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AGRICULTURAL TECHNOLOGY, FOOD SECURITY AND NUTRITION: INSIGHT FROM OIL PALM SMALLHOLDERS IN GHANA

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ACRONYMS

APRA	Agricultural Policy Research in Africa
FAO	Food and Agriculture Organization of the United Nations
FE	fixed effect
FIES	Food Insecurity Experience Scale
IMR	Inverse Mills Ratio
OLS	Ordinary Least Squares
POLS	Pooled Ordinary Least Squares
WDDS	Women Dietary Diversity Score

EXECUTIVE SUMMARY

The use of agricultural technologies has facilitated gains from agricultural commercialisation for smallholder farmers in Africa. Practices that involve these technologies play an important role in tackling poverty and food insecurity in Sub-Saharan Africa. Hence, the link between agricultural technology practices, food security and nutrition is important, and has relevant implications for policymaking. Using new panel data for oil palm producers in Ghana from the Agricultural Policy Research in Africa (APRA) consortium, we shed light on the relationship between the use of agricultural practices, food security and nutrition outcomes, focusing especially on the mediating role of women empowerment.

We find that for oil palm producers in south-western Ghana, the use of at least one agricultural practice among irrigation and the use of agrochemicals is significantly linked with women's dietary diversity, and this relationship is mediated by our measure of women empowerment. Women empowerment appears to be a positive factor for household food security, regardless of the technological use status. Further, looking at the intensity of technology use, accounting for heterogeneity in use, women empowerment remains a significant factor mediating the relationship between fertiliser use and food insecurity. However, while the use of at least one agricultural practice is linked with improved women's dietary diversity for the group of women that score better in terms of our measure of empowerment, it appears associated with increased household food insecurity for the group of women that score lower on our measure of empowerment.

The implications of our results for policy and practice are as follows. Appropriate support for facilitating agricultural practices is important for household food security and women's nutrition. While providing access to technology is particularly relevant, it is not enough on its own, and complementary policy interventions that improve women empowerment and women's bargaining power within the household play an essential role in improving nutrition outcomes for women.

1 INTRODUCTION

The use of agricultural technologies contributes to economic development for smallholder farmers in Africa. The increase in agricultural commercialisation, facilitated by the dissemination of such technologies, plays an important role in tackling poverty and food insecurity in Sub-Saharan Africa (Von Braun, 1995). But women's role in these processes and within the household should be carefully considered (Harris-Coble, LeBeau and Colverson, 2018). It is important to evaluate how different practices involving agricultural technologies – relevant to specific crops – and any inherent gender dynamics are associated with improvements in household food security, as well as nutritional outcomes for women in particular. However, there has been insufficient attention to localised evidence on these aspects, and while the above has received broad attention, fewer studies consider them together (Passarelli et al., 2018; Kassie et al., 2020).

In this paper, we address the above research gap by studying the linkage between technology use, nutrition, and food security in Ghana, focusing on the mediating role of women empowerment, using panel data from a survey with oil palm producing farm households from the Agriculture Policy Research in Africa (APRA) consortium. Previous studies investigating agricultural technology use, and its impact on the welfare of smallholder farmers, indicate that farmer characteristics and the physical attributes of the area where households live, determine how, and the extent to which, technology affects farmers' welfare. Therefore, our approach is informed by local evidence as critical in fostering and strengthening knowledge about and the returns from the use of technologies in practice.

What also emerges from previous studies is that often the main interest for women is in ensuring household food security (Aryal et al., 2020), and "non-priced values" concerning nutritional, ecological, institutional and educational matters. In order to ensure these outcomes, women's own position in the household plays a critical role that cannot be ignored (Njuguna et al., 2016). However, there may be situations where women are unable to ensure both household food security and better nutrition for themselves, an aspect that we explore in this paper.

This study links with Kassie et al. (2020) and builds on it in several ways. First, technology is captured as the use of different agricultural practices – agrochemicals or irrigation – based on a preliminary technical analysis about growing oil palm in Ghana that suggests these practices are essential to increase productivity. We focussed on these two technologies because the main issues related to oil palm management in Ghana include poor water availability, insufficient drainage and poor nutrient management – namely, the failure to consider the correct nutrient requirement of the crop and to use fertilizers and crop residues correctly (IPNI, 2015). Analyzing these two practices can therefore provide useful insights on their contribution, not only to oil palm productivity, but also to farmers' food security and nutrition. Second, we use new panel data from farm household surveys that are representative of oil palm producers in specific areas of Ghana. Further, we capture empowerment by combining information about women's inputs on personal decisions, the use of their wages, minor household expenditures, decisions on sales, and inputs and outputs use.

To understand the direct nexus between technology use, nutrition, and food security, but also the role of women empowerment as a factor, we use panel regression methods and a Heckman model. The remainder of this paper is organised as follows. Section 2 presents a brief review of the literature and discusses the conceptual framework that guides the analysis. Section 3 presents the data, outlines summary statistics, and explains the empirical framework to be applied in the analysis. In Section 4, the empirical results are presented, and key insights are discussed. Section 5 concludes with policy implications.

2 OVERVIEW AND FRAMEWORK

2.1 Technology use by gender

Several studies focus on the adoption of agricultural technologies by female farmers (Damisa and Igonoh, 2007; Tanellari et al., 2014; Namonje-Kapembwa and Chapoto, 2016; Mensah, Villamor and Vlek, 2018), finding that factors such as farmer experience, dependency ratio, family remittance and income positively influence female farmers' adoption. Households with female participation in decision-making are more likely to adopt technology; however, women sometimes have a weaker understanding of climate-smart agricultural practices, which affects their ability and willingness to influence intra-household decision-making processes around adoption (Aryal et al., 2020). This leads us to a relevant factor that affects female adoption and that concerns their level of education, their access to extension and learning opportunities. Matshe, Zikhali and Chilonda (2010) studied the role of female education levels on female farmers' decisions to purchase chemical fertiliser in Zimbabwe, finding a positive and significant effect of education on female farmers' adoption. Ragasa et al. (2013) investigated gender differences in access to extension services and how this translates to observed differences in technology adoption and agricultural productivity in Ethiopia – finding that receiving advice from extension agents was positively related to the adoption of improved seed and fertiliser for both females and males. Lastly, Mishra et al. (2020) investigated the role of self-learning in explaining female adoption of hybrid seed, inorganic fertiliser or pesticides in Uganda. They found that farmers' self-experimentation matters but, facing fewer opportunities for learning than male-headed households, a weaker impact of self-learning for female-headed households was observed.

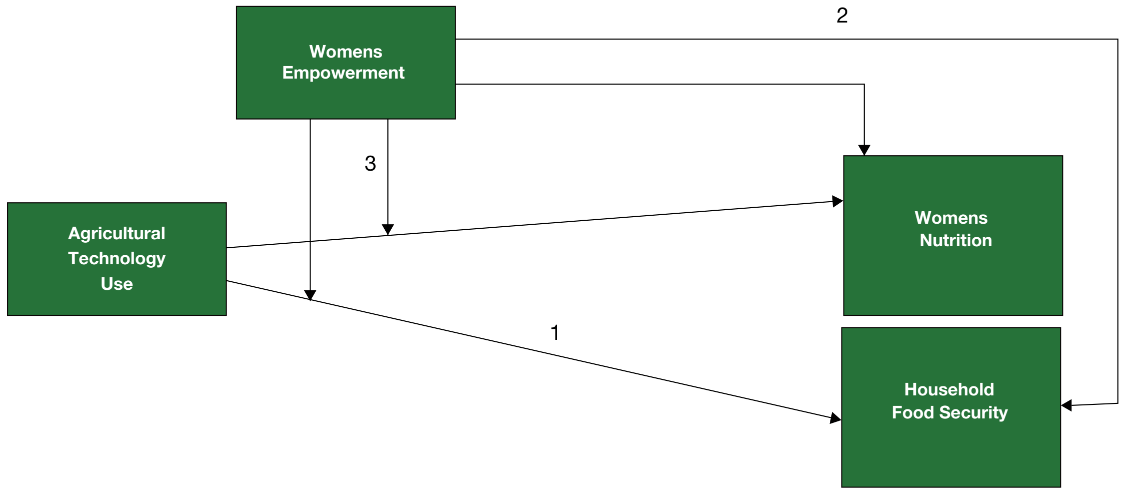
Other studies have compared the outcomes of adopting agricultural technologies between male and female farmers (Doss and Morris, 2001; Diiro, Ker and Sam, 2015), whereas further studies that added joint control over land in their analysis, obtained mixed results (Ndiritu, Kassie and Shiferaw, 2014; Gebre et al., 2019). Controlling for the demographics of the manager, and plot characteristics, Marenya, Kassie and Tostao (2015) found that joint management of agricultural plots is associated with higher fertiliser application rates on maize plots, but with lower fertiliser application on non-food cash plots. Joint management would therefore work well under the assumption that the benefits from additional production would be available to all household members equally (Haider, Smale and Theriault, 2018). Theis et al. (2018) explored who within the household used and controlled a small-scale irrigation technology in Ethiopia, Ghana, and Tanzania, focusing on women typically cultivating both joint and individually-managed plots, with some independent control over income. Overall, rights over technology were found to be distributed differently among the households considered. Women valued irrigation, especially for crops and plots where they controlled management and from which they had the right to derive profit. However, this right is particularly weak when there is information asymmetry over the sales of joint production. Furthermore, the right to use a technology does not necessarily confer other rights and it may simply represent a greater labour burden for women.

2.2 Technology use, gender and nutrition

What emerges from some studies is that women are often more interested in "non-priced values", such as nutrition rather than income (Aryal et al., 2020). The level at which they can achieve these, however, is affected by their position and empowerment in the household. Some literature has attempted to put these three elements (technology use, women empowerment and nutrition) together. For example, Kassie et al. (2020) investigated the moderating effect of women's empowerment on the relationship between adoption of a push-pull organic pest control system and women's dietary diversity in western Kenya. They found that women's empowerment had a positive and significant effect on the women's dietary diversity score regardless of technology adoption status. Although technology adoption has a positive impact on women's dietary diversity, its effect therefore appears stronger for households where women are seen as more empowered.

Nkonya, Kato and Ru (2020) analysed the characteristics of irrigation adoption in Mali and its impact on

Figure 2.1. Conceptual framework



Source: Authors' own, 1, 2 and 3 indicate pathways

household dietary diversity across sex of irrigators. The share of women irrigators was significantly lower than their male counterparts. The authors highlight the importance of women participating in farmer groups as a way to increase their propensity to adopt irrigation, since this could be an entry point for capacity building on irrigation. Additionally, the authors found that irrigation increased the consumption of nutrient-rich food groups, which significantly improved household nutrition in addition to increasing income.

Passarelli et al. (2018) investigated the potential for small-scale irrigation to contribute to improved diets, and whether the women's empowerment pathway could link irrigation to household (especially child and maternal) dietary diversity in Ethiopia and Tanzania, using cross-sectional data. Dietary diversity was higher in woman-headed households in Ethiopia, while the opposite was noticed in Tanzania. Njuguna et al. (2016) examined the dynamics of female adoption of drought-tolerant, early-maturing seeds in relation to improvements in food security. Nutritional, ecological, institutional, and educational elements affected women's adoption, and gains in a range of measures of household food and nutrition security after adoption were noted.

2.3. Conceptual framework

Figure 2.1 shows a framework for understanding direct and indirect links between agricultural technology use, women's empowerment, and women's dietary diversity, similar to Kassie et al. (2020).

The first pathway relates to the effect of technology use on women's dietary diversity and household food security, which could operate through many mechanisms such as production or income (Kidane, Maetz and Dardel, 2006; Sanchez, 2019; Bairagi, Mishra and Durand-Morat, 2020; Obayelu et al., 2021).

The second pathway is that woman's empowerment has a direct effect on her dietary diversity and on household food security. Women, seen as more empowered, are expected to have better knowledge of nutrition and health in general. They also have more control on household resources to apply that knowledge to the quality of their diets and to the food security of the household. This is because they may be able to afford nutritious food, either through their own production or purchase in the market and also consume more food themselves. Doss (2006), analysing Ghana, showed that women's share of assets, particularly farmland, significantly increased food budget shares (Galiè et al., 2019). Thus, women's empowerment can lead to improved nutrition for them and for all household members (Malapit and Quisumbing, 2015; Malapit et al., 2015).

Lastly, the third pathway concerns the role of women's empowerment in mediating the effects of technology adoption on dietary diversity. Many previous studies agree on the fact that women are more interested in nutrition and the quality of household diets. And women that participate more in household decisions or that can have more control on resources are able to ensure that a potential increase in food availability or in income is translated to strong household food security (Passarelli et al., 2018). Finally, pathway represents the interaction of women's empowerment in determining whether any increased income or other crop production due to the use of agricultural technology use impacts women's dietary diversity (Kassie et al., 2020). Using the framework, we analyse the following research questions:

RQ1: What is the link between agricultural technology use, household food security, and dietary diversity for women?

RQ2: What is the role of women empowerment for women's dietary diversity and household food security?

RQ3: What is the mediating effect of women empowerment on the relationship between technology use and nutrition or food security?

We use panel data, context specific for oil palm growers in Ghana. We capture technology use specific for oil palm based on a review of the agricultural practices needed in the sector. Lastly, we capture empowerment combining input on wage and on minor household expenditure with decision on crops' sales, use of inputs on the plot managed and use of outputs.

3 METHODS

3.1. Sampling and data

The data used in this study are derived from household surveys conducted in 2017 and 2019 by APRA. The districts involved were the Ahanta West and Mpohor districts located within the oil palm belt of south-western Ghana. The districts were selected because of the high concentration of oil palm production by smallholder farmers and because two of Ghana's "big four" oil palm companies (Norpalm Ghana Ltd and Benso Oil Palm Plantation Ltd), and a medium-scale oil palm processing company (Building Business on Values, Integrity and Dignity, B-BOVID), are based in this area. After a review of the literature, two visits in the area and the identification of the broader channels through which oil palm producers sell their fruits after harvesting, a list of communities in which farmers were engaging with the various commercialisation channels was obtained. Since a reliable sampling frame was not available, 20 communities were randomly selected and a census for constructing a frame was carried out. Based on sample size calculation,[1] the original idea was to draw on a sample of 600 oil palm grower households at random, adequate to represent each ex-ante group (different sales channels). Nevertheless, a larger sample was needed due to the heterogeneity within the sale channels; thus, a sample of 700 households was targeted. The first survey round was conducted in 2017 and covered 726 oil palm farm households. The second survey round was conducted in 2019, when 137 households were added to the sample (Dzanku et al., 2020). Attrition in the sample was very low, as only 60 households were not re-interviewed.

The survey used a structured core questionnaire to collect data from the randomly-selected households on plots cultivated, agricultural production and marketing, non-farm activities and income sources, assets owned by households, food security and dietary diversity. Information both at the individual and at the household level were included in the questionnaire and specific sections about women's income, nutrition, decisions within the household and information about care work were embodied. Data were collected through face-to-face interviews with the household head or another adult family member with relevant knowledge about the questions when the head was not available. A team of enumerators was trained and supervised by the senior researchers (Saha, Sabates-Wheeler and Thompson, 2021).

Table 3.1. Number of households in the sample using and not using agricultural practices considered on oil palm plots

	2017		2019		Pooled sample	
	Non-users	Users	Non-users	Users	Non-users	Users
At least one of the practices	547 (75.66)	176 (24.34)	644 (81.11)	150 (18.89)	1191 (78.51)	327 (21.49)
Irrigation	703 (91.70)	20 (8.30)	781 (91.06)	13 (8.94)	1484 (91.36)	33 (8.64)
Agrochemicals	561 (77.59)	162 (22.41)	649 (81.74)	145 (18.26)	1210 (79.76)	307 (20.24)

Note: Percentage shares are shown in parentheses.

Source: Authors' own

1. The sample size calculations were based on four statistical assumptions: (a) a 5 per cent level of signifi cance (i.e., $\alpha = 0.05$); (b) a 0.144 standard deviation of the outcome variables of interest for rural Western Region, which was estimated using household dietary diversity scores based on the Ghana Living Standards Survey data (GLSS6); (c) less than 0.10 expected change (or difference) in the outcome variable (i.e., effect size < 0.10); and (d) statistical power of 80 per cent (Dzanku et al., 2020).

3.2. Measurement of key variables

Technology use – practices

The main explanatory variable is the use of at least one agricultural practice (irrigation or agrochemicals), that were selected based on considerations that emerged from a technical analysis about growing oil palm. The use of these practices was captured through a dummy variable at the household level. The dummy equals 1 if the household adopts at least one of the two practices. Table 3.1 displays the number of households in the sample reporting using and not using the practices considered on oil palm plots. We also captured the intensity of technology use as a variable from 0 to 2, according to the number of practices used by each household. Since there could be heterogeneity in agrochemicals use, a household that used 5kg of fertiliser cannot be treated the same as another that used 25kg; thus, we also considered the intensity of agrochemical use separately.

Women empowerment

Our measure of women's empowerment is based on a score – which we call "empowerment score" – that goes from zero to five according to the number of the above-mentioned domains in which women reported that they had some sort of control.[2] We then used this measure to identify two groups of women: one that included women who scored better in terms of empowerment, and one formed of women with a lower empowerment score. To represent these two groups, a dummy was one if the empowerment score was equal to or greater than a certain threshold, and zero otherwise.

Women dietary diversity

In the literature, indicators about dietary diversity are often used at the household level, but we go further and use this score at the individual level since we have information on female dietary diversity. In particular, we used the Women Dietary Diversity Score (WDDS), developed by the Food and Agriculture Organization of the United Nations (FAO) (Kennedy, Ballard and Dop, 2011) as one of the outcome variables. The dietary diversity score was calculated by summing the number of food groups consumed by the individual respondent over the 24-hour recall period. Nine food categories were considered: starchy staples (grains and white roots); fruits and vegetables rich in vitamin A; other fruits and vegetables; organ meat; meat and fish; legumes, nuts and seeds; eggs; and milk and milk products. Thus, the WDDS was a variable that ranges from 0 to 9. This variable was created by firstly generating food group variables for those food groups that need to be aggregated; secondly, the variable WDDS was generated as the sum of all food groups included in the dietary diversity score. In our dataset, this variable ranged from zero to eight, meaning that there is no woman who consumed food from all nine food groups.

Household food security

To represent household food security status, we used the Food Insecurity Experience Scale (FIES) created by FAO. FIES represents a statistical measurement scale of the severity of food insecurity at the household or individual level, and it is based on people's direct yes/no responses to eight questions related to their access to adequate food (Cafiero, Viviani and Nord, 2018). Analysed together, these questions form a quantitative tool to measure the prevalence of food insecurity in a population: they cover different food-related experiences, and they are associated with a different level of severity of food insecurity. A valuable contribution of FIES is that it also captures psychosocial aspects related to anxiety or uncertainty regarding the ability to obtain enough food. A second key innovation of FIES is that it produces estimates that can be compared across countries (FAO, 2021). Using the Rash test, we obtained a raw score that ranged from zero to eight.

3.3. Descriptive statistics

Table 3.2 briefly defines the main variables for this analysis.

Table 3.3 shows the summary statistics for the two outcomes both by technology use (users and non-users) and by empowerment status (low and high). In all the samples considered, users had a higher WDDS (difference significant in the pooled and in the 2019 samples) and a lower FIES (significant for the pooled and the 2017 samples). Women with a higher empowerment score had on average a greater WDDS in 2017 but not in 2019 and in the pooled sample (but these differences are not significant). However, they had a lower FIES compared to the group of women with lower levels of empowerment, and this difference was significant in 2017 and in the pooled sample.

Table 3.4 shows the descriptive statistics for other socio-economic characteristics used in the analysis, for the samples of technology users and non-users.

2 This variable is missing if the woman under consideration stated that she did not have control over any domain analysed; otherwise, if we did not have a reply for a single domain, we consider it as zero.

Table 3.2. Definition of the main variables used in the analysis

Indicator	Definition of the indicator
Technology	
Technology use	Dummy = 1 if the household uses at least one technology (among irrigation and agrochemicals) Continuous variable from zero to two for the quantity of fertiliser used.
Quantity of fertiliser used	Kilograms of fertiliser used.
Women's outcome	
WDDS	Number of food groups consumed based on 24-hour recall out of nine: (1) starchy staples; (2) green leafy vegetables; (3) vitamin-A rich fruits and vegetables; (4) other fruits and vegetables; (5) organ meat; (6) meat and fish; (7) eggs; (8) legumes and nuts; (9) milk and milk products.
Household outcome	
FIES	Number of food insecurity sub-indicators in the past 12 months out of eight: (1) worry about not having enough food to eat because of a lack of money or other resources; (2) unable to eat healthy and nutritious food because of a lack of money or other resources; (3) ate only a few kinds of foods because of a lack of money or other resources; (4) skip a meal because there was not enough money or other resources to get food; (5) ate less than you thought you should because of a lack of money or other resources; (6) ran out of food because of a lack of money or other resources; (7) hungry but did not eat because there was not enough money or other resources; (8) went without eating for a whole day because of a lack of money or other resources.
Empowerment	
Empowerment	
Women empowerment score	Dummy = 1 if the empowerment score is equal or greater than a threshold.
	Score from zero to five according to the number of the domains in which women have some sort of control. Missing values for any single subdomain are considered as zero.
Subdomain indicators	
Main manager of the household's plots	At least one female household member makes decisions about which crops to grow and which inputs to be used on the plot
Decision-making on outputs use	At least one female household member makes decisions about how to use the output from the plot
Decision-making on crops sale	At least one female household member makes decisions about whether to sell crops
Inputs on wage use	Women in the household feel they can make at least some personal decisions regarding the use of their wage, if they want to
Inputs on minor expenditure	Women in the household feel they can make at least some personal decisions regarding minor expenditure, if they want to

Source: Authors' own

Some statistical differences in these variables between these two groups can be observed. For the pooled sample, a greater percentage of women in user households scored better in terms of empowerment (empowerment score equal to or greater than two), compare to those in non-user households. On average it seems that women in the user households spent slightly more time on care work, but the difference was not significant.

Household heads in user households were on average younger and slightly more educated than their non-user counterparts. The average number of household members and female members in each household was similar, but slightly higher for users. User households cultivated more hectares of land, and they dedicated a slightly higher number of plots to oil palm. Concerning wealth, adopter households had a larger asset ownership score, and the difference was significant in the pooled and in the sample of 2019.

3.4 Empirical strategy

Pooled Ordinary Least Squares

A panel OLS regression model with an interaction term was carried out for each of the outcome variable under analysis:

Table 3.3 Descriptive statistics of the outcome variables by technology use and women's empowerment

	2017		2019		Pooled sample	
	Non-users	Users	Non-users	Users	Non-users	Users
WDDS	3.091 (1.221)	3.791 (1.118)	2.915 (1.063)	3.190*** (1.004)	2.999 (1.144)	3.512*** (1.106)
FIES	1.763 (2.119)	0.858* (1.436)	1.559 (2.347)	1.060 (2.019)	1.656 (2.243)	0.952* (1.106)
N	417	134	461	116	878	250
	2017		2019		Pooled sample	
	Low empowerment score	High empowerment score	Low empowerment score	High empowerment score	Low empowerment score	High empowerment score
WDDS	3.190 (1.029)	3.275 (1.279)	3.071 (.884)	2.952 (1.081)	3.136 (.966)	3.104 (1.189)
FIES	1.962 (2.024)	1.444* (1.996)	1.709 (2.305)	1.423 (2.304)	1.848 (2.153)	1.433* (2.162)
N	105	448	86	496	191	944

Note: Users and non-users refer to the use of at least one of the two practices under review. Mean values are shown with standard deviations in parentheses. Differences in means between users and non-users are tested for statistical significance. * p<0.05, ** p<0.01, *** p<0.001

Source: Authors' own

$$WDDS_{it} = \alpha + \beta_1 \cdot tech_{it} + \beta_2 \cdot \ empower_{it} + \beta_3 \ \cdot tech * empower_{it} \ + \beta_4 X_{it} + \varepsilon_{it} \quad (1)$$

$$FIES_{it} = \alpha + \beta_1 \cdot tech_{it} + \beta_2 \cdot empower_{it} + \beta_3 \ \cdot tech * empower_{it} \ + \beta_4 X_{it} + \varepsilon_{it} \quad (2)$$

Where *WDDS* is the Women Dietary Diversity Score, *FIES* is Food Insecurity Experience Scale, *tech* is the technology variable indicating the number of practices used (count variable from 0 to 2), *empower* is the empowerment dummy, *tech*empower* is the interaction term and X is a vector of control variables that include the household characteristics: age and education of the household head, number of household members, number of female members in the households, hectares of land cultivated, number of plots cultivated with oil palm and asset score. Lastly, t indicates the time periods (in this case two) and i the individuals.

Fixed effect models

Afterwards, the same specifications expressed above were used in a fixed effect (FE) model:

$$WDDS_{it} = \alpha + \beta_1 \cdot tech_{it} + \beta_2 \cdot empower_{it} + \beta_3 \ \cdot tech * empower_{it} + \beta_4 X_{it} + \sum_{j=1}^{N-1} \mu_j D_{ji} + \varepsilon_{it} \quad (1')$$

$$FIES_{it} = \alpha + \beta_1 \cdot tech_{it} + \beta_2 \cdot empower_{it} + \beta_3 \ \cdot tech * empower_{it} \ + \beta_4 X_{it} + \sum_{j=1}^{N-1} \mu_j D_{ji} \ + \varepsilon_{it} \quad (2')$$

Finally, we also add a time dummy:

$$WDDS_{it} = \alpha + \beta_1 \cdot tech_{it} + \beta_2 \cdot \ empower_{it} + \beta_3 \cdot tech * empower_{it} \ + \beta_4 X_{it} + \sum_{j=1}^{N-1} \mu_j D_{ji} + \sum_{s=1}^{T-1} \tau_s D_{st} + + \varepsilon_{it} \quad (1'')$$

$$FIES_{it} = \alpha + \beta_1 \cdot tech_{it} + \beta_2 \cdot empower_{it} \ + \beta_3 \cdot tech * empower_{it} \ + \beta_4 X_{it} \ + \sum_{j=1}^{N-1} \mu_j D_{ji} \ + \sum_{s=1}^{T-1} \tau_s D_{st} \ + \varepsilon_{it} \quad (2'')$$

Heckman's model

Standard regression techniques can be biased due to potential selection bias in the use of agricultural practices and in the empowerment status. Therefore, correcting for self-selection or endogeneity is needed to account for time-varying unobserved heterogeneity.

A major problem in estimating the outcomes in our case (WDDS and FIES equations) is that the sample identified as empowered may not be a random draw from the population. In other words, the women included in the empowered group may be a selective group in terms of some 'unobservable' variables – such unobservable variables that determine empowerment, low dietary

Table 3.4. Socio-economic characteristics

	2017		2019		Pooled sample	
	Non-users	Users	Non-users	Users	Non-users	Users
Women empowerment (dummy)	0.617 (0.487)	0.636* (0.482)	0.630 (0.483)	0.617* (0.488)	0.624 (0.485)	0.628** (0.484)
Care work by women (hours)	7.949 (5.390)	9.193 (6.148)	5.762 (3.304)	6.295 (3.806)	6.799 (4.548)	7.848 (5.383)
Age of household head (years)	52.232 (13.169)	50.801* (12.667)	53.200 (12.880)	51.4 (11.373)	52.756 (13.017)	51.077** (12.075)
Education of household head (years)	6.978 (4.655)	8.744*** (4.855)	7.533 (4.914)	8.813** (4.141)	7.278 (4.803)	8.776*** (4.534)
Household size	4.358 (2.230)	4.614 (2.349)	4.643 (2.356)	5.1* (2.185)	4.512 (2.303)	4.837 (2.285)
Number of female members	2.506 (1.321)	2.572 (1.348)	2.408 (1.256)	2.525 (1.244)	2.453 (1.287)	2.550 (1.298)
Land cultivated (ha)	8.009 (7.630)	11.922*** (12.284)	8.179 7.674	9.764*** (8.829)	8.101 (7.651)	10.929*** (10.870)
No. plots cultivated with oil palm	1.255 (0.561)	1.244* (0.568)	1.270 (0.536)	1.313 (0.677)	1.264 (0.546)	1.276* (0.621)
Asset score	0.353 0.146	0.434 (0.161)	0.373 (0.153)	0.429*** (0.163)	0.364 (0.150)	0.432*** (0.162)
N[3]	547	176	644	150	1191	326

Note: Users and non-users refer to the use of at least one of the two practices under review. Mean values are shown with standard deviations in parentheses. Differences in means between users and non-users are tested for statistical significance. * p<0.05, ** p<0.01, *** p<0.001.

Source: Authors' own

diversity or high household food security could be potentially correlated. Under such circumstances, conventional estimation of the outcomes equations by OLS may yield biased coefficient estimates. To solve this issue, we employ the Heckman correction procedure using a two-step approach – treating the selection effect as an omitted variable problem (Heckman, 1979), and using the Inverse Mills Ratio (IMR) from the first stage equation.

In the first stage we estimate the participation equation using a probit model for women empowerment:

$$Prob[fem\_emp=1]=\Phi(\alpha_0+\alpha_1 carework_i+\alpha_2 hh\_members_i +\alpha_3 land_i+\alpha_4 assets_i+ \alpha_5 female\_memb_i+\alpha_6 age_i +\alpha_7 educ_i+ \alpha_8 age\_female_i+ \alpha_9 edu\_female_i+ \alpha_{10} Z_i) \text{ with } i=1,..1527$$

For WDDS, Z is a vector of instruments including whether a woman has brought at least a plot to the family (allocated by the woman's clan or as inheritance from her family) and if the household head is female. For FIES, the Z vector includes whether a woman has bought at least a plot to the family (allocated by the woman's clan or as inheritance from her family) and whether there has been a death of a child in the past year. We then used the probit coefficients from the first stage equations to compute the selection term (the IMR, an empirical measure of 'unobservable' variables in the empowerment equation) to be used in the second stage equations for the two outcomes, computed as a pooled OLS and with fixed effects (without and with time dummies). For each outcome, the second stage was computed both for the groups with high and low empowerment status, with bootstrapped standard errors. In the equations we also included a vector of a household's variables: time spent on all care work by women, age and education of the household head, number of household members, number of female members in the households, hectares of land cultivated, number of plots cultivated with oil palm, and the asset score.

3 Number of observations is lower for some variables

4 PRELIMINARY RESULTS

4.1 Panel regressions

Table 4.1 shows results from the panel regression using the WDDS as a dependent variable. Column I displays the coefficient for the use of the two agricultural practices, column II is the practice's use plus the level of empowerment dummy and column III shows the results of the specification with interaction effects (using the intensity of technology use – from zero to two – as the main explanatory variables and the women empowerment dummy). Then, in column IV control variables were added to the model with the interaction terms. Column V and VI report the coefficients for the FE model without and with the time dummy, respectively. The use of one of the practices under analysis on oil palm plots seems to positively affect the nutrition outcome in a significant way in all of the specifications. The interaction term is significant in column V, meaning that the relationship between the use of two practices and WDDS also depends on empowerment status.

Table 4.1. Regression results for the use of the two agricultural practices on WDDS

	WDDS					
	POLS	POLS	POLS	POLS	FE	FE+T
	I	II	III	IV	V	VI
Practices use						
Use of one practice	0.462*** (0.085)	0.461*** (0.086)	0.481*** (0.097)	0.356*** (0.096)	0.427** (0.176)	0.426** (0.170)
Use of two practices	0.165 (0.317)	0.162 (0.318)	0.021 (0.346)	0.066 (0.336)	-0.814 (0.656)	-0.372 (0.642)
Women empowerment (dummy)		-0.029 (0.088)	-0.016 (0.101)	0.390 (0.332)	0.151 (0.951)	0.026 (0.920)
1.practice #1.empowerment			-0.095 (0.207)	-0.031 (0.201)	0.191 (0.369)	0.216 (0.357)
2.practices#1. empowerment			0.925 (0.878)	0.712 (0.852)	2.843** (1.395)	1.606 (1.376)
Constant	3.066*** (0.043)	3.073*** (0.048)	3.070*** (0.050)	2.364*** (0.248)	5.418*** (1.516)	2.431 (1.607)
Additional controls	No	No	No	Yes	Yes	Yes
Time dummy	No	No	No	Yes	No	Yes
F statistic	14.6	9.8	6.1	7.2	2.7	4.0
R-squared	0.03	0.03	0.03	0.11	0.12	0.18
N	933	933	933	932	932	932

Note: POLS = Pooled Ordinary Least Square; FE = fixed effect; T = time dummy. Additional controls are: no. of household members, land cultivated (ha), no. of oil palm plots, asset score, no. of female members, age of the household head, education of the household head, and whether or not it was a female-headed household. Standard errors in parenthesis * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Source: Authors' own

Table 4.2 displays the results from the panel regression with FIES as the dependent variable. The use of one practice under analysis seems to reduce the score in the first three specifications. Women empowerment has a positive and significant effect on food security in column II to IV. However, the interaction term is not significant in this case. This could mean that women empowerment plays a stronger role in reducing food insecurity, regardless of a households' technological status.

Tables 4.3 and 4.4 report results for the two outcomes using an additive indicator for women empowerment instead of the dummy variable. This indicator is built by summing the sub-domains used to construct the empowerment score, and dividing the sum by five.

Results for the use of agrochemicals

Table 4.5 displays the results considering the quantity of fertiliser used by households (kg) as an explanatory variable for the two outcomes. A unit increase in fertiliser use seems to worsen both outcomes in the FE models, reflecting the trade-off between investments in technology and in food security and nutrition. However, concerning food insecurity, the coefficient for the interaction term is significant. Thus, there is a difference in the expected FIES among the group of women who scores less in terms of empowerment – as their FIES is expected to increase by 0.939 – and the other that scores better – which should expect a decrease in FIES by 0.687 (0.939-1.624).

4.2. Results from the Heckman's model

Table 4.6 shows the second stage of the Heckman's model for the two groups of women with different level of empowerment score. The top of the table displays results for the women's nutrition outcome. The use of at least one of the practices under review on oil palm plots significantly increases the dietary diversity of women, who score better in terms of empowerment in all of the three specifications. For women with lower level of empowerment, results are not significant.

The bottom part of Table 4.6 shows results from the second stage, considering household food insecurity as an outcome. The use of at least one of the agricultural practices significantly reduces FIES for women with

Table 4.2. Regression results for the use of the agricultural practices on FIES

	FIES					
	POLS	POLS	POLS	POLS	FE	FE+T
	I	II	III	IV	V	VI
Practices use						
Use of one practice	-0.581*** (0.152)	-0.576*** (0.152)	-0.730** (0.358)	-0.412 (0.343)	0.287 (0.608)	0.307 (0.609)
Use of two practices	0.038 (0.566)	-0.032 (0.563)	-0.516 (1.022)	-0.605 (0.975)	1.972 (1.484)	2.161 (1.510)
Women empowerment (dummy)		-0.573*** (0.170)	-0.632*** (0.198)	-0.669*** (0.196)	-0.455 (0.364)	-0.413 (0.369)
1.practice #1.empowerment			0.188 (0.395)	0.095 (0.378)	-0.373 (0.660)	-0.405 (0.662)
2.practices#1. empowerment			0.688 (1.226)	0.910 (1.170)	-1.485 (1.793)	-1.707 (1.823)
Constant	1.501*** (0.077)	1.967*** (0.158)	2.016*** (0.179)	3.319*** (0.447)	0.992 (2.224)	0.289 (2.445)
Additional controls	No	No	No	Yes	Yes	Yes
Time dummy	No	No	No	Yes	No	Yes
F statistic	7.3	8.7	5.3	9.9	2.1	2.0
R-squared	0.02	0.03	0.03	0.13	0.09	0.09
N	935	935	935	935	935	935

Note: POLS = Pooled Ordinary Least Square; FE = fixed effect; T = time dummy. Additional controls are: no. of household members, land cultivated (ha), no. of oil palm plots, asset score, no. of female members, age of the household head, education of the household head, and whether or not it was a female-headed household. Standard errors in parenthesis * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Source: Authors' own

Table 4.3. Regression results for the use of the agricultural practices on WDDS

	WDDS					
	POLS	POLS	POLS	POLS	FE	FE+T
	I	II	III	IV	V	VI
Practices use						
Use of one practice	0.462*** (0.085)	0.474*** (0.094)	0.520*** (0.183)	0.396** (0.182)	0.393 (0.362)	0.478 (0.353)
Use of two practices	0.165 (0.317)	0.186 (0.340)	-0.541 (0.583)	-0.465 (0.574)	-2.804*** (1.072)	-1.519 (1.099)
Women empowerment (additive indicator)		0.071 (0.139)	0.067 (0.162)	0.276 (0.359)	-1.000 (0.873)	-0.559 (0.856)
1.practice #1.empowerment			-0.097 (0.325)	0.016 (0.321)	0.200 (0.631)	0.101 (0.614)
2.practices#1. empowerment			1.744 (1.132)	1.598 (1.115)	6.076*** (2.114)	3.951* (2.135)
Constant	3.066*** (0.043)	3.035*** (0.084)	3.037*** (0.093)	2.475*** (0.301)	7.762*** (2.299)	2.489 (2.658)
Additional controls	No	No	No	Yes	Yes	Yes
Time dummy	No	No	No	No	No	Yes
F statistic	14.6	8.5	5.6	4.9	2.6	3.5
R-squared	0.03	0.03	0.03	0.08	0.15	0.20
N	933	783	783	782	782	782

Note: POLS = Pooled Ordinary Least Square; FE = fixed effect; T = time dummy. Additional controls are: no. of household members, land cultivated (ha), no. of oil palm plots, asset score, no. of female members, age of the household head, education of the household head, and whether or not it was a female-headed household. Standard errors in parenthesis * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Source: Authors' own

lower levels of empowerment, but only in the Pooled Ordinary Least Square (POLS) specification.

Empowerment status plays a mediating role in the relation between technology use and the two outcomes. The Heckman model for WDDS confirms our initial hypothesis that women with higher levels of empowerment could increase their WDDS using agricultural technology. Food insecurity seems to be reduced by the use of technologies in households where women score worse in terms of empowerment. This means that, when faced with a trade-off between their nutrition and household food security, and having less control over their household's resources, they privilege the latter.

Table 4.4. Regression results for the use of agricultural practices on FIES

	FIES					
	POLS	POLS	POLS	POLS	FE	FE+T
	I	II	III	IV	V	VI
Practices use						
Use of one practice	-0.581*** (0.152)	-0.667*** (0.166)	-0.994*** (0.321)	-0.636** (0.305)	-0.092 (0.545)	-0.085 (0.546)
Use of two practices	0.038 (0.566)	0.108 (0.597)	0.548 (1.026)	0.135 (0.968)	2.208 (1.617)	2.346 (1.711)
Women empowerment (additive indicator)		0.365 (0.245)	0.216 (0.285)	-2.580*** (0.599)	-1.508 (1.294)	-1.479 (1.302)
1.practice #1.empowerment			0.680 (0.573)	0.504 (0.541)	0.140 (0.951)	0.128 (0.954)
2.practices#1. empowerment			-1.083 (1.993)	-0.071 (1.880)	-2.155 (3.191)	-2.384 (3.325)
Constant	1.501*** (0.077)	1.407*** (0.148)	1.480*** (0.164)	3.824*** (0.501)	0.694 (3.414)	0.109 (4.137)
Additional controls	No	No	No	Yes	Yes	Yes
Time dummy	No	No	No	No	No	Yes
F statistic	7.3	6.3	4.1	10.3	1.6	1.4
R-squared	0.02	0.02	0.03	0.15	0.09	0.09
N	935	784	784	784	784	784

Note: POLS = Pooled Ordinary Least Square; FE = fixed effect; T = time dummy. Additional controls are: no. of household members, land cultivated (ha), no. of oil palm plots, asset score, no. of female members, age of the household head, education of the household head, and whether or not it was a female-headed household. Standard errors in parenthesis * p<0.1; ** p<0.05; *** p<0.01

Source: Authors' own

Table 4.5. Regression results for the use of agrochemicals for WDDS and FIES

	WDDS			FIES		
	POLS	FE	FE+T	POLS	FE	FE+T
Agrochemicals (kg)	-0.054 (0.044)	-0.293** (0.140)	-0.293** (0.140)	-0.156 (0.135)	0.939* (0.459)	0.939* (0.459)
Women empowerment (dummy)	0.807 (0.651)	-4.460* (2.433)	-4.323* (2.440)	-1.299* (0.693)	5.004** (1.962)	5.004** (1.962)
1.fert*1. empowerment	-0.033 (0.097)	0.001 (0.227)	0.001 (0.227)	-1.624*** (0.520)	-1.624*** (0.520)	0.077 (0.159)
Constant	2.183*** (0.494)	6.867 (6.711)	3.340* (1.850)	4.601*** (0.982)	-10.905 (8.367)	8.892 (57.083)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Time dummy	No	No	Yes	No	No	Yes
F statistic	2.3	2.3	2.3	4.2	2.4	2.4
R-squared	0.11	0.52	0.52	0.17	0.53	0.53
N	239	239	239	239	239	239

Note: POLS = Pooled Ordinary Least Square; FE = fixed effect; T = time dummy. Additional controls are: no. of household members, land cultivated (ha), no. of oil palm plots, asset score, no. of female members, age of the household head, education of the household head, and whether or not it was a female-headed household. Standard errors in parenthesis * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Source: Authors' own

Table 4.6. Heckman's second stage results for WDDS and FIES

	WDDS					
	High level of empowerment			Low level of empowerment		
	POLS	FE	FE+T	POLS	FE	FE+T
Use of at least one practice	0.453*** (0.101)	0.478** (0.188)	0.399** (0.198)	0.156 (0.203)	-0.697 (3.532)	-0.697 (3.343)
Constant	3.142*** (0.248)	8.758** (4.212)	2.201 (2.134)	1.798*** (0.501)	15.598 (26.875)	15.991 (100.206)
Time dummy	No	No	Yes	No	No	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.04	0.12	0.20	0.10	0.70	0.70
N	745	745	745	150	150	150
	FIES					
	High level of empowerment			Low level of empowerment		
	POLS	FE	FE+T	POLS	FE	FE+T
Use of at least one practice	-0.123 (0.402)	0.006 (0.539)	0.025 (0.535)	-0.343*** (0.126)	-0.059 (0.266)	-0.059 (0.250)
Constant	2.396** (1.136)	-2.549 (7.758)	-1.945 (2.532)	3.342*** (0.528)	6.933* (4.207)	1.920 (1.534)
Time dummy	No	No	Yes	No	No	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.08	0.10	0.10	0.12	0.10	0.10
N	218	218	218	679	679	679

Note: Standard errors in parenthesis; * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Source: Authors' own

5 CONCLUSION AND POLICY IMPLICATIONS

Using new panel data for oil palm producers in Ghana, we looked at the use of agricultural technology, for new insights on food security and nutrition with a special focus on women and their empowerment. Using a FE model with interaction terms, along with a Heckman model, we investigated the mediating role of women empowerment for the nexus between technology on one hand, and food security and women's nutrition outcomes on the other.

Results show that the use of agricultural practices is linked with improved women's dietary diversity, but also that women empowerment mediates this relationship, with a positive impact for the group of women who scored better in terms of empowerment. The other group of women with a lower empowerment score, however, seem to have had better outcomes in terms of household food security. This demonstrates that while providing access to technology is relevant, it is not enough on its own, and complementary policy interventions with the aim to increase women empowerment play an essential role in improving women nutrition outcomes within the household.

We acknowledge some limitations of our analysis. First, our data are not nationally representative but characterise a specific local context. Second, the two waves of data collection span a short period of time, so this paper can only look at the short-term effects of technology use on women nutrition, which would take time to evolve and improve. Third, we do not have data on children's nutrition, but this is a future direction of research as it is commonly understood that women give priority to children's quality of diet, overshadowing their own nutrition.

The study has implications relevant to policymaking. It highlights the importance of considering the impact of agricultural technologies on household food security and women's nutrition. Combined with this, the promotion of women empowerment and women's bargaining power within the household is key. This could be improved by including women in agricultural training – also together with men – and providing them with inputs that they can manage on their own. Future research should focus on other technologies and varied contexts. To make results stronger, it would be useful to replicate the analysis using nationally-representative data for external validity.

REFERENCES

Aryal, J.P., Farnworth, C.R., Khurana, R., Ray, S., Sapkota, T.B. and Rahut, D.B. (2020) 'Does women's participation in agricultural technology adoption decisions affect the adoption of climate-smart agriculture? Insights from Indo-Gangetic Plains of India', *Review of Development Economics* 24(3): 973-990. doi: 10.1111/rode.12670.

Bairagi, S., Mishra, A.K. and Durand-Morat, A. (2020) 'Climate risk management strategies and food security: Evidence from Cambodian rice farmers', *Food Policy* 95: 1-12. doi: 10.1016/j.foodpol.2020.101935.

Von Braun, J. (1995) 'Agricultural commercialization: impacts on income and nutrition and implications for policy', *Food Policy* 20(3): 187-202.

Cafiero, C., Viviani, S. and Nord, M. (2018) 'Food security measurement in a global context : The food insecurity experience scale', *Measurement* 116: 146-152. doi: 10.1016/j.measurement.2017.10.065.

Damisa, M.A. and Igonoh, E. (2007) 'An Evaluation of the Adoption of Integrated Soil Fertility Management Practices among Women Farmers in Danja, Nigeria', *Journal of Agricultural Education and Extension* 13(2): 107-116. doi: 10.1080/13892240701289478.

Diiro, G.M., Ker, A.P. and Sam, A.G. (2015) 'The role of gender in fertiliser adoption in Uganda', *African Journal of Agricultural and Resource Economics* 10(2): 117-130.

Doss, C. (2006) 'The Effects of Intrahousehold Property Ownership on Expenditure Patterns in Ghana', *Journal of African Economies* 15(1): 149-180. doi: 10.1093/jae/eji025.

Doss, C.R. and Morris, M.L. (2001) 'How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana', *Agricultural Economics* 25: 27-39.

Dzanku, F.M., Asante, K.T., Quarmine, W. and Hodey, L.S. (2020) *Smallholder Farmers' Choice of Oil Palm Commercialisation Model and Household Welfare in South-Western Ghana.* APRA Working Paper 43. Brighton: Future Agricultures Consortium. Available at: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/15714 (Accessed: 29 September 2022).

FAO (2021) *The Food Insecurity Experience Scale*. Available at: https://www.fao.org/in-action/voices-of-the-hungry/fies/en/ (Accessed: 2 October 2021).

Galiè, A., Teufel, N., Girard, A.W., Baltenweck, I., Dominguez-Salas, P., Price, M.J., Jones, R., Lukuyu, B., Korir, L., Raskind, I.G., Smith, K. and Yount, K.M. (2019) 'Women' s empowerment, food security and nutrition of pastoral communities in Tanzania: Women's empowerment, food security and nutrition of pastoral communities in Tanzania', *Global Food Security* 23: 125-134. doi: 10.1016/j.gfs.2019.04.005.

Gebre, G.G., Isoda, H., Rahut, D.B., Amekawa, Y. and Normura, H. (2019) 'Gender differences in the adoption of agricultural technology: the case of improved maize varieties in southern Ethiopia', *Women's Studies International Forum* 76. 102264. doi: 10.1016/j.wsif.2019.102264.

Haider, H., Smale, M. and Theriault, V. (2018) 'Intensification and intrahousehold decisions: Fertilizer adoption in Burkina Faso', *World Development* 105: 310-320. doi: 10.1016/j.worlddev.2017.11.012.

Harris-Coble, L., LeBeau, K. and Colverson, K. (2018) *Gender in the dairy value chain and implications for the GIRINKA program ("One Cow per Poor Family") in Rwanda, Feed the Future Innovation Lab for Livestock Systems*. Gainesville: Feed the Future Innovation Lab for Livestock Systems.

Heckman, J.J. (1979) 'Sample Selection Bias as a Specification', *Econometrica* 47(1): 153-161.

IPNI (2015) *Oil Palm Best Management Practices in Ghana. Mid term report.* Georgia: International Plant Nutrition Institute (IPNI).

Kassie, M., Fisher, M., Muricho, G. and Dirro, G. (2020) 'Women's empowerment boosts the gains in dietary diversity from agricultural technology adoption in rural Kenya', *Food Policy* 95(July): 101957. doi: 10.1016/j.foodpol.2020.101957.

Kennedy, G., Ballard, T. and Dop, M.C. (2011) *Guidelines for measuring household and individual dietary diversity.* Rome: Food and Agriculture Organization of the United Nations (FAO).

Kidane, W., Maetz, M. and Dardel, P. (2006) *Food security and agricultural development in Sub-Saharan Africa (SSA): Building a case for more public support.* Rome: Food and Agriculture Organization of the United Nations (FAO).

Malapit, H.J.L., Kadiyala, S., Quisumbing, A.R., Cunningham, K. and Tyagi, P. (2015) 'Women's Empowerment Mitigates the Negative Effects of Low Production Diversity on Maternal and Child Nutrition in Nepal', *The Journal of Development Studies* 51(8): 1097-1123. doi: 10.1080/00220388.2015.1018904.

Malapit, H.J.L. and Quisumbing, A.R. (2015) 'What dimensions of women's empowerment in agriculture matter for nutrition in Ghana?', *Journal of Food Policy* 52: 54-63. doi: 10.1016/j.foodpol.2015.02.003.

Marenya, P., Kassie, M. and Tostao, E. (2015) 'Fertilizer use on individually and jointly managed crop plots in Mozambique', *Journal of Gender, Agriculture and Food Security* 1(2): 62-83.

Matshe, I., Zikhali, P. and Chilonda, P. (2010) 'Education and agricultural inputs use by female farmers in Zimbabwe', *Agenda* 24(86): 96-110. doi: 10.1080/10130950.2010.10540523.

Mensah, M., Villamor, G. and Vlek, P.L.G. (2018) 'Gender specific determinants of inorganic fertilizer adoption in the semi-arid region of Ghana', *West African Journal of Applied Ecology* 26: 179-192.

Mishra, K., Sam, A.G., Dirro, G.M. and Miranda, M.J. (2020) 'Gender and the dynamics of technology adoption: Empirical evidence from a household-level panel data', *Agricultural Economics* 51(6): 857-870. doi: 10.1111/agec.12596.

Namonje-Kapembwa, T. and Chapoto, A. (2016) *Improved Agricultural Technology Adoption in Zambia: Are Women Farmers Being Left Behind?* Working Paper 106. Lusaka: Indaba Agricultural Policy Research Institute (IAPRI).

Ndiritu, S.W., Kassie, M. and Shiferaw, B. (2014) 'Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya', *Food Policy* 49: 117-127. doi: 10.1016/j.foodpol.2014.06.010.

Njuguna, E., Brownhill, L., Kihoro, E., Muhammad, L. and Hickey, G.M. (2016) 'Gendered technology adoption and household food security in semi-arid Eastern Kenya', in J. Njuki, J.R. Parkins and A. Kaler (eds.) *Transforming Gender and Food Security in the Global South*. New York: Routledge.

Nkonya, E., Kato, E. and Ru, Y. (2020) 'Drivers of Adoption of Small-Scale Irrigation in Mali and Its Impacts on Nutrition across Sex of Irrigators', IFPRI *Discussion Paper,* 01924. Washington DC: International Food Policy Research Institute (IFPRI).

Obayelu, A.E., Arowolo, A.O., Oyawole, F.P., Aminu, R.O. and Ibrahim, S.B. (2021) 'Chapter 5 - The linkage between agricultural input subsidies, productivity, food security, and nutrition', *Food Security and Nutrition* 107-124. doi: 10.1016/B978-0-12-820521-1.00005-8.

Passarelli, S., Mekonnen, D., Bryan, E. and Ringler, C. (2018) 'Evaluating the pathways from small-scale irrigation to dietary diversity: evidence from Ethiopia and Tanzania', *Food Security* 10: 981-997.

Ragasa, C.., Berhane, G., Tadesse, F. and Taffesse, A.S. (2013) 'Gender Differences in Access to Extension Services and Agricultural Productivity', *Journal of Agricultural Education and Extension* 19(5): 437-468. doi: 10.1080/1389224X.2013.817343.

Saha, A., Sabates-Wheeler, R. and Thompson, J. (2021) 'Insights into smallholder capacity for agricultural commercialisation: Evidence from four African contexts', *The European Journal of Development Research*. doi: 10.1057/s41287-021-00414-z.

Sanchez, P.A. (2019) *Properties and Management of soils in the Tropics*. Second Edition. Cambridge: Cambridge University Press.

Tanellari, E., Kostandini, G., Bonabana-Wabbi, J. and Murray, A.. (2014) 'Gender impacts on adoption of new technologies: the case of improved groundnut varieties in Uganda', *African Journal of Agricultural and Resource Economics* 9(4): 300-308.

Theis, S., Lefore, N., Meinzen-Dick, R. and Bryan, E. (2018) 'What happens after technology adoption? Gendered aspects of small- scale irrigation technologies in Ethiopia, Ghana, and Tanzania', *Agriculture and Human Values* 35(3): 671-684. doi: 10.1007/s10460-018-9862-8.

Capretti, L., Saha, A., Jena, F. And Dzanku, F.M. (2022) *Agricultural Technology, Food Security and Nutrition: Insight From Oil Palm Smallholders in Ghana.* APRA Working Paper 95. Brighton Future Agricultures Consortium.

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