Only about three in every 10 of the sampled farmers cultivated maize farms on a large scale (>2 ha), while seven in every 10 farmers cultivated maize on a small scale (≤2 ha). The average maize farm size of the sampled farmers was 1.6 ha, and the difference between small-scale (0.9 ha) and large-scale (3.4 ha) farmers was statistically significant. Except for yield and food consumption score for the unmatched farmers (without correcting for endogeneity), the mean statistics of the small-scale and large-scale farmers differed significantly. Generally, two conclusions can be drawn from this study, based on the studied hypotheses.

Firstly, the average treatment effect from the comparable groups (after correcting for endogeneity) shows that the scale of production has a significant impact on only the yield and income of the farmers. Large-scale production increased yield by 8% and income by 96% over the yield of small-scale farmers. The scale of production had no significant impact on fertilizer application rate, consumption expenditure, or food security, although the small-scale farmers performed better at mean levels. However, considering the fundamental relevance of higher yield and income on farm households, it is important to design policies that will favor crop production beyond 2 ha. For instance, the fertilizer subsidy program restriction in which a farmer is entitled to no more than 15 bags could result in low fertilizer use per hectare among large-scale farmers since they would need to buy extra fertilizers at commercial prices. Such policies may not incentivize farmers to participate in large-scale production and should be reviewed. Already, the indication from this study is that the large-scale farmers used lower quantities of fertilizer but had a higher yield than the small-scale farmers. This suggests that increasing fertilizer application to the recommended 350–500 kg/ha rate may not give the desired yields under small-scale production. Therefore, the policy design of the Government of Ghana's Planting for Food and Jobs (PFJ) to limit the fertilizer subsidy program to small-scale farmers (no more than 15 bags (750 kg) of subsidized fertilizer per farmer) should be reevaluated since the results of this study show that small-scale farmers use more fertilizer per hectare than large-scale farmers. Although Ghanaian agriculture is dominated by small-scale production, the revision of public policies to support large-scale production could enable the country to sustainably produce enough food to feed its citizens.

Secondly, although off-farm employment is high, especially among small-scale farmers, its impact on most of the livelihood outcomes was insignificant. Diversification significantly improved the yield of large-scale farmers by 13.9% and their FCS by 15.2%. On the other hand, it improved the consumption expenditure of small-scale farmers by 25.1% and their income by 40.7%. So, while diversification helps large-scale farmers meet their food needs, it helps small-scale farmers meet their cash needs. Therefore, the design of every project or policy for the promotion of off-farm employment among farmers must take into consideration the primary objective of the policy alongside the farmers' scale of production. About two in every five farmers sold (commercialized) part of their harvested maize output. Generally, this had a significant impact on the livelihoods of the farmers. Specifically, commercialization improved the fertilizer application rate of large-scale farmers by 175.4% and income by 208.7%, but significantly reduced their yield by 12.2%. Although commercialization had no significant impact on the fertilizer application rate and yield of the small-scale farmers, it significantly improved their food security by 8.9%, per capita consumption expenditure by 27.5%, and income by 61.2%. These results support the hypothesis for farm commercialization and market opportunities as tools for improving the livelihoods of the farmers.

Overall, smallholder farmers must not be considered as a homogenous group of people, but their heterogeneity should be considered in the design of rural and agricultural projects. The current fertilizer application rates, as related to the observed yields, suggest that the high fertilizer application rate recommendation is not sustainable. Instead of overemphasizing fertilizer (high application rates) for yield improvement, stakeholders including MoFA and non-governmental organizations must consider providing more training and sensitization for farmers on the adoption of complementary production practices alongside fertilizer application. To improve yields with the current fertilizer application rates, extension services provided to farmers on appropriate fertilizer use (application of recommended fertilizers at recommended times and rates) must be stepped up by both public and private extension officers within the agroecological zones. The current fertilizer price hikes, which pose a challenge to fertilizer use by farmers in Ghana, also provide an opportunity to reexamine sustainable maize production in the country at the current fertilizer application rates.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

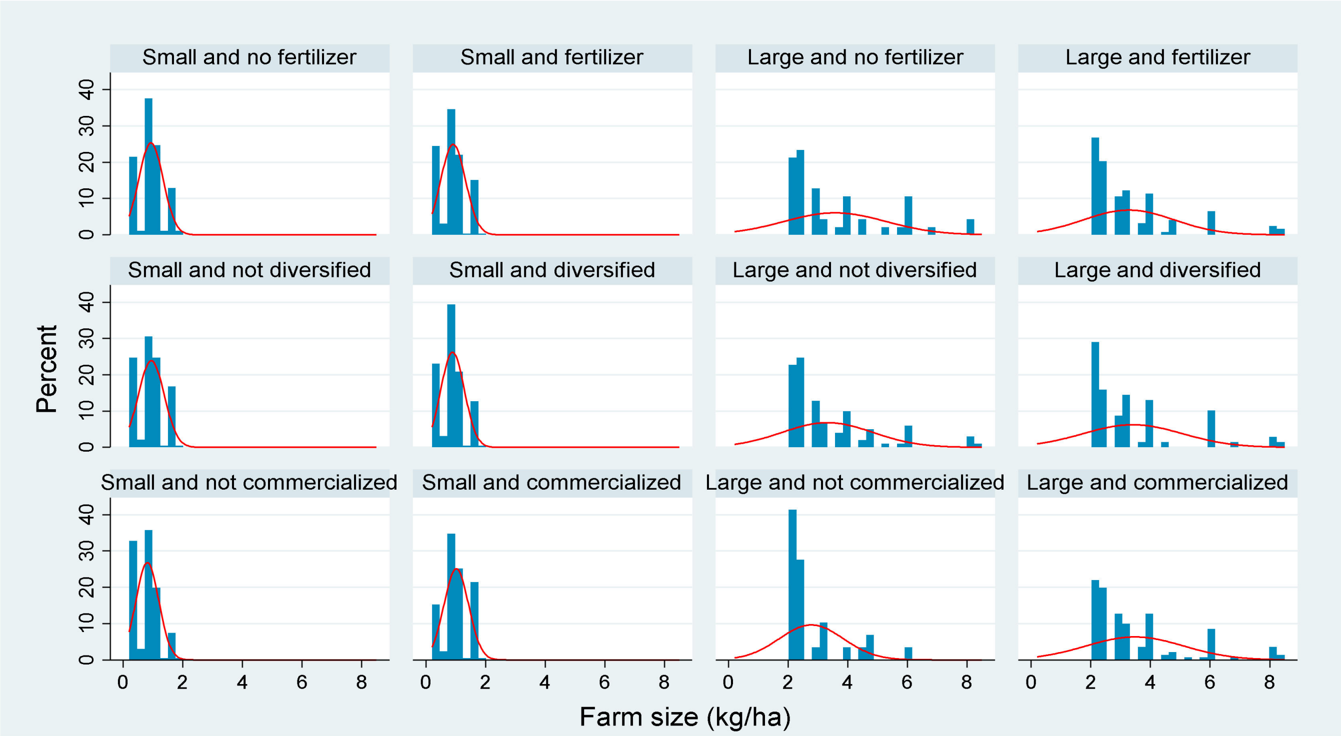

Figure A1. Distribution of cultivated area among farmers.

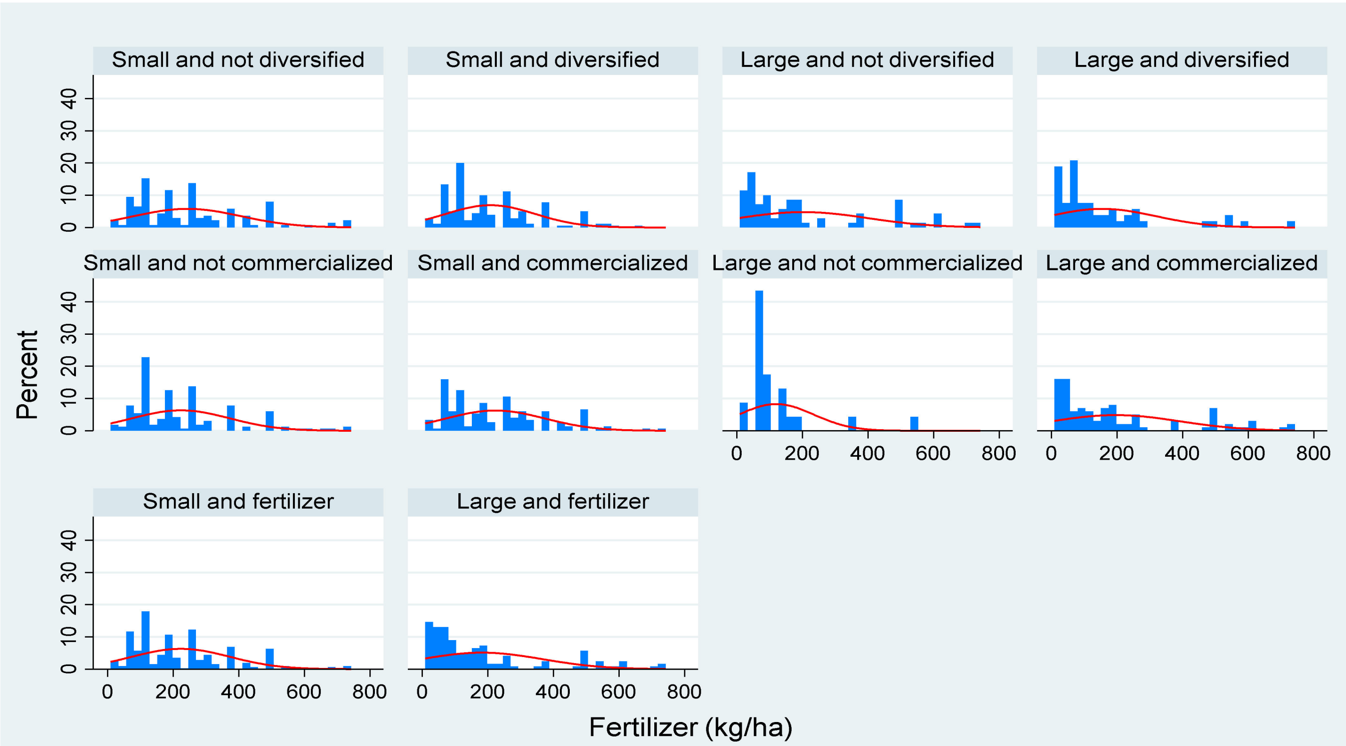

Figure A2. Distribution of fertilizer application rate among farmers.

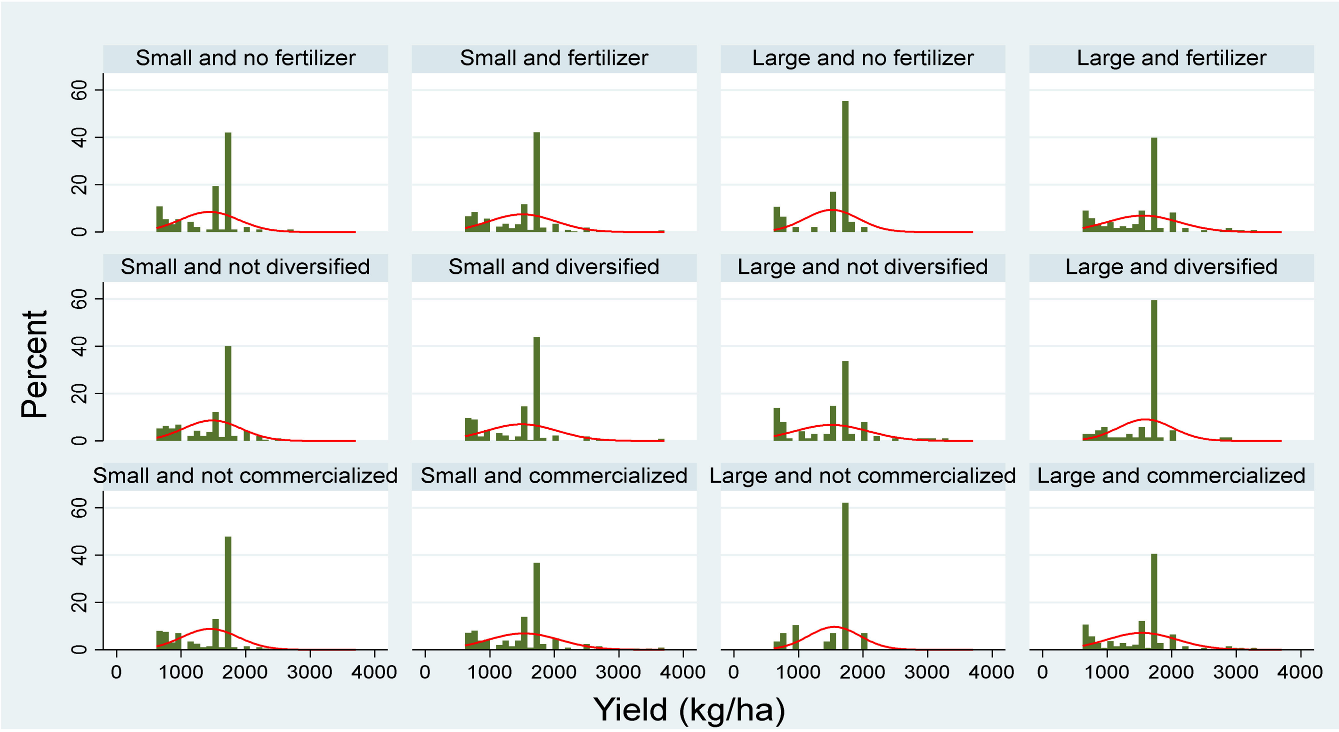

Figure A3. Yield distribution among farmers.

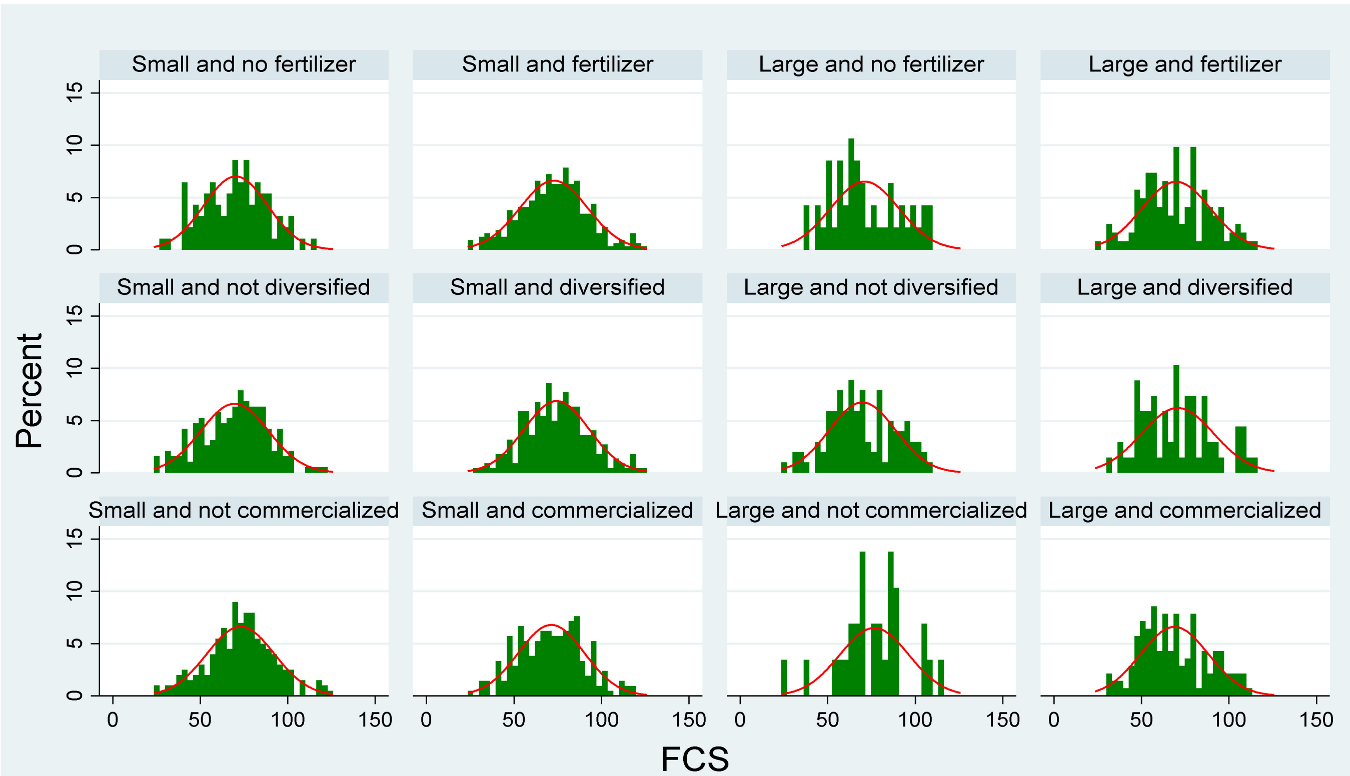

Figure A4. FCS distribution among farmers.

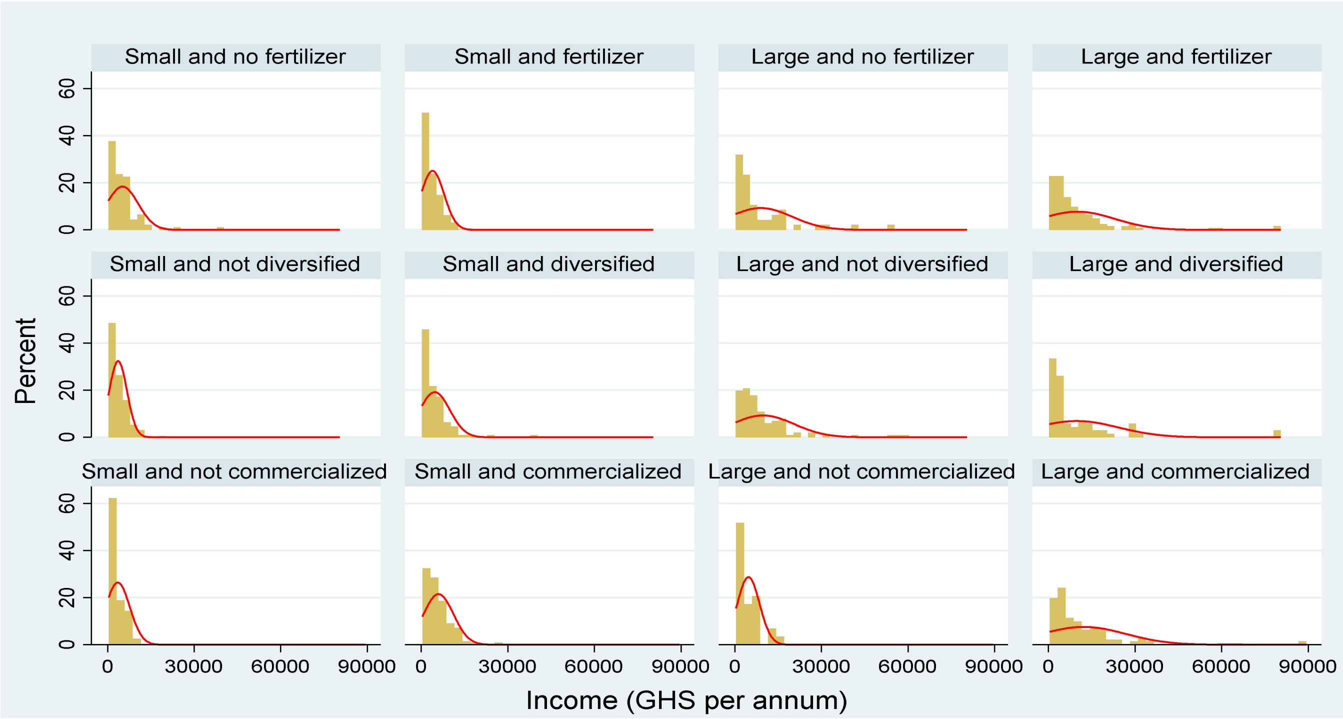

Figure A5. Income distribution among farmers.

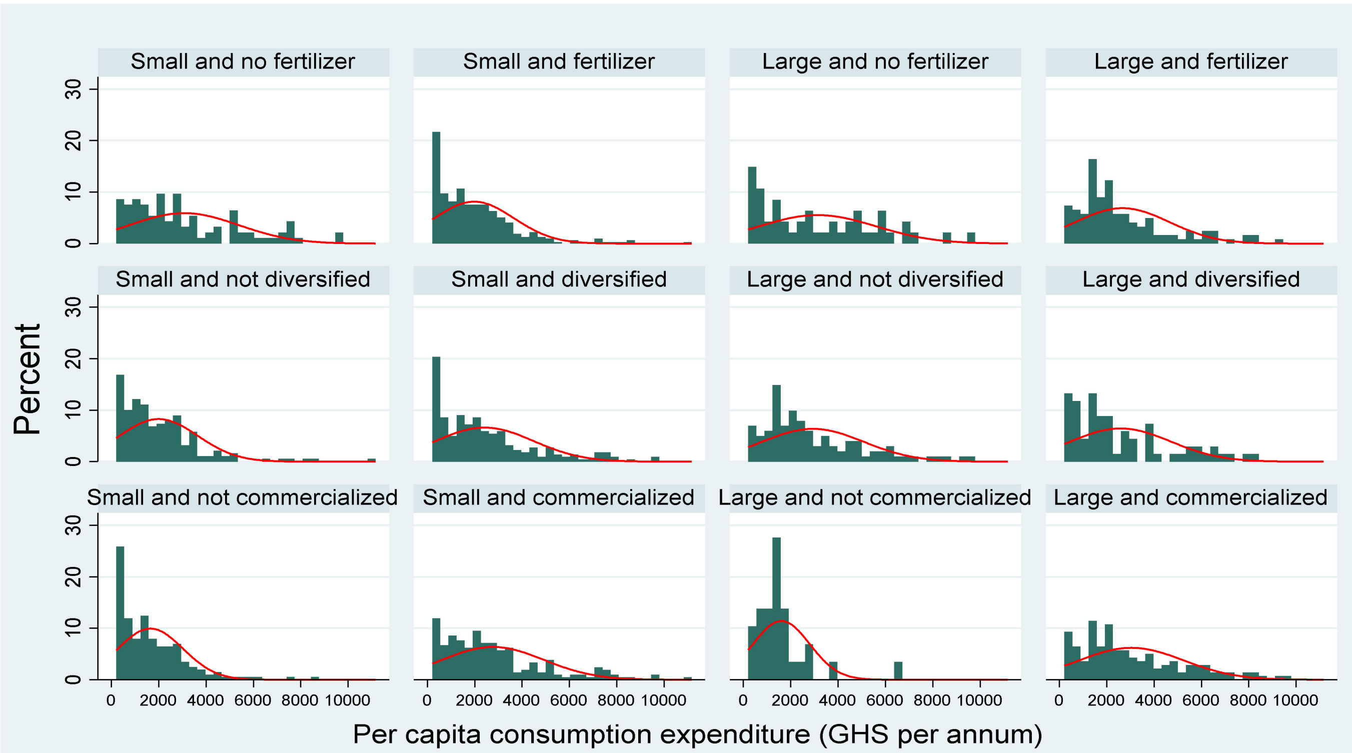

Figure A6. Distribution of per capita consumption expenditure among farmers.

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