Research report

Increasing Ghanaian farmers' incomes and understanding the link to purchasing solar energy products: An assessment of five interventions

Insights from AgroCenta, Ghana

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Cover photo: AgroCenta agents arriving for a community visit and engagement ©AgroCenta

Executive Summary

Crop farming in Ghana is dominated by small-scale farmers, accounting for 68.3% of total cultivated area in the country.[1] However, despite their important role in Ghana's agricultural sector and economy more generally, small scale farmers largely lack access to important support services that affect their productivity and survival due to the risky nature of their craft as perceived by financial institutions.[2][3] The challenges such as the lack of collateral and marketing infrastructure often leave farmers highly vulnerable to market and weather conditions.

AgroCenta is an agricultural technology firm founded in 2015 with a mission to provide access to formal produce markets to small scale farmers in Ghana. Specifically, the company aims to provide friendly financing, marketing and other support such as advice for usage of different clean and efficient energy agricultural tools to help small scale farmers improve their productivity. This research was commissioned by AgroCenta and Shell Foundation, with funding from the Foreign Commonwealth and Development Office (FCDO) under the Catalysing Agriculture by Scaling Energy Ecosystems (CASEE) programme. The objective of this research is to evaluate the effect of better access to farm inputs, agricultural extension information, credit and market on farmers' income and solar energy access.

The main research questions are:

1. To what extent does better access to farm inputs, agricultural extension information, formal credit and formal markets result in increased income for small-scale farmers?
2. Does higher income for small-scale farmers result in increased investment in solar energy devices?

In order to answer these questions, AgroCenta conducted **a survey with farmers** in the Upper East and Eastern Regions of Ghana and used descriptive and regression techniques to analyse data collected from the survey. Descriptive techniques are statistical approaches of establishing tendencies or potential relationships between variables such as averages, frequencies, proportions and group differences in mean values. Regression techniques, on the other hand, are methods of establishing relationships between measurements of one variable that is suspected to depend on the measurements of one or more other variables. Specifically, AgroCenta tested five hypotheses outlined below. **The key findings from the research are presented under each**.

Hypothesis 1: Increased access to farm inputs does not lead to increased income for farmers

Hypothesis found to be false for white maize: Better access to farm inputs is associated with a higher income for farmers, especially when they grow white maize.[4] There is no large difference in access to specific farm inputs between female and male farmers. However, data suggests that the proportion of female farmers using multiple inputs decreases as the number of inputs increases. The latter could be attributed to a multiplicity of gender-biased behaviours documented by past studies in Ghana.[5]

Hypothesis 2: Better access to agricultural extension information does not lead to increased income for farmers

Hypothesis found to be false for AgroCenta customers, and true for non-AgroCenta customers: While access to agricultural extension information received from formal sources (i.e., Ministry of Food and Agriculture or a combination of Ministry of Food and Agriculture and AgroCenta) is not associated with a higher income, **farmers who get information exclusively from AgroCenta are found to have a higher**

[1] World Bank (2018).
[2] The International Labour Organization (ILO) estimates that 30% of employed people in Ghana work in the agriculture sector. https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=GH.
[3] Miranda et al. (2017); Alliance for Financial Inclusion (2018).
[4] Better access is defined as current use of more than one input in the farm. More than one input is a requirement for cultivation of all the four crops considered in this study.
[5] Ragsdale et al (2022).

income compared to those who do not. Extension information from the Ministry of Food and Agriculture was considered to suffer from quality and lack of timeliness in delivery.[6] AgroCenta, on the other hand, partners with professionals in dispensing extension information in repeated and timely farmer engagement sessions. A larger proportion of female farmers receive information from AgroCenta only, compared to male farmers. There is, however, no significant difference in incomes between males and females receiving extension information from AgroCenta.

Hypothesis 3: Access to formal credit does not lead to increased income for farmers

Hypothesis found to be true, but there is a nuance: There is no evidence of association between higher income and access to formal credit between farmers **who have accessed or not accessed formal loans** (bank or micro finance institution (MIF).[7] However, **those who reported having ever accessed a bank loan reported a higher income per acre** while those who reported having **accessed an MFI loan reported a lower income per acre**. The higher income on the part of those who had ever accessed bank loans may be due to actual productivity or selection by banks based on ownership of other property that can serve as collateral. Furthermore, the farmers did not confirm if they had actually used the proceeds from bank loans to finance farming activities. Most farmers, who reported having accessed a bank or MFI loan, still indicated that they used personal savings from farming to finance their farming activities. There is a **big difference in access to formal credit between female and male farmers.** Female farmers comprise a smaller proportion of those who reported having ever accessed a bank (36%) or an MFI (39%) loan, compared to male farmers (at 64% and 61%, respectively). In addition, a slightly higher proportion of women access a single source of farming finance.

Hypothesis 4: Access to formal markets does not lead to increased income for farmers

Hypothesis found to be false: Selling farm produce such as yellow maize, white maize, millet and soybean to **formal marketing channels (aggregators including AgroCenta) is associated with a higher income** compared to those who sell to unorganised markets such as local markets. The majority of farmers (73%) who sell the largest proportion of their produce to AgroCenta feel they obtain good value for their produce compared to less than half who feel they get paid a good price when selling to other aggregators and local market (46% and 22%, respectively).

Hypothesis 5: Higher income does not result in increased investment in solar energy devices

Hypothesis found to be true for only some solar investments: Lastly, the study finds that **higher farmer income is associated with the prospective purchase of solar home systems (SHS), but no other solar energy devices.** In fact, results show that the odds of purchasing solar TV, cooker and lantern decrease with an increase in farmer income. Given any level of income, women are more likely to purchase a solar cooker compared to men. On the other hand, given any level of income, men are more likely to purchase a solar torch compared to women.

The findings from the research lead to **the following recommendations** for AgroCenta's future support to increase farmers' income and their access to solar energy:

a) **It is important to support farmers' access to inputs as it may lead to higher income.** Specifically, **support to white maize** should be sustained. **Women-focused input access strategies** should be considered to ensure that women have access to multiple farm input and to formal markets to boost their incomes.
b) **Encourage the sale of produce to formal marketing channels as opposed to local markets,** where often farmers feel they do not receive a fair price for their crops. Aggregators should consider strategies of incentivising farmers to divert bigger shares of their produce to aggregated markets as it leads to higher income.

[6] Antwi-Agyei &Stringer (2021).
[7] Higher income is income (money) derived from the sale of the four popular crops (white maize, yellow maize, millet and soybean) that were the subject of the study.

c) **Invest in increased access to extension information from AgroCenta**, as it is beneficial to the farmers: this may include improving coverage and contact with farmers in order to override the influence of other sources of extension information that has known shortcomings.[8] It is good to **maintain the intake of women while encouraging more men** to enlist in agricultural extension information provided by AgroCenta.

d) As most of surveyed farmers use individually saved farming income to fund their farming activities**, more research is needed to understand the optimal structure of formal credit available to small scale farmers**. It is important to investigate strategies of mobilising the individual savings into bank deposits, as this creates financial information profiles that can make it easier to rate farmer credit worthiness. Understanding this can help AgroCenta target its interventions in needed areas.

e) **Intention to buy a given solar energy device may vary by income and gender, so relevant targeting strategies are useful**. Encouraging the purchase of solar home systems can be a good starting point as farmers with a higher income desire that product, regardless of gender.

[8] Antwi-Agyei and Stringer (2021).

Contents

List of Abbreviations

CASEE	Catalysing Agriculture by Scaling Energy Ecosystems
CEO	Chief Executive Officer
CSIR	Centre for Scientific and Industrial Research
FCDO	Foreign, Commonwealth & Development Office
GDP	Gross Domestic Product
GHS	Ghanaian Shilling
ILO	International Labour Organization
MFI	Micro finance institution
MoFA	Ministry of Food and Agriculture
SHS	Solar Home System
USD	United States Dollar

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1. Introduction

Agriculture is important in Ghana's economy with its share in non-oil GDP estimated at 18.5%. The rural economy is more dependent of agriculture with 65.2% of the total employed population in rural areas, working in the sector, while 38% of people at the national level are employed in the agriculture sector.[9] Crop farming is dominated by small-scale farmers, with cultivation in less than 10 hectares of land accounting for 68.3% of total cultivated area.[10] Despite their important role in Ghana, small scale farmers largely lack access to important support services like certified extension information, credit and farming technology that affect their productivity and survival.[11] Formal finance institutions avoid small scale farmers in Ghana due to the risky nature of small-scale farming and difficulties in designing appropriate financing instruments.[12] The risk emanates from the lack of collateral, systemic losses due to weather and climate changes, and the lack of marketing infrastructure that leaves farmers vulnerable to the vagaries of nature and trade.

AgroCenta is an agricultural technology firm founded in 2015, with the primary aim of solving two of the above challenges: access to finance and markets by small scale farmers in Ghana. The company currently provides small scale farmer-friendly financing services, a digital marketing platform that links large produce off-takers with small-scale farmers, farm inputs and agricultural extension information. AgroCenta aims at scaling up its operations by venturing into selling of clean (solar) energy to help small-scale farmers to improve their productivity. As part of this effort, AgroCenta with funding from the Foreign Commonwealth and Development Office (FCDO) has been working with Shell Foundation (UK Registered Charity) under the Catalysing Agriculture by Scaling Energy Ecosystems (CASEE) programme to test different innovative approaches to improve the access to solar energy for small scale farmers.

2. Research Objectives and Methodology

AgroCenta commissioned a local consultant to conduct research in the Upper East and Eastern Regions of Ghana between 24th May and 28th July 2022 to improve the company's understanding on the relationship between the higher income of small-scale farmers and their investment in solar energy devices. Findings from this research will help AgroCenta target its financing support to farmers to access solar energy, thus increasing their farming productivity.

The research aims to answer two research questions:

1. To what extent does better access to farm inputs, farming information, credit and markets result in increased income for small-scale farmers?
2. Does higher income result in increased investment in solar energy devices?

To answer these two questions, the researcher also collected and analysed gender disaggregated data.

As part of the research, AgroCenta set out to test the following hypotheses:

Hypothesis 1: Increased access to farm inputs does not lead to increased income for farmers

Hypothesis 2: Better access to agricultural extension information does not lead to increased income for farmers

Hypothesis 3: Access to formal credit does not lead to increased income for farmers

Hypothesis 4: Access to formal markets does not lead to increased income for farmers

[9] Ghana Living Standards Survey (2019).
[10] World Bank (2018).
[11] Ibid.
[12] Miranda et al. (2017); Alliance for Financial Inclusion (2018).

Hypothesis 5: Higher income does not result in increased investment in solar energy devices

To answer these research questions and test the hypotheses, the researcher employed a quantitative research approach.

Primary data was collected from a survey with farmers from the Upper East and Eastern Regions of Ghana where AgroCenta's market is. The survey was designed by the researcher, in consultation with AgroCenta. The sample was taken from a dataset of estimated 60,000 farmers, who had, at any one time, registered with AgroCenta's marketing platform.[13][14] To allow for non-response and incomplete interviews common in rural surveys, the target sample size (denoted as 'n') was 800 farmers. This sample included farmers who sold their produce to AgroCenta and those who sold through other marketing channels (including to the local market and other aggregators) since it was difficult to split the groups upfront as farmers sell to different markets simultaneously. Of the total of 800 farmers who were approached, only 719 completed questionnaires. AgroCenta's field agents visited farmers and administered the questionnaires between 24/5/2022 and 28/7/2022.

For data analysis, the researcher used two methods namely **(1) descriptive statistics,** frequencies and mean/average tests to extract the prevalence of the phenomenon and differences between farmer groups based on gender, markets and other attributes and **(2) logistic regression** techniques to test the hypotheses. Descriptive techniques are statistical approaches of establishing tendencies or potential relationships between variables such as averages, frequencies, proportions and group differences in mean values. Regression techniques, on the other hand, are methods of establishing relationships between measurements of one variable that is suspected to depend on the measurements of one or more other variables. In this case, logistic regression was used to establish whether a higher income derived from farming and other relevant factors influence the prospects of farmers buying given solar devices. In particular, to assess whether access to information, inputs, markets and credit services are associated with any increase in income, we used a regression environment to allow for consideration of multiple factors that may have a bearing on income generated from farming.[15][16]

The research has some limitations which are acknowledged by AgroCenta. There is a mismatch between the information required and the budget available for research. As a result, AgroCenta used its field agents to collect data for the survey. It could have been better if professional research assistants had been hired to work alongside the field agents in data collection. Moreover, the timeframe for conducting the research was short; yet, working with small-scale farmers requires a longer timeframe for tasks such as piloting the survey to understand the phenomenon concerned as well as testing the data collection instruments. Finally, the data does not allow the establishment of impact (causal analysis) between farmer income and prospective solar device purchase due to the research design which was developed within the constraints of limited funding and time. The report provides early insights that can be further researched.

[13] This is an online platform where farmers are paid for produce delivered or sold to AgroCenta. Farmers can access it from their phones at https://agrocenta.com/platforms.

[14] Since this is a largely prevalence study (establishing the spread of a phenomenon among farmers), with no specific parameter of interest known beforehand, the researcher used the simple sampling rule assuming a margin of error of +(-) 5% and a confidence interval of 95%. From the formula given in Israel (2003), this would require a sample of about 400 units.

[15] The dependent variable in the regression setting is income earned from farming the 4 crops per acre. The explanatory variables are in two categories: those of concern to the study (number of inputs applied; access to bank loan; access to formal market and information) and those representing other control factors relevant in moderating the income of the farmer.

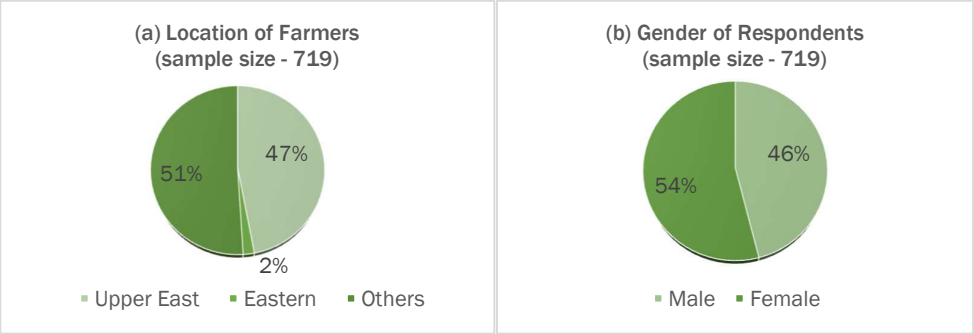
[16] In addition to the variables of concern to the study, additional variables were incorporated in as far as the available data could permit. These additional variables are age of the farmer; size of the family of the farmer; farm size; gender of the farmer; location of the farmer (region); assets owned; having title to land; membership to cooperative society; education of farmer; size of family; and distance to local market. Together, these variables explain about 60% of the variation in income of the farmer (proceeds per acre).

The report is structured as follows. **Section 2.1** below provides the profiles of respondents before the report presents the study findings in **Section 3**. **Sections 3.1 to 3.4** answer research question 1 and highlight that while better access to some key accessories is correlated with an increased farmer income, this is not the case for all the factors the research examines. **Section 3.5** deepens the analysis by exploring cross cutting factors such as volume of produce and gender differences in farmer productivity and adoption of crops. **Section 3.6** answers research question 2, suggesting that regardless of the income of respondents, their preferences for solar home systems (SHS) are strong. However, findings indicate that having a higher income does not always translate into an increased investment in other solar energy devices. The report concludes with **Section 4** which outlines the lessons and recommendations from the study and sheds light on the extent to which better access to farm inputs, agriculture extension information, credits and market result in increased income for farmers.

2.1. Characterizing the sample

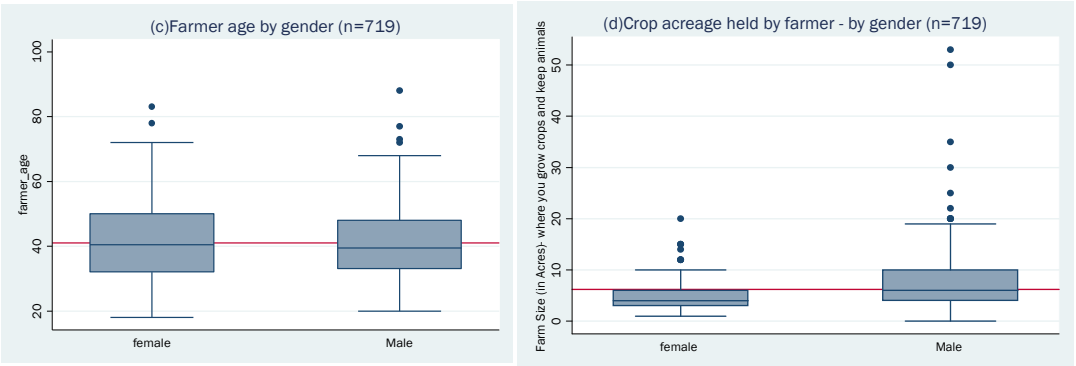
The total number of farmers in the sample is **719 farmers**, of which **54% are women** (**Figure 1 (b)**). Most of the farmers reside in Upper East (51%) and Eastern (47%) administrative regions of Ghana, with some 12 farmers in the sample being from three other regions. This is due to administrative boundaries' errors during data collection (**Figure 1 (a)**).

Figures 1 (a) and (b): Location and gender of farmers



The average age of a farmer is **41 years,** while the overall range is from 18 to 88 years (**Figure 1 (c)**). Over 77% of farmers are under 50 years; AgroCenta clients are on average 2 years younger than the rest of the farmers. The average size of land held by a farmer is 6.2 acres ranging from 1- 52 acres (**Figure 1 (d)**). **Male farmers have on average 2.5 more acreage of land compared to female farmers.**[17]

Figures 1 (c) and (d): Age and crop acreage held by farmer (by gender)

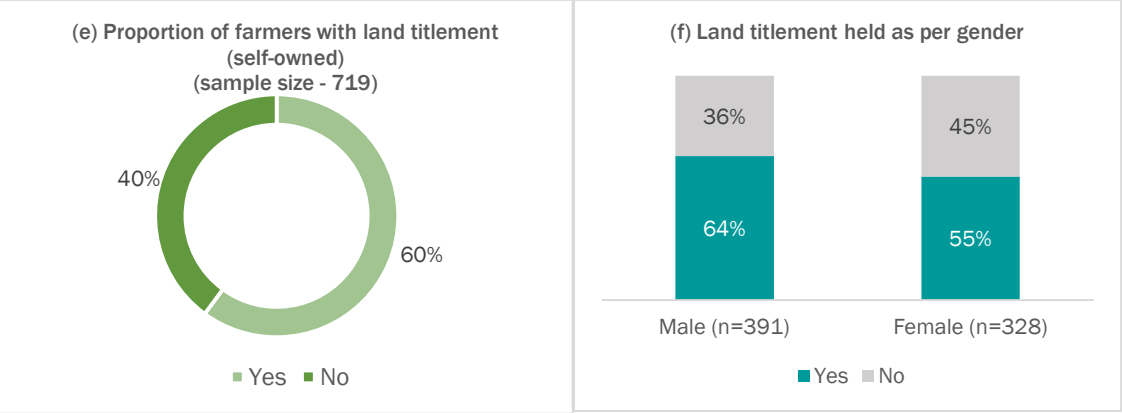


[17] The red lines in **Figures 1 (c)** and **(d)** show the average age of a farmer and the average size of land held, respectively. The dots identify the outliers in the data set and the grey boxes demonstrate where most of the farmers lie along the y axis.

More than half (60%) of the farmers have title deeds as proof of ownership of the farms. **Higher proportion of male farmers (64%) have title deeds to their farms than female farmers (55%) based on Figure 1(e) and (f).**

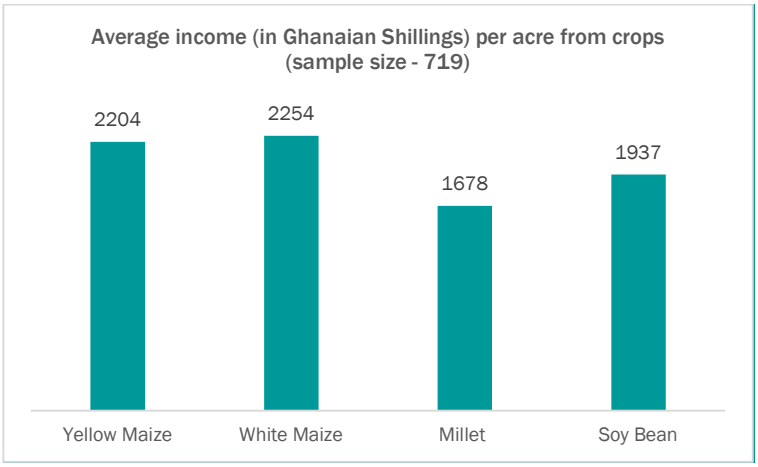
Thirty-five (35) percent of the farmers have no qualification of formal education, 24% have primary level, 38% have secondary level and only 3% have acquired college level education. **Female farmers account for more than half (55%) of those with no formal education qualification.**

Figures 1 (e) and (f): Land entitlement of farmer (by gender)



The average total earnings of surveyed farmers per acre from cultivation and sale of yellow maize, white maize, millet and soybean is Ghanaian Shilling (GHS) 2,200 (USD 228.5), GHS 2,254 (USD 234), GHS 1,679 (USD 174), and GHS 1,937 (USD 201), respectively (**Figure 2**). The average total income per acre is GHS 2,176 (USD 226). **Male farmers earn on average GHS 352 (USD 36.6) more than their female counterparts** (**Table 8** in Annex 2). This is partly because men tend to have more land than women (see above).

Figure 2: Average income earned per acre of crop



3. Research Findings

3.1. Better access to farm inputs and increased income

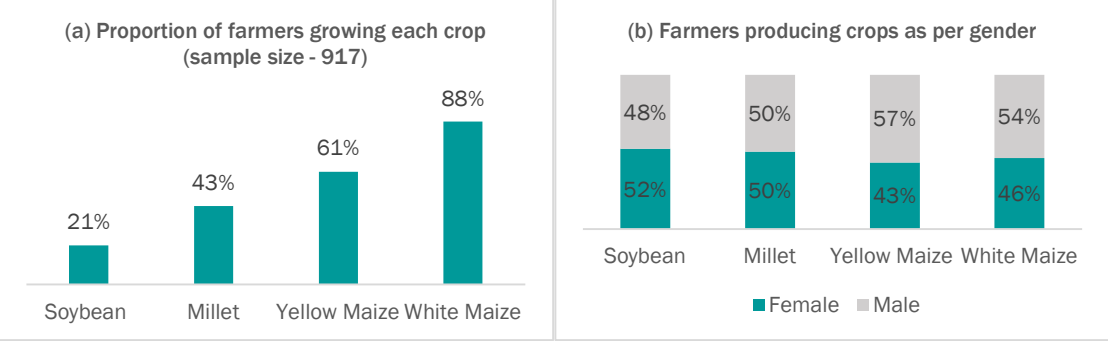
This section discusses findings from the survey about the relationship between farmers' access to farm inputs and their income. The findings show that increase in farm inputs does not lead to an increase in

income for farmers producing all the crops such as yellow maize, millet and soybean except for white maize. This confirms hypothesis 1 is false for white maize as enlisted in **Section 2** of this report.

3.1.1. Individual crops

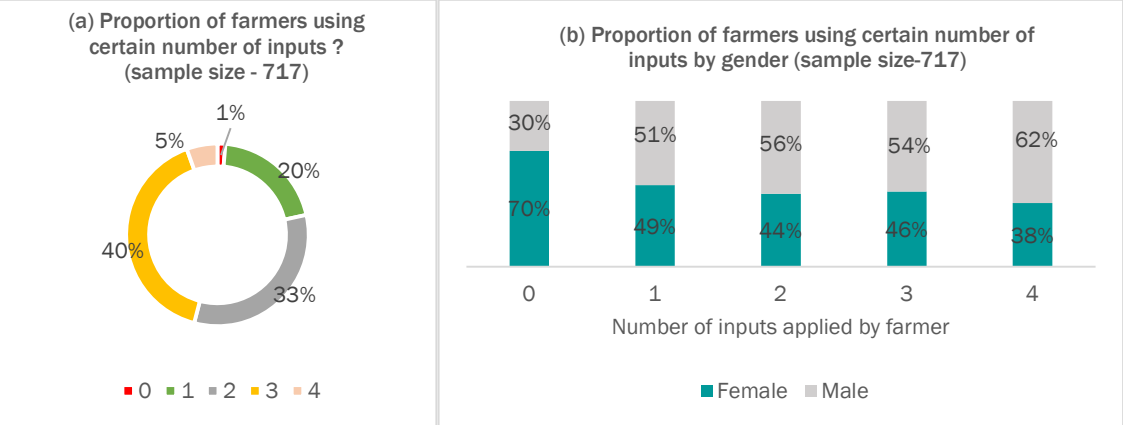
As per the survey, **four main crops were popular among the farmers** – 88% of them produced **white maize**, 61% produced **yellow maize**, 43% produced **millets** and 21% produced **soybean** (**Figure 3 (a)**). We further analysed the production patterns by gender and found that **while white and yellow maize are popular among farmers, a greater proportion of these are produced by male farmers**. On the other hand, at least 50% of the farmers producing soybean and millets are women (**Figure 3 (b)**).

Figure 3: Crops cultivated by farmers (and by gender)



Next, we analysed trends in application of agriculture inputs for each of these crops. Farmers typically apply a combination of four inputs – **weedicides, pesticides, herbicides and certified seeds**. From **Figure 4 (a)** 73% of the farmers use 2 or 3 inputs, with 20% of farmers using only a single input. However, it must be noted that **female farmers use a smaller number of inputs than male farmers** (as illustrated in **Figure 4 (b)**) – seven out of every ten farmers that were not using any inputs are female. This pattern is attributed to a series of social biases cited by other studies that culminate into females not being able to access inputs at the same rate as males.[18] An example of this is control of family financial and land resources by spouses or male relatives that may need to be established in future studies.

Figure 4: Number of inputs farmers used by farmers

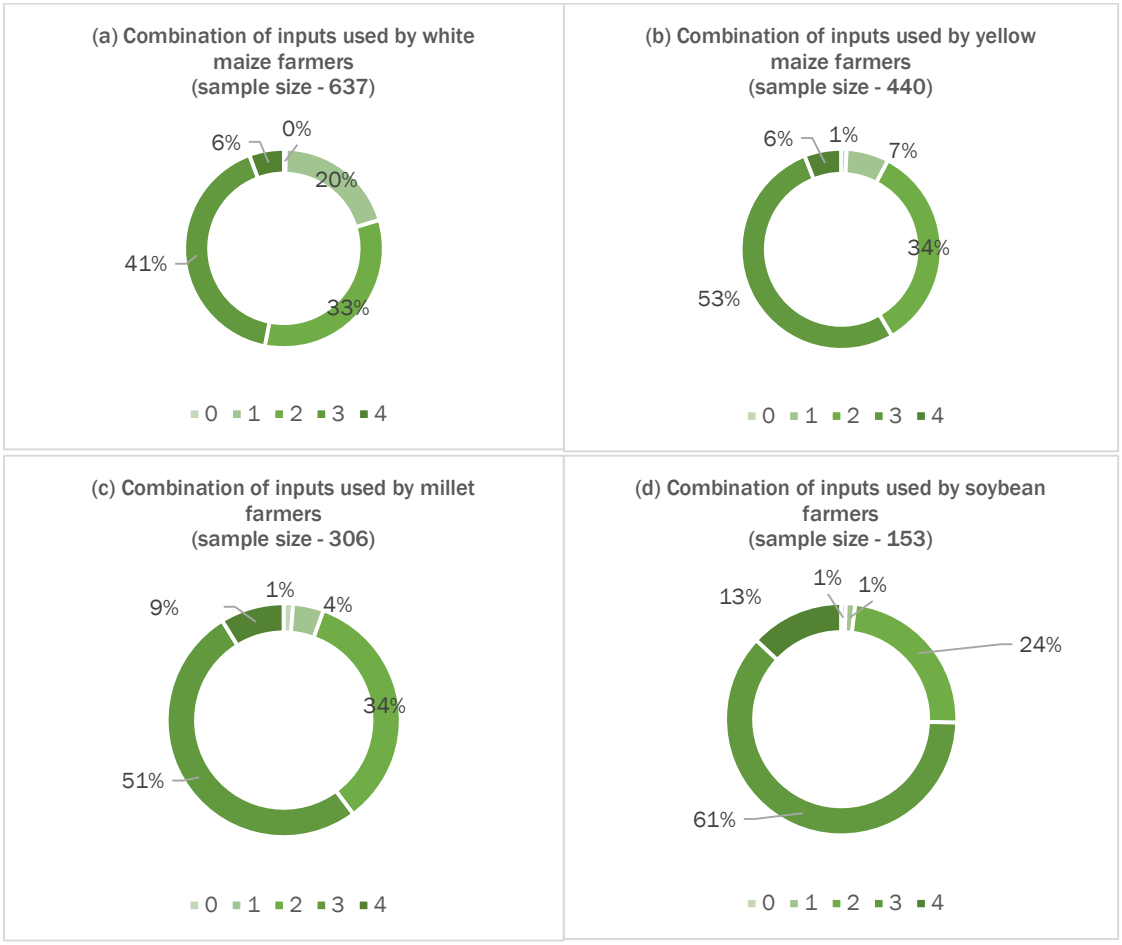


The combination of inputs used by farmers varies a little depending on which crop is cultivated. From **Figure 5**, every farmer of white maize applies at least one input (**Figure 5(a)**). The highest proportion (13%) of those applying all the four inputs is found among farmers of soybean, and so is that of farmers

[18] The most recent study is Ragsdale et al (2022).

applying three inputs (**Figure 5(d)**). Millet and yellow maize farmers also contribute most of the farmers using a single (one) input (**Figures 5 (b) and (c)**).

Figure 5: Combination of inputs applied by crop

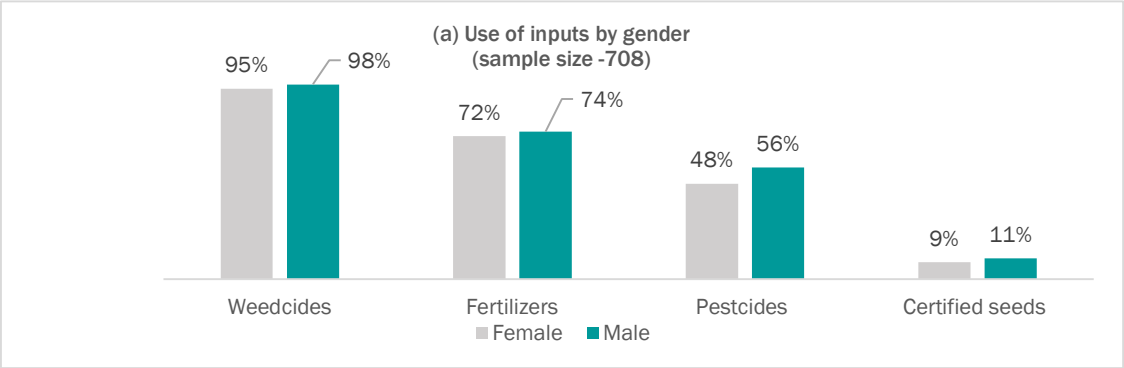


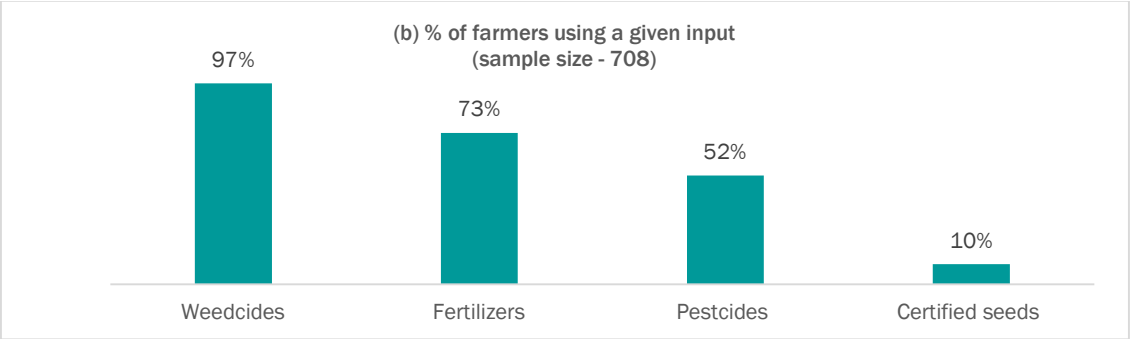
Weedicides are applied by almost all (97%) the farmers, followed by fertilizers (73%), pesticides (52%) with the least popular input being certified seeds which is applied by only 10% of the farmers (**Figure 6 (b)**). Most farmers use seeds that are saved from their past harvests due to lack of knowledge, risk aversity, high cost and untimely access to seeds, among other things.[19][20] **There is no large difference in access to individual inputs between male and female farmers (Figure 6 (a)), implying females are not under-represented in the application of given inputs.**

We calculated correlations between number of inputs applied by farmers and their income (in Ghanian Shillings) per acre of land for **yellow maize, millet and soybean**. While the estimates show that the correlations are positive for each, they are not statistically significant indicating that **the probability of a higher income being associated with an increased use of inputs is very low** for these crop types.[21][22] However, **application of more than one input in white maize cultivation is associated with a lower** income derived from the crop.[23]

[19] CSIR (2018).
[20] Osei et al (2020).
[21] The positive correlations range between 0.17 and 0.25 for each crop.
[22] Refer to Table 1 in Annex 2 to review estimates generated from statistical analysis.
[23] A statistically significant correlation between the number of inputs and income (GHS/acre) for white maize is negative (i.e., -0.1357).

Figure 6: Input use by farmers





3.1.2. All crops

Overall, the higher the number of inputs applied, the higher the total income derived from farming the four crops. Regression analysis show that one additional input increases total income by 27% (see **Table 10** in Annex 2).

3.2. Better access to agricultural extension information and increased income

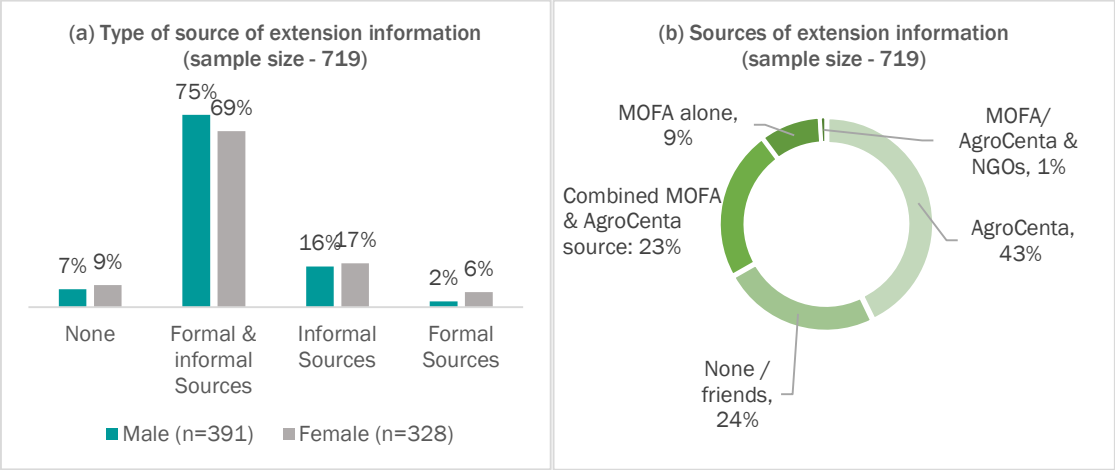
This section discusses findings from the survey with regard to the association between farmers' access to agricultural extension information and their income.

Farmers access agricultural extension information from various sources, but **access to formal sources is considered superior to informal sources**. Farmers receiving agricultural extension information from formal sources are expected to have access to scientifically verified advice on farming, and for this reason it is termed as 'better access'. The main formal sources are **Ministry of Food and Agriculture (MoFA), AgroCenta or a combination of the two**. Majority of farmers (72%) in the sample combine both formal and informal sources of farming information. There are also farmers who report not having access to any formal information (**Figure 7 (a)**).[24]

The largest source of formal extension information is AgroCenta used by 43% of farmers, followed by a combined MoFA and Agrocenta source (23%) and MoFA alone (9%); 24% has no access to formal extension information (they either use none at all or get some information from neighbours) (**Figure 7 (b)**). There is a possibility of spill-over effects of extension information, given that 88% of farmers also indicate receiving some information from neighbours.[25]

[24] This is sourced from organized agencies that deploy trained officers or representatives.
[25] Vandevelde, Van Campenhout, & Walukano, W. (2021).

Figure 7: Sources of agricultural extension information



Farmers who report **using formal sources of extension information** (a combination of MoFA with AgroCenta or just MoFA alone) **report a lower income** per acre (by GHS 559 or USD 58) compared to those who receive no formal extension information (**Table 2** in Annex 2).[26] This implies that information from MOFA-related sources does not lead to higher income, contrary to expectation since these are formal sources of extension information. The lack of training, high farmer-to-extension-officer ratios, lack of relevant extension materials and mobility problems are all negative impediments to the quality of extension information delivered to the farmer by government extension officers and can represent some of the reasons behind the ineffectiveness of MOFA-related formal extension information.[27]

However, the farmers who report **receiving formal extension information exclusively from AgroCenta report a higher income per acre of GHS 453 (USD 47).**[28] Noticeably, **a larger proportion of female farmers receive formal extension information from AgroCenta only**, compared to that of male farmers. There is however no significant difference in incomes between males and females using extension service from AgroCenta.

3.3. Access to formal credit and increased income

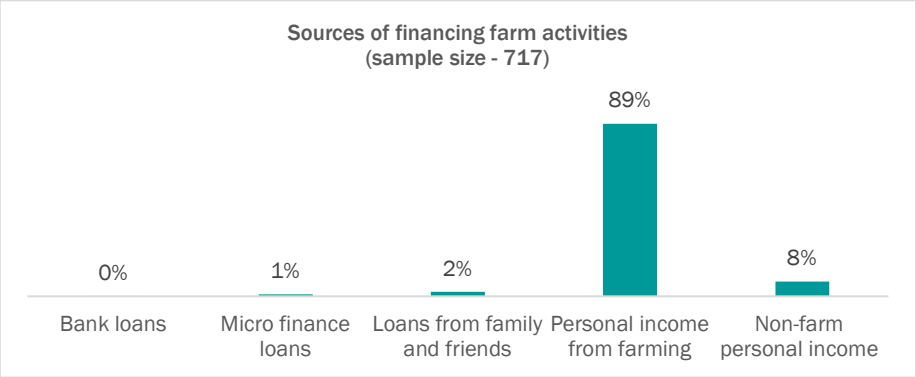
This section discusses findings from the survey with regard to the association between farmers' access to formal credit and their income. Findings from the survey suggest that hypothesis 3 that access to formal credit does not lead to increased income for farmers is true.

Farmers reported having access to 4 main sources of finance for their farming activities. These are **bank loans, personal savings, income from farm, and loans from friends and family**. Most farmers reported accessing one or two sources of credit, with a **slightly higher proportion (47%) of female than that of male (41%) farmers reporting access to a single source of finance.**

Bank loans are considered a reliable formal source of finance for agricultural activities but require collateral security that may not be available to small scale farmers. Formal sources of finance are generally non-existent with farmers in this sample. Most of the farmers (89%) reported using personal income from farming to finance their activities, while less than 2% are using either micro-finance or bank loans (**Figure 8**).

[26] From the researcher's experience when farmers received information from both MoFA and AgroCenta, they were not so sure which information to use because information given by both sources was not always complementary to each other. In that case, information from AgroCenta might not be used as effectively as it might on its own.
[27] Antwi-Agyei & Stringer (2021).
[28] This is further corroborated through statistical analysis which shows that there is a 95% chance that higher income is observed among those receiving extension information from AgroCenta only.

Figure 8: Sources of financing for farm activities



Although farmers reported having accessed bank loans or micro-finance institution (MFI) loans (12% and 6%, respectively from **Figures 9 (a)** and **9 (b) formal loans are not a common source of financing farming activities** based on **Figure 8**. Female farmers are under-represented among farmers who had reported having accessed formal loans. From **Figure 9 (c)** and **9 (d) females represent a smaller proportion of farmers who had accessed microfinance and bank loans**, respectively. The difference in access rate of bank loans relates to an earlier observed bias against females in ownership of title deeds and lower land acreage as discussed in **Section 2.1.**

There is no difference in total income per acre between farmers who have accessed or not accessed formal loans (bank or MIF).[29] There is therefore **no evidence of association between higher income and access to formal credit.** However, those who reported having ever accessed a bank loan reported a higher income per acre (**Table 3 (b)** in Annex 2), while those who reported having ever accessed an MFI loan reported a lower income per acre (**Table 3 (c)** in Annex 2). Our data suggests that that **there is more than 95% chance of a higher income among those who have ever accessed a bank loans and a lower income among those who have accessed an MFI loan**.[30] The higher income on the part of those who had ever accessed bank loans may be due to actual productivity or endowment-related selection by banks. Furthermore, the farmers did not confirm if they had used the proceeds from the bank loan to finance farming activities. Most farmers who reported having accessed a bank or MFI loan still indicated they used personal savings from farming to finance their farming activities.

Banks are observed to be averse to small-scale farmers in Ghana which could explain the earlier observation of very limited use of formal credit facilities to finance farming.[31] From the analysis, **there is no evidence to support the association between accessing formal credit and income.** Rather, **the results imply that access to informal credit sources is associated with lower income**. Farmers who use non-farm personal income or loans from friends and family to finance farming activities earn less (by 27% and 28%, respectively) than those that use personal savings from farming (see **Table 10** in Annex 2).

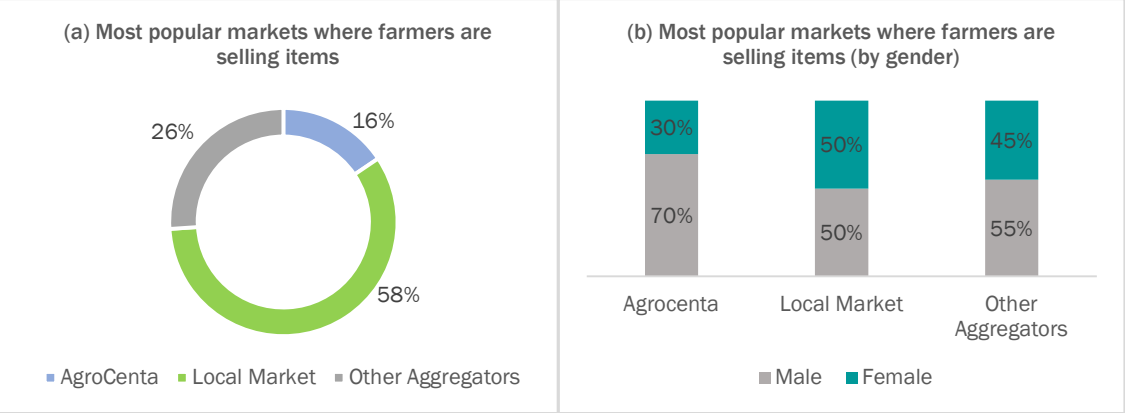
3.4. Access to formal markets and increased income

This section discusses findings from the survey with regard to the association between farmers' access to formal market and their income. Findings from the survey indicate that **better market access (i.e., access to formal markets) for some produce such as yellow maize, white maize, millet and soybean results in increased income for surveyed farmers**, which makes hypothesis 4 that access to formal markets does not lead to increased income for farmers false.

[29] The difference in incomes between the two groups is not any different from zero, as the t-value is less than the standard 1.96 (**Table 3 (a)** in Annex 2).
[30] The t-values (3.19 & 5.52, respectively) are greater than 1.96.
[31] Urdry, C. et al. (2020).

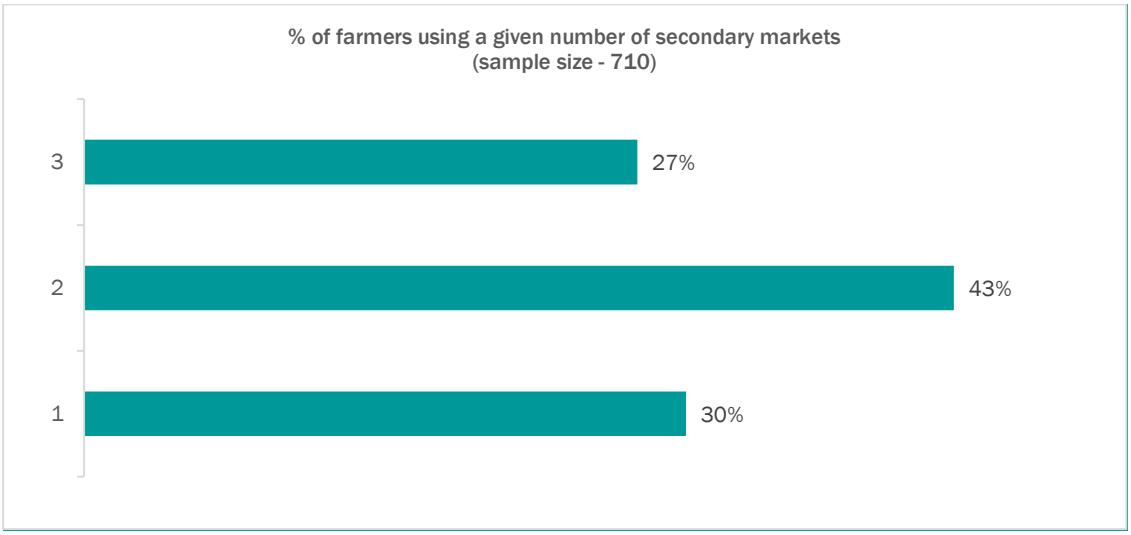
Farmers in the sample sell their produce to three main destinations: **AgroCenta; other aggregators; and the local market** (directly and indirectly through brokers). The local market has the biggest share among markets where farmers dispose most of their produce, accounting for 58% of surveyed farmers. This is followed by sale to other aggregators (26%) with the least market share held by AgroCenta (16%) (**Figure 10 (a)**). 70% of those who sell most of their produce to AgroCenta are men (see **Figure 10 (b)**).

Figure 10: Main market for produce



Market diversification is evident in this sample of farmers. Apart from the main market where farmers sell most of their produce, farmers sell to one, two or three other markets. Forty-three (43) percent of farmers sell to two other markets in addition to the primary market, implying access to multiple markets (**Figure 11**).

Figure 11: Number of secondary markets accessible to farmers



Findings from the survey indicate that better market access (i.e., access to formal markets) for some produce results in increased income for surveyed farmers. **Farmers selling their produce to organized markets (aggregators including AgroCenta)** earn on average GHS 713 (or USD 74), GHS 1,328 (or USD 137.9), GHS 554 (USD 57.5) and GHS 665 (USD 69) **more income per acre cultivated of yellow maize,**

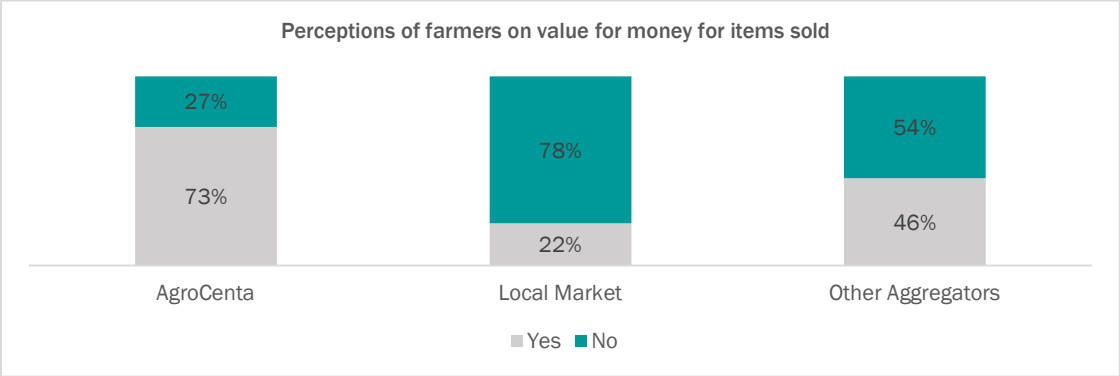
white maize, millet and soybean respectively; compared to those who sell to other unorganized markets like selling directly and indirectly to the local markets (**Table 4** in Annex 2).[32]

Further, selling most of the produce to a formal market (aggregators including AgroCenta) avails a premium of GHS 29 (USD 3) per bag of white maize, GHS 65 (USD 6.7) per bag of yellow maize and GHS 31 (USD 3.2) per bag of millet to farmers (**Table 6** in Annex 2).[33] The probability that there is a difference in the mean price per bag of a crop between the two groups (i.e those who sell and those who don't sell most of their produce to aggregators) is greater than 95% for all three crops.[34]

In addition, **farmers selling most of their produce to aggregators earn GHS 805 (USD 83.6) more income per acre** compared with those who sell in the local markets (**Table 9** in Annex 2).[35]

The majority of farmers (73%) selling the largest proportion of their produce to AgroCenta feel they get paid a good price for their produce compared to 46% and 22% of those who feel the same when selling to other aggregators and the local market, respectively (**Figure 12**). **Although the local market is popular with farmers, they feel they do not obtain a desired value for their produce**. On average, farmers selling most of their yellow maize produce to AgroCenta report a higher sale price (by GHS 37 or USD 3.8) per bag compared to those selling elsewhere. However, **it is important to note that selling most produce to AgroCenta does not necessarily maximise farmer's overall income.**

Figure 12: Perception on value for produce



Holding all other factors constant, **selling produce to more than one market (diversification) is associated with a higher income.** It was observed earlier that farmers in this sample have a primary single market where they sell more than half of their produce, and also a secondary market where they dispose smaller portions of produce. **Farmers who sell most of their produce to aggregators earn a higher income per acre (by 17%) compared to those who sell to the local market. Selling most of the produce to AgroCenta is associated with less income (by 26%): however, sale of smaller portions of harvest to AgroCenta is associated with a higher income (21%).**[36] This finding is in line with farmers' strategy for market diversification, i.e. to take advantage of perceived and real benefits from each available market. Farmers in the sample sell different proportions of their produce to different markets, and it is hard to attribute a higher income to one specific market.

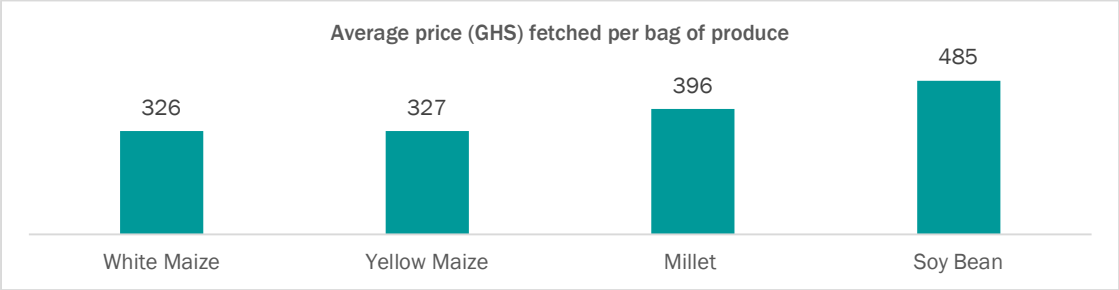
[32] There is a 95% probability of observing higher income among those selling to aggregators, given that the t-values are all greater than 1.96 for the four crops.
[33] However, the only premium supported by data from AgroCenta is GHS 60 (USD 6.2) on yellow maize.
[34] The t-value is greater than 1.96
[35] The t-values in both cases are greater than 1.96 indicating there is more than 95% chance that the observed differences in incomes are actually true.
[36] Data is not available to further investigate this finding. Further research will need to track farmers over time in order to make further observations on this point.

3.5. Cross cutting factors that influence the level of income

Having described the statistical association between farmers' income and various variables such as farm inputs, agricultural extension information, access to formal credit and access to formal market, this section deepens the analysis by exploring cross cutting factors. In doing so, the research sheds light into additional factors that one needs to consider when providing support to increase incomes for small scale farmers.

First, farmers selling most of their produce to aggregators harvest more of every crop (by 1.7 bags of white maize; 2.5 bags of yellow maize and 1.2 bags of millet and soybean) than those who don't sell to aggregators. The average selling price per bag of these crops is GHS 326 (USD 33.8), GHS 327 (USD 33.9), GHS 396 (USD 41.1) and GHS 485 (USD 50.4) for white maize, yellow maize, millet and soybean, respectively (**Figure 13**). As a result, **the increased income comes from a bigger volume of produce or more produce these farmers have than other farmers who do not sell to aggregators**.

Figure 13: Average price fetched per bag of produce



Second, **male farmers harvest on average 1.2 more bags of yellow maize and 0.9 more bags of soybean per acre compared to female farmers.** This finding highlights issues that explain observed gender differences in productivity and even adoption of crops cited by other research.[37][38] It also raises other issues such as the quality of land accessible to females and type of technology used in cultivation of crop among others that may explain the observed differences in yields. Investigating the sources of these gender differences would require a different study design that is outside the current scope.

Third, **male farmers fetch a higher average price (by GHS 42 or USD 4.4 and GHS 21 or USD 2.2 per bag of yellow maize and millet sold, respectively) than female farmers** (**Table 5** in Annex 2). **Male farmers earn GHS 37 (USD 3.8) more per bag of yellow maize from sale to organized markets compared to female farmers** (**Table 7** in Annex 2).

3.6. Higher Income and Increased Investment in Solar Energy Devices

This section discusses findings from the survey for the second research question of whether higher income results in increased investment in solar energy devices. Findings from the survey suggest mixed results and are not able to confirm or deny hypothesis 5. While the hypothesis that higher income does not result in increased investment in solar energy devices is true for devices such as a crop dryer, TV, cooker and lantern, it is false when it comes to the purchase of a solar home system, i.e., **the study finds that higher income is associated with the prospective purchase of SHS**.

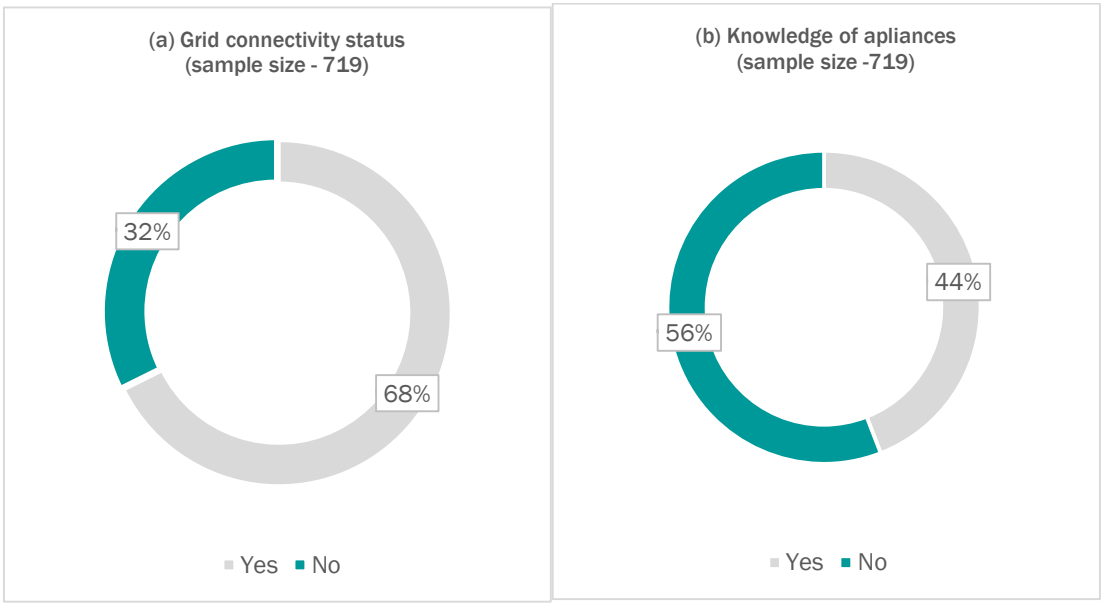
More than half (69%) of the surveyed farmers are connected to grid electricity (**Figure 14 (a)**), and an equal share use it as a main source of lighting (**Figure 15 (a)**). From **Figure 14 (b)**, **more than half of the**

[37] Britwum & Akorsu (2016) cite that women from the Upper East Region described soybean as among other things *'…difficult to cultivate…;'*

[38] Gebre, Isoda, Rahut, Amekawa & Nomura (2021) also observed gender differences in maize productivity in Ethiopia.

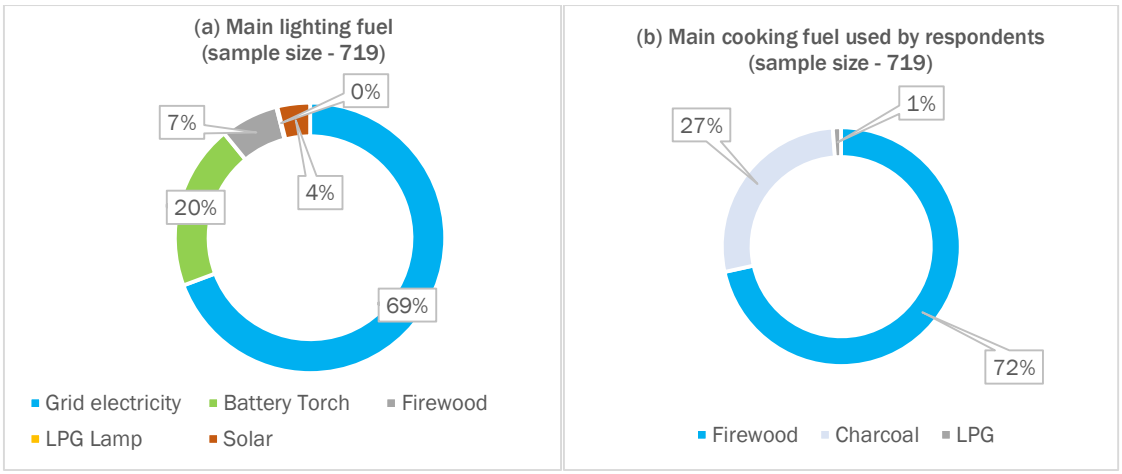
farmers (56%) do not have any knowledge on solar energy, with no differences in prevalence of knowledge between male and female farmers.

Figure 14: Grid connectivity status and knowledge on solar appliances



There is also very limited use of solar at the household level, with only 4% of farmers using it as a main source of lighting (Figure 15 (a)). The main lighting fuel used by the farmers is grid electricity followed distantly by battery-powered torches, while firewood dominates cooking (Figure 15 (b)).

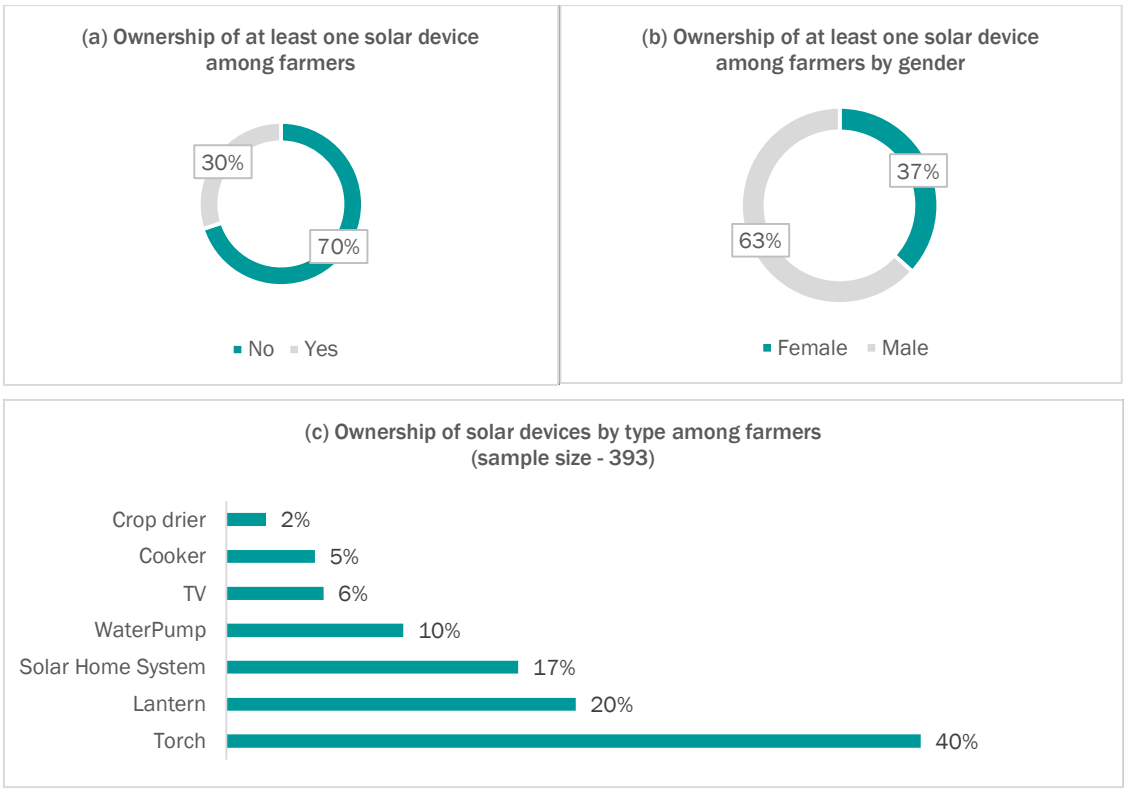
Figure 15: Main lighting and cooking fuel used by farmers



Thirty (30) percent of the farmers own at least one solar device (Figure 16 (a)), with a higher proportion of men than women among the sub-sample that currently owns at least one device (Figure 16 (b)). The most popular solar device currently owned by the farmers is a solar torch owned by 40% of those who own any solar device (Figure 16 (c)). Farmers who currently own at least one solar device reported a higher mean farm income (i.e., GHS 2,277 or USD 236.4) than those who don't (i.e., GHS 2,033 or USD 211).[39]

[39] The probability of a non-zero difference in the mean reported farming incomes between those who own and those who don't own a solar device is greater than 95% since the reported t-value is greater than the standard 1.96 (Table 12 in Annex 2).

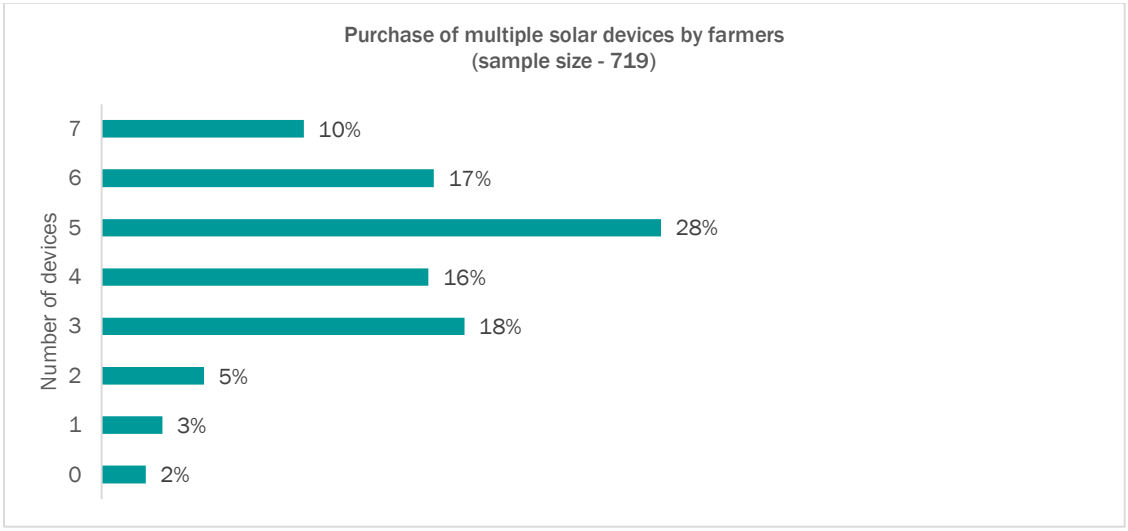
Figure 16: Ownership of solar devices among farmers



Prospects of owning a solar device

Almost all (98%) farmers who were surveyed and who have different income levels in the sample indicated **they would buy at least one solar device**. They were also **willing to buy multiple solar devices** (if they have more income) with about a third (28%) willing to buy a total of five (5) items (**Figure 17**).

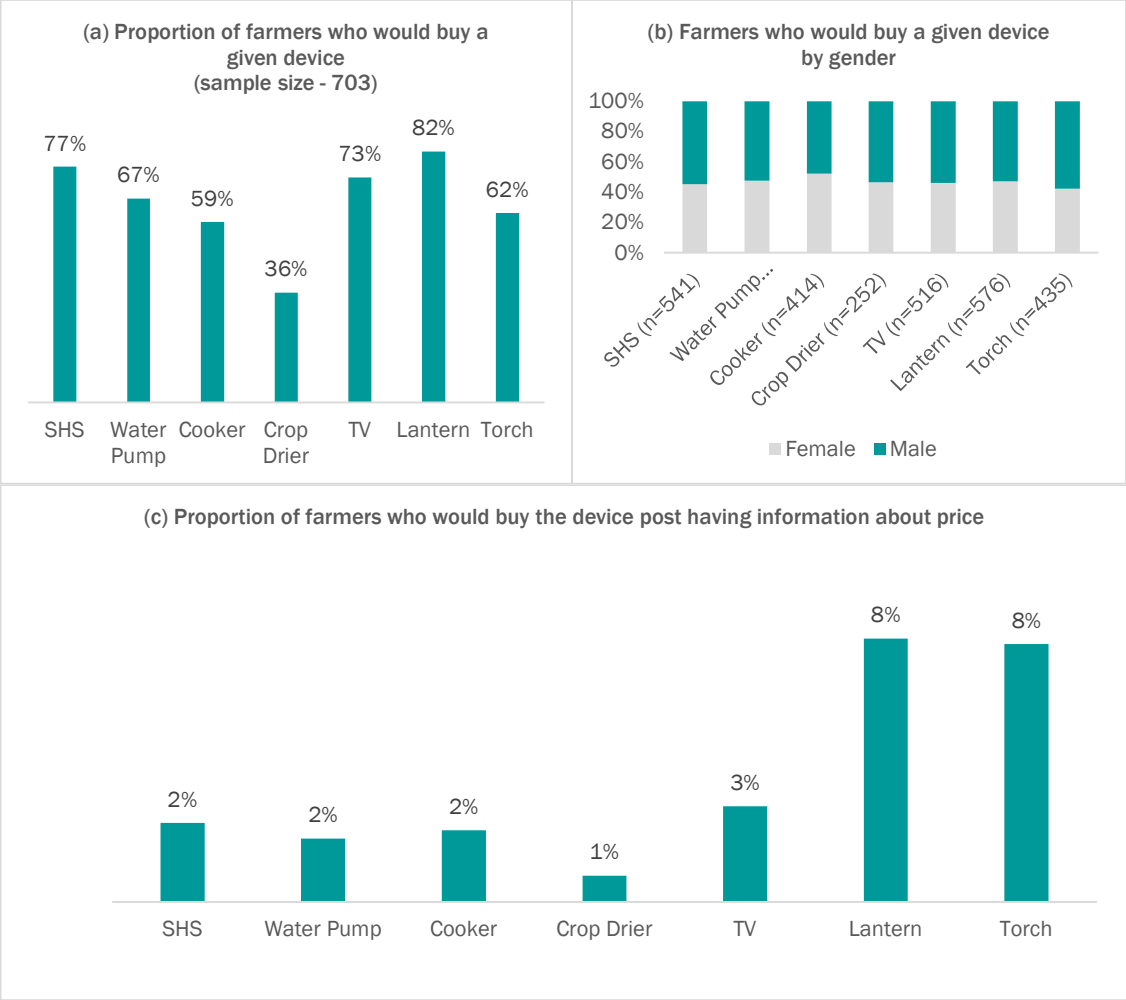
Figure 17: Number of solar devices a farmer is willing to purchase



From **Figure 18 (a), a solar lantern, a solar home system and a TV would be the most bought items** as 82%, 77% and 73% of potential purchasers indicating they would buy the items, respectively. When asked what they would buy first, a solar water pump and a solar TV appear popular. The prioritized items for a second buy are a solar cooker and a solar home system.

Male farmers form majority of potential buyers of all the solar devices given, except that of solar cookers where women form a slight majority of 52% (**Figure 18 (b)**). This is reasonable given that cooking is considered a woman's traditional role in Ghana and they would be more interested in cooking solutions. The prevalence of the desire to purchase any of the 7 devices may change if the respondents are provided with further information about the price of each device. In this study, the majority of the **respondents were not aware of the prices of these devices** (**Figure 18 (c)**).

Figure 18: Preferences among farmers to purchase solar devices



The study sought to understand the nature of association between the income of a farmer and the prospects of buying a solar device in the future. There were 15 farmers who had no intention of buying any solar device in the future: half of them had access to the national grid. From **Table 12** in Annex 2, those who would purchase at least one solar device reported an average income per acre that was GHS 1,054 (USD 109.4) lower compared to those who indicated they would not purchase any item in the future. **Therefore, with respect to the prospective purchase of any single device, there is more than 95% probability that those who would purchase at least one device have lower (and not higher as initially hypothesised) income.**

However, a look at the prospective purchase of **specific solar devices and income reveals mixed results**. From **Table 14** in Annex 2, those respondents who would buy a solar pump earn GHS 955 (USD 99.2) less than those who would not buy it; those who would buy a solar TV also earn GHS 387 (USD 40.2) less compared to those who would not buy it. However, those who would buy a solar torch, or a solar home system earn a higher income by GHS 211 (USD 21.9) and GHS 496 (USD 51.5), respectively,

compared to those who would not buy it (see Table 14). **The probability that a purchaser of a solar home system or a solar torch would have a higher income than a non-purchaser is greater than 95%.**[40] **Hypothesis 5 is therefore not true for a solar torch and solar home system.**

Further, there are gender differences in the tendency of a higher income and prospective purchase of specific devices. In the sub-sample of females (Table 14 in Annex 2), prospective buyers of solar home system had a higher income of GHS 761 (or USD 79) compared to those who would not buy the item. Among the male farmers as shown in Table 15, prospective buyers of solar lanterns reported a higher income (by GHS 395 or USD 41), compared to those who would not buy them. The probability that a female who will buy a solar home system and a male who will buy a solar lantern have higher incomes than non-purchasers in their categories is greater than 95%.[41] **Hypothesis 5 is therefore not true for the cases of male purchasers of lanterns and female purchasers of solar home systems**.

From the estimated regression equations for seven products (Tables 16 to 22 in Annex 2), the odds of purchasing a solar home system increase with an increase in the income of a farmer (Table 16). However, the odds of purchasing a solar device decreases with increase in income for the following devices: crop dryers (Table 17); solar cookers (Table 18); solar torches (Table 21) and solar TVs (Table 22). For the rest of devices (lanterns and water pumps), the data does not support an association between higher or lower income and odds of purchase**. Further, male farmers are less likely to purchase a solar cooker and more likely to purchase a torch compared to their female counterparts**.

It is important to note that apart from farming income, the other factors that may explain a farmer's decision to purchase a given solar device vary depending on the use of the device and profile of the farmer. Other variables that may explain the decision to purchase a solar device in the future include **sale of any portion of produce to AgroCenta** (because selling to AgroCenta is expected to deliver better prices and value to farmers); **possession of more assets**; **the regions where a farmer resides**; and **the living conditions** as defined by permanency of living structure) among others.

4. Lessons and recommendations

The research has gained valuable findings that shed light on the extent to which better access to farm inputs, agriculture extension information, credits and market result in increased income for farmers.

- **Having access to more than one farm input is associated with a higher income for a farmer; the more the number of inputs the farmer uses, the higher the income**. This is especially true for white maize cultivation. This finding means that support to farmers to access more farm inputs especially weedicides, pesticides, and herbicides is likely to result in increased income for farmers who harvest white maize. While there is no large difference in access of individual farm inputs between female and male farmers, data suggests that the proportion of female farmers using multiple inputs decreases as the number of inputs increases. This may be because they have difficulties in accessing additional inputs due to gender bias.
- **Accessing agricultural extension information from formal sources is not associated with a higher income; however, farmers who get information exclusively from AgroCenta have higher incomes.** AgroCenta's extension information may be more relevant to farmers' needs compared to what is provided by other sources such as the Ministry of Food and Agriculture, whose extension information may lack in quality and timely delivery. A larger proportion of female farmers receives information from AgroCenta only, compared to male farmers, but there is no difference in incomes between these men and women.
- **There is no evidence that access to formal credit (banks and micro finance) is associated with a higher income; however, accessing a bank loan appears to be correlated with a higher income**

[40] The t-values are greater than the standard 1.96.
[41] The respective t-values on Tables 15 and 16 are greater than 1.96.

per acre and accessing an MFI loan with a lower income per acre. This may be due to actual productivity or bank selection based on property ownership serving as collateral. There is a slight difference in access to formal credit between female and male farmers with a slightly smaller proportion of females having ever accessed a bank or an MFI loan, compared to males. In addition, a slightly higher proportion of females access a single source of finance, which may point to difficulties they face in accessing multiple sources.

- **Selling to aggregators (formal marketing channels) is associated with a higher income earned**; farmers feel they do not get fair value of produce at the local market. The current arrangement where farmers sell to multiple buyers is actually associated with higher incomes.
- **Higher income does not automatically translate to purchase of all devices, and it is important to understand other drivers of intent to purchase a specific device.** Higher income is associated with the prospective purchase of a solar home system and a solar torch, but not other devices such as a crop dryer, a TV, a cooker and a lantern.
- **Given any level of income, there are gender differences in the prospects of purchasing given solar devices:** considerations of what solar device is of interest to a particular gender may be important in an investment and marketing strategy. Women are more likely to purchase some devices (like solar cookers in this case) if they decide to spend their farm income. Males, on the other hand, are more likely to purchase solar torches. Moreover, farmers who sell any produce to AgroCenta have higher odds of purchasing a solar home system than those who do not.

The findings from the research lead to **the following recommendations** for AgroCenta's future support to increase farmers' income and their access to solar energy:

1. **It is important to support farmers' access to inputs.** Specifically, support to white maize should be sustained while investigating the role of multiple inputs in cultivation of other crops. Women-focused input access strategies should be considered to ensure that women have access to multiple farm input and to formal markets to boost their incomes.
2. **Encourage sale of larger share of produce to aggregators**, as it leads to higher income than selling to local market where often farmers do not receive a fair price for their crops**.** Aggregators should also consider strategies of incentivising farmers to divert bigger shares of their produce to aggregated markets as it leads to higher income.
3. **Invest in increased access to extension information from AgroCenta**, as it is beneficial to the farmers: this may include improving coverage and contact with farmer as to override influence of other sources of extension information that has known shortcomings.[42] It is good to maintain the intake of women while encouraging more men to enlist in agricultural extension information provided by AgroCenta.
4. As most of surveyed farmers use farming income to fund their farming activities, **more research is needed to understand the optimal structure of formal credit available to small scale farmers and strategies of converting farmer income savings into formal credit institutions**. Understanding this can help AgroCenta to target its interventions in needed areas.
5. **Intention to buy a given solar energy device may vary by income and gender** and relevant targeting strategies are useful. Encourage the purchase of solar home systems can be a good starting point as farmers with higher income desire that product, regardless of gender.

[42] Antwi-Agyei &Stringer (2021).

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Annex 2. Descriptive results

Correlation (Pearson correlation) coefficient

This is a statistical measure of the strength of a linear association between two variables. The correlation can be positive (implying higher values of variable 1 are associated with higher values of variable 2) or negative (implying higher values of variable 1 are associated with lower values of variable 2).

Probability (p) value

This is a quantitative indicator of the likelihood of a phenomenon manifesting in data due to pure chance, and therefore not supporting the proposition or relationship under investigation. This is used to indicate the level of significance of statistical results, with the threshold of p-value being acceptable in most studies as 0.05 (5%). If the p-value relating to any estimate of a relationship is greater than 0.05, then the estimate is not any different from zero.

T-test (also known as 'Student t')

This is an inferential statistical tool for evaluating the difference in means between two groups. An independent t-test is applied here to assess differences in means between two groups that are derived from the same sample. The difference in the means is assumed to be zero (null hypothesis).

When the t-value (test statistics that tells us whether or not to reject the null hypothesis) is greater than 1.96, the probability (p-value) associated with this t-value is greater than 0.05 (5%). This means that the difference in the means is not equal to zero (that the two means being tested are actually not equal to each other), and there is less than a 5% chance that the observed difference is actually zero.

The degrees of freedom

This refers to the number observations less the number of associations sought among these observations (the number of parameters estimated using those observations). For instance, in a sample of 717 observations, if we calculate two means from two different sub-samples of males and female, then the number of observations that are free to vary are calculated as 717-2=715.

Table 1: Pairwise correlation between productivity and income earner and number of inputs applied

Crop type	Correlation between productivity (bags/acre) and number of inputs (p-value)	Correlation between income/acre and number of inputs (p-value)
Yellow maize	-0.0741 (0.1218)	0.1709 (0.000)
White maize	-0.1127 (0.0045)	-0.1357(0.0003)
Millet	-0.0137 (0.8078)	0.1817(0.0000)
Soya	0.0677 (0.3995)	0.2507(0.0000)

Table 2: T-tests of difference in income earned per acres by type of extension information received

Receives extension information from:	Formal sources (AgroCenta+MoA or MoA only)		AgroCenta only	
	T=-3.0914; df=715		T=-4.3535; df=715	
	Observations	Mean	Observations	Mean
No	199	2365.394	409	1912.019
Yes	518	2007.323	308	2365.231
Combined	717	2106.704	717	2106.704
Difference		358.071		-453.2118

Table 3: T-tests of income differences based on access to formal sources of credit

	(a) T-test on total income per acre by status of access to formal credit (bank loan or MFI loan)		(b) T-test on total income per acre by status of access to bank loan		(c) T-test on total income per acre by status of access to MFI loan	
	T=0.4357; df=692		T=-3.1944; df=692		T=5.5262; df=692	
Group (accessed bank/MFI loan	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**
No	571	2187.011	608	2114.663	653	2246.812
Yes	123	2127.833	86	2613.858	41	1057.031
Combined	694	2176.523	694	2176.523	694	2176.523
Difference		**59.1786**		**499.1952**		**1189.781**

Table 4: T-tests of difference between income earned per acre by type of market of credit

Income/ acre from:	White maize		Yellow maize		Millet		Soybean	
	T=-7.0646; df=599		T=-8.2276; df=416		T=-2.8604; df=249		T=-2.4139; df=143	
Sells to formal markets (aggregators)	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**
No	367	1923.885	254	1731.624	193	1550.746	108	1767.932
Yes	234	2645.716	164	3061.606	58	2105.517	37	2433.502
Combined	601	2204.931	418	2254.043	251	1678.94	145	1937.767
Difference		-721.8319		-1328.982		-554.7711		-665.5698

Table 5: T-tests of difference in earnings per bag of crop by gender

Differences in earnings per bag of:	Yellow maize (by gender)		Millet (by gender)	
	T=-5.0877; df=426		T=-2.0220; df=250	
Gender	**Observations**	**Mean**	**Observations**	**Mean**
Female	179	302.905	123	385.935
Male	249	345.261	129	407.093
Combined	428	327.54	252	396.7659
Difference		-42		-21.1581

Table 6: T-tests of difference in earnings per bag of crop by market

Differences in earnings per bag of: (among those selling	White maize	Yellow maize	Millet

by aggregators)						
	T=-4.8191; df=622		T=-8.1099; df=426		T=-2.5304; df=250	
Sell most produce to aggregators	Observations	Mean	Observations	Mean	Observations	Mean
No	375	314.7733	260	301.8846	194	389.5619
Yes	249	344.5783	168	367.2619	58	420.8621
Combined	624	326.6667	428	327.5467	252	396.7659
Difference		-29.805		-65.3773		-31.300

Table 7: T-tests of difference in earnings by gender among those who sell most produce to aggregators (organized markets)

Differences in earnings per bag of:	Yellow maize	
	T=-2.5528; df=166	
	Observations	Mean
Female	53	341.8868
Male	115	378.9565
Combined	168	367.2619
Difference		-37.0697

Table 8: Gender differences in total income per acre

Differences in total income earned per acre		
	T=-3.4131; df=692	
Gender	Observations	Mean
Female	319	1986.17
Male	375	2338.45
Combined	694	2176.52
Difference		-352.27

Table 9: Difference in total income per acre by market

Differences in total income by market		
	T=-7.9304; df=715	
Sells most produce to aggregators	Observations	Mean
No	419	1771.927
Yes	298	2577.414
Combined	717	2106.704
Difference		-805

Table 10: Regression coefficients and marginal values

	Coefficient	Marginal Values
Eastern Region	*1.3517*	*286.3989*
others	*0.6642832*	*94.30972*
exten_AgroCenta_exclusive - Yes	0.0072268	0.725298
where_you_sellMOST- AgroCenta	*-0.3064415*	*-26.3938*
where_you_sellMOST- other aggregators	*0.160657*	*17.42821*
1.whereelse_AgroCenta	*0.1912451*	*21.07562*
total_markets	*0.142316*	*15.29409*
total_inputs_used	*0.2433692*	*27.55395*
1.certifiedseeds_used	*-0.5760659*	*-43.7895*

1.pestcides_used	***-0.3232133***	***-27.6181***
1.fertilizers_used	-0.1797326	-16.4506
total_cropscultivated	***0.1308981***	***13.98516***
gender_farmer -Male	0.0497621	5.102103
educ_classes-primary	-0.0013014	-0.13006
educ_classes-secondary	0.0868632	9.074746
educ_classes-secondary	0.1302912	13.91601
size_family	***-0.0243562***	***-2.4062***
title_inname	***0.171037***	***18.65346***
farmsizeinacreswhereyougrowcrops	-0.0084533	-0.84177
distance_market	***0.0098503***	***0.989897***
membership_cooperative	***-0.2868032***	***-24.9341***
common_financesource-Banks/mfi	-0.2752332	-24.0605
common_financesource-personal non-farm income	***-0.3223638***	***-27.5565***
common_financesource-loans from friends and family	***-0.3387569***	***-28.7344***
total_assets	***0.0855755***	***8.93438***
farmer_age	0.0040315	0.403964
farmer_Agesd	-0.0000987	-0.00987
cons	***5.662385***	***28683.43***

*Bold means the coefficient is significant

Table 11: Differences in income by current ownership of a solar device

Differences in income by status of owning at least one solar device		
	T=2.145; df=717	
Sells most produce to aggregators	**Observations**	**Mean**
No	502	2033
Yes	215	2277
Combined	717	2106
Difference		-244

Table 12: Income differences by prospects of purchasing any device

Differences in income by expressed intention to purchase:	At least one solar device	
	T=2.91; df=715	
Would purchase at least one solar device	**Observations**	**Mean**
No	15	3138.83
Yes	702	2084.70
Combined	717	2106.70
Difference		1054.18

Table 13: Income differences by prospects of purchasing given devices

Differences in income by expressed	Solar pump	Solar TV	Solar torch	Solar home system

intention to purchase:								
	T=-9.2254; df=715		T=-3.3589; df=715		T=-1.9840; df=715		T=-4.1459; df=715	
Would purchase a solar device	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**
No	250	2729	201	2385.5	282	1978.401	177	1733.08
Yes	467	1773	516	1998.103	435	2189.88	540	2229.17
Combined	717	2106	717	2106.704	717	2106.704	717	2106.704
Difference		955		387.397		-211.4782		-496.0894

Table 14: Income differences of female farmers by prospects of purchasing given devices

Differences in income by expressed intention to purchase:	Solar Cooker		Solar Home System		Solar Pump		Solar TV	
	T=2.8805; df=326		T=-4.4115; df=326		T=5.8692; df=326		T=2.7885; df=326	
Would purchase a solar device	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**
No	112	2236.86	83	1362.85	105	2560.10	90	2277.89
Yes	116	1773.43	245	2124.37	223	1635.77	238	1800.746
Combined	328	1931.67	328	1931.67	328	1931.672	328	1931.67
Difference		463.43		-761.52		924.33		477.15

Table 15: Income differences of Male farmers by prospects of purchasing given devices

Differences in income by expressed intention to purchase:	Solar Pump		Solar TV		Solar Lantern	
	T=6.9599; df=387		T=1.9777; df=387		T=-2.3335; df=387	
Would purchase a solar device	**Observations**	**Mean**	**Observations**	**Mean**	**Observations**	**Mean**
No	145	285.356	111	2472.75	84	1944.54
Yes	244	1899.47	278	2167.06	305	2339.60

Combined	389	2254.28	389	2254.29	328	-395.06
Difference		951.88		305.68		

Annex 3. Logistical regression results for purchase of solar energy device

A statistical model of relationships takes the structure Y=f (X_1, X_2, X_3, … X_n), where Y is the dependent variable, whose outcome is being predicted in the model, and Xs are the independent variables. In the models below the dependent variable is the top item in the second column (e.g., 'wouldbuy_SHS').

Independent variables are those variables included in the model to help explain Y (they are listed in column 1 in the below models).

A logistic regression is a statistical technique of modelling relationships between a variable that has only two values (known as outcomes) on one hand, and other variables that may assume an interval or an outcome nature. For instance, 'would buy _SHS' is an outcome variable indicating if a farmer would buy SHS or not.

The co-efficient indicates the 'log odds' of achieving the outcome (dependent variable). If positive (negative) and statistically significant, then a unit increase in the relevant independent variable increases (decreases) the log odds of an outcome (buying a given solar device).

***denotes statistically significant coefficient (at 5% level of significance).

Table 16: Logistic regression for purchase of SHS

	(1)
VARIABLES	wouldbuy_SHS
LTOTALINCOME_PERACRE	0.380**
	(0.181)
farmer_age	-0.00142
	(0.0527)
farmer_Agesd	8.77e-05
	(0.000572)
1.REGION	-3.188***
	(0.390)
2.REGION	-2.440***
	(0.683)
1.toAgroCenta_any	1.370***
	(0.270)
1.educ_classes	0.245
	(0.281)
2.educ_classes	0.661**
	(0.296)
3.educ_classes	0.633
	(0.615)
1.gridconnectivity	-0.302
	(0.624)
1.solar_connectivity	-0.410
	(0.720)
1.solar_knowhow	-1.100***
	(0.305)
1.permanent	-0.616**
	(0.309)
1.duration	-3.222***
	(0.476)
total_assets	-0.321*
	(0.181)
1.owns_SHS	-0.0794
	(0.385)
1.main_ligitingfuel	-0.263
	(0.658)
2.main_ligitingfuel	-2.338***
	(0.680)
3o.main_ligitingfuel	-

4.main_ligitingfuel	-0.378
	(1.042)
Constant	3.241*
	(1.908)
Observations	686

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 17: Logistic regression for purchase of solar crop drier

VARIABLES	(1) wouldbuy_cropdrier
LTOTALINCOME_PERACRE	-0.363**
	(0.172)
1.educ_classes	0.354
	(0.250)
2.educ_classes	-0.207
	(0.253)
3.educ_classes	0.0396
	(0.537)
1.REGION	1.771***
	(0.419)
2.REGION	2.388***
	(0.661)
1.toAgroCenta_any	-1.944***
	(0.208)
farmsizeinacreswhereyougrowcrops	0.0246
	(0.0234)
total_cropscultivated	0.0233
	(0.156)
total_assets	0.0938
	(0.158)
farmer_age	0.0238
	(0.0511)
farmer_Agesd	-0.000537
	(0.000570)
1.gridconnectivity	-0.454**
	(0.207)
1.solar_connectivity	0.454
	(0.413)
1.owncrop_drier	2.902***
	(1.125)
Constant	2.073
	(1.650)
Observations	687

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 18: Logistic regression for purchase of solar cooker

VARIABLES	(1) wouldbuy_solarcooker
LTOTALINCOME_PERACRE	-1.239***
	(0.178)
farmer_age	0.0394
	(0.0452)
farmer_Agesd	-0.000534
	(0.000493)
1.gender_farmer	-0.621***
	(0.197)
1.REGION	0.445
	(0.345)

2.REGION	0.881 (0.687)
1.toagrocenta_any	-0.406* (0.222)
1.educ_classes	0.0473 (0.257)
2.educ_classes	0.360 (0.261)
3.educ_classes	-0.103 (0.531)
1.gridconnectivity	0.728*** (0.214)
1.solar_connectivity	0.765* (0.397)
1.solar_knowhow	-0.706*** (0.256)
1.permanent	-0.458* (0.257)
1.duration	-1.887*** (0.338)
total_assets	-0.0518 (0.162)
1.cooking_fuel	0.121 (0.233)
2.cooking_fuel	1.213 (0.890)
1.ownsolarcooker	-0.0597 (0.573)
Constant	10.54*** (1.671)
Observations	687

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 19: Logistic regression for purchase of solar lantern

VARIABLES	(1) wouldbuy_solarlantern
LTOTALINCOME_PERACRE	0.164 (0.170)
1.REGION	-0.407 (0.360)
2.REGION	1.071 (1.107)
l_total_hh_expenditure	0.354*** (0.137)
1.gridconnectivity	-0.0594 (0.235)
1.solar_connectivity	-1.649*** (0.373)
distance_market	0.00278 (0.0110)
1.solar_knowhow	-0.141 (0.277)
1.educ_classes	-0.192 (0.282)
2.educ_classes	-0.118 (0.257)
3.educ_classes	-0.336 (0.567)
1.permanent	0.0132 (0.290)
total_assets	-0.0944

	(0.183)
1.own_solarlantern	-0.828***
	(0.308)
Constant	-1.722
	(1.515)
Observations	678

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 20: Logistic regression for purchase of solar pump

VARIABLES	(1) wouldbuy_solarpump
LTOTALINCOME_PERACRE	-0.232
	(0.188)
farmer_age	0.0403
	(0.0531)
farmer_Agesd	-0.000217
	(0.000590)
1.REGION	-2.123***
	(0.351)
2.REGION	-1.325*
	(0.709)
1.toAgroCenta_any	-0.705***
	(0.251)
1.educ_classes	0.216
	(0.281)
2.educ_classes	0.390
	(0.271)
3.educ_classes	0.643
	(0.609)
1.gridconnectivity	-1.281***
	(0.244)
1.solar_connectivity	-1.015**
	(0.466)
1.solar_knowhow	0.215
	(0.301)
1.irrigation_status	0.107
	(0.546)
1.permanent	0.838***
	(0.261)
farmsizeinacreswhereyougrowcrops	-0.0272
	(0.0216)
1.duration	-0.249
	(0.349)
total_assets	0.479***
	(0.178)
1.solar_pump	-0.360
	(0.466)
Constant	2.295
	(1.837)
Observations	687

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 21: Logistic regression for purchase of solar torch

VARIABLES	(1) wouldbuy_solartorch
LTOTALINCOME_PERACRE	-0.604***
	(0.156)
farmer_age	0.0213
	(0.0427)
farmer_Agesd	-0.000277
	(0.000470)
1.gender_farmer	0.388**
	(0.187)
1.REGION	0.307
	(0.313)
2.REGION	0.894
	(0.819)
1.toagrocenta_any	1.029***
	(0.221)
1.educ_classes	-0.117
	(0.247)
2.educ_classes	-0.221
	(0.244)
3.educ_classes	0.541
	(0.530)
1.gridconnectivity	0.400**
	(0.197)
1.solar_connectivity	0.284
	(0.388)
1.solar_knowhow	-0.799***
	(0.236)
1.permanent	-0.593**
	(0.246)
1.duration	-1.039***
	(0.334)
total_assets	-0.358**
	(0.158)
1.own_solartorch	-0.370
	(0.227)
Constant	5.744***
	(1.541)
Observations	687

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 22: Logistic Regression for purchase of solar TV

VARIABLES	(1) wouldbuy_solarTV
LTOTALINCOME_PERACRE	-1.084***
	(0.186)
farmer_age	-0.105**
	(0.0508)
farmer_Agesd	0.00111*
	(0.000577)
1.REGION	0.593*
	(0.356)

2.REGION	1.613
	(1.143)
1.toAgroCenta_any	-0.192
	(0.245)
1.educ_classes	0.445
	(0.281)
2.educ_classes	0.0979
	(0.260)
3.educ_classes	0.608
	(0.580)
1.gridconnectivity	0.0716
	(0.218)
1.solar_connectivity	0.103
	(0.419)
1.solar_knowhow	-0.980***
	(0.275)
1.permanent	-0.442
	(0.280)
1.duration	-0.597*
	(0.349)
total_assets	-0.485***
	(0.181)
1.cooking_fuel	-0.634**
	(0.247)
2.cooking_fuel	1.516
	(1.123)
1.ownsolar_TV	-0.892
	(0.542)
Constant	13.55***
	(1.867)
Observations	687

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1