



Research article

Farm household access to agricultural services in northern Ghana

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ABSTRACT

Access to agricultural services promotes agricultural production and livelihoods of smallholders in most developing countries. This study explores the factors affecting smallholders' access to agricultural services in northern Ghana. The study relied on survey data for the analysis. We estimated a multivariate probit model to assess the factors influencing access to agricultural services and a generalized Poisson regression model to evaluate the factors affecting the degree of access to these services. The results indicated that farmers had varying degree of access to different agricultural services. The most accessed service was agricultural extension (63% access) while the least was farm credit (40% access). Access to services and the degree of access (number of services accessed) were both influenced by household size, farming experience, household income, farmer group membership, and geographical location. In addition, the number of services accessed by farmers was influenced by participation in off-farm work. The paper proposed measures to enhance smallholders' access to agricultural services to promote agricultural production, food security and rural livelihoods.

1. Introduction

Government support to agriculture in the form of service provision is vital to the growth and productivity of smallholder agriculture in developing countries. Consequently, there are conscious attempts by governments in developing countries to increase support to the agricultural sector through the provision of essential agricultural support services. These services include provision of irrigation, agricultural credit, input subsidy, agricultural extension and mechanization (tractorization services) to smallholders. The goal is to improve smallholders' access to these services in order to improve agricultural productivity and rural livelihoods.

Notwithstanding the critical role of access to services in agricultural production and productivity, many small-scale farmers in Ghana and other developing countries have limited access to these services. Majority of agricultural producers in developing countries are peasants who live in remote communities with limited access to most agricultural services. Poor road infrastructure, long distances to farms, and inaccessibility to many service providers are constraints that hinder many smallholder farmers from accessing agricultural services. Governments in developing countries therefore need to improve road infrastructure, and offer logistical support to service providers to enable them to reach farmers in remote places. The critical challenge, therefore, is how to ensure that

services are made accessible to farmers to enhance farm performance and food security.

A major factor necessary to improve agricultural production in developing countries is access to extension services (Anang et al., 2020). In a recent study in Ghana, Anang et al. (2020) showed that access to agricultural extension enhanced technology adoption and farm income of peasant farmers. Access to agricultural extension improved technology adoption by farm households (Wossen et al., 2017; Ghimire et al., 2015; Asfaw et al., 2012) as well as household income (Danso-Abbeam et al., 2018; Gebrehiwot, 2015; Davis et al., 2012). Agricultural extension agents train farmers on modern production practices and introduce them to innovative ways of farming to enhance productivity. Extension workers also assist farmers to form groups and link these groups to credit institutions and other stakeholders in the agricultural sector. However, as indicated by McNamara et al. (2014), there is one extension worker to 1300 farmers in Ghana. The challenge of low accessibility to extension services is therefore critical.

Ghana's agriculture is largely rainfed (Kuwornu and Owusu, 2012) with just 3% of farmland under irrigation (Diao, 2010), leading to low productivity (ISSER, 2006). Irrigation development is however a necessary prerequisite for agricultural growth (van Koppen et al., 2005). Empirical evidence shows that irrigation improves agricultural productivity (see Xie et al., 2014; You et al., 2014), food security and household

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income (Sellamuttu et al., 2013), and household consumption (Kuwornu and Owusu, 2012; Dillon, 2008). Anang et al. (2017) also showed that irrigation access improved technical efficiency of Ghanaian rice producers. Irrigation enables intensification of production thereby enhancing productivity. Irrigation technology extends the growing period for crops, allowing multiple production to generate higher output and income for farm households. During the long dry season in northern Ghana, many smallholder farmers without access to irrigation seek off-farm jobs as a means of income generation to support their families. Expanding irrigation access to smallholders in rural areas is one of the assured ways to eradicate rural poverty.

Farm subsidies have regained popularity in recent years in many developing countries after a period of decline in subsidy support in the 1980s and 1990s due to structural adjustment programs. Agricultural input subsidies remain one of the popular social intervention policies of governments in developing countries partly because of its political attractiveness. In principle, subsidies on factors of production reduce the cost of production and promote technology adoption (Lunduka et al., 2013). Access to input subsidy increased productivity and food security of producers in Malawi (Dorward and Chirwa, 2011). Morris et al. (2007) opined that productivity growth in African agriculture is hinged on agricultural subsidies. Access to subsidy is however not without challenges and concerns. Prominent among the concerns are the cost and budgetary implications to national governments and the fact that subsidies have the potential to distort funding for agriculture (Jayne et al., 2013). Many farmers are excluded from subsidy programs while distribution sometimes ends up favoring large and influential farmers. In Ghana, access to input subsidy (particularly inorganic fertilizer and improved seeds) has improved in recent times among smallholders, but the challenge of inaccessibility is still widespread.

Dittoh (2006) noted that the foremost need of farmers in northern Ghana is access to credit. Farmers' inability to access credit, particularly formal credit, has been well documented (Anang et al., 2015; Boniphace et al., 2015; UNCTAD 2015). Agricultural credit is important to Ghanaian farmers because of high incidence of poverty among farmers, declining soil fertility, and high cost of production. Farmers need credit to finance important and urgent farm operations. When farmers do not get access to finance at the time it is needed, this can lead to huge loss in farm output, putting the livelihood of the farm family at risk. Farm credit has direct bearing on farm output through its impact on input acquisition and farm investment, and indirectly through its influence on risk behavior. For example, due to credit constraints, farmers may opt for less productive activities that have lower risk. Studies by Nkegbe (2018) and Abdallah (2016) showed that access to credit improved technical efficiency of Ghanaian maize farmers. Thus, farm credit enables smallholders to produce more efficiently by combining resources in a judicious manner to increase productivity.

The provision of agricultural mechanization services is another important service aiding smallholder agriculture in Ghana. Farm mechanization in the form of tractor services for land preparation is an important activity in smallholder production. The use of tractors to plow farm lands improves soil aeration and incorporates crop residue into the soil. Access to tractor services also enhances speedy and improved land preparation, which has been reported to improve agricultural production and farm performance in general (Mehta et al., 2014; Obi and Chisango, 2011). Lack of access to mechanization services however remains a challenge to many smallholder farmers as reported in some studies (Clarke, 2000; Sims and Kienzie, 2016). Majority of smallholders in rural areas cannot access or afford mechanization services, thus relying on less efficient methods of land preparation. According to Houssou and Chapot (2015) and Clarke (2000), farm mechanization enables farmers to expand their crop land to meet the need for higher farm output. Authors such as Clarke (2000) and Sims and Kienzie (2016) blame Africa's low farm productivity on lack of access to mechanization services rather than technical inefficiency. This calls for expansion in the provision of

mechanization services, which according to Diao et al. (2014) has an increasing demand in Ghana.

Most of the earlier studies on access to agricultural services have focused on access to agricultural extension services (Anang et al., 2020; Danso-Abbeam et al., 2018; Wossen et al., 2017; Ghimire et al., 2015), access to irrigation (Anang et al., 2017; Xie et al., 2014; You et al., 2014; Kuwornu and Owusu, 2012), access to credit (Nkegbe, 2018; Abdallah, 2016; Anang et al., 2016), access to subsidy (Jayne et al., 2013; Dorward and Chirwa, 2011), and access to farm mechanization (Anang, 2018; Mehta et al., 2014; Obi and Chisango, 2011). These studies did not involve access to multiple services and thus, do not provide a comprehensive discussion of the rate or degree of access to these services. A holistic approach to analyzing farm household's access to agricultural services with regards to both accessibility and the degree of access is crucial as farmers require these services simultaneously to derive maximum benefit from them due to the complementary synergies that exist among such services. For instance, strong complementarity exists between input subsidy and agricultural extension services, as well as between farm credit, extension and irrigation. In general, the five services under investigation complement each other, and have joint effect on production.

In the light of the foregoing, this paper investigates the factors affecting smallholders' access to agricultural services and in particular, the number of services accessed. Empirical data on farmers' access to key agricultural services in developing countries is limited and this paper seeks to contribute by providing such empirical evidence. Furthermore, to the best of our knowledge this paper is among a few which examines the simultaneous access to different agricultural services by smallholders. The findings are expected to guide policymakers to formulate policies for enhancing agricultural service provision to farmers particularly those in remote areas where the country obtains most of its agricultural produce. Furthermore, our findings will guide the targeting and implementation of such services to enhance agricultural productivity in Ghana.

2. Overview of government support to agriculture through agricultural service provision

The provision of agricultural support services to farmers is a statutory government obligation. However, the discharge of this obligation is subject to many factors, especially financial and budgetary constraints. Major agricultural support services in Ghana include provision of agricultural extension, subsidy, irrigation, credit and mechanization services. These services are targeted at all crop farmers. There is also a mass spraying exercise for the cocoa sector to control insect pests that destroy cocoa farms which has been operational for several years.

Agricultural extension service is by far the commonest and most widespread agricultural service provided to smallholders in Ghana in terms of coverage and scale of operation. The Agricultural Extension unit of the Department of Agriculture, now under the Municipal, Metropolitan and District Assemblies, carries out day-to-day extension service delivery through its agricultural extension agents (AEAs). Agricultural extension workers provide training to farmers in modern production practices and disseminate agricultural information to farmers. They also help farmers to form groups and access production inputs. These services enable producers to enhance technology adoption, productivity and income (Anang et al., 2020).

Access to public irrigation services is very limited in Ghana and many developing countries. In spite of the existence of several sites suitable for irrigation development in the country, land developed for irrigation purposes remains woefully inadequate. Besides the public large-scale irrigation dams, there are other forms of irrigation facilities that provide irrigation to farmers. Dug-outs, sprinkler irrigation, among other systems are used to provide water for crop production during the dry season. The Irrigation Development Authority (IDA) is in charge of irrigation development in Ghana. Day-to-day management of irrigation canals and farms at the irrigation sites is however entrusted to the irrigation

water user associations, with supervision from the IDA. Recently, the government of Ghana has introduced a One Village One Dam (1V1D) initiative to provide every village with one dam for agricultural production and other uses. In this study, access to irrigation is defined as the use of irrigation from an irrigation scheme to farm.

Recently, the government of Ghana has introduced an input subsidy program that provides mineral fertilizers and improved seeds to farmers at a subsidized price. The fertilizer subsidy program started in 2008, and has gone through some reforms in terms of operational modalities. The main aim of the subsidy program is to increase fertilizer application rates and adoption of improved seeds among Ghanaian farmers, especially grain producers, to enhance productivity and farm income.

Financial services, especially microcredit provision, remain one of the most critical challenges facing Ghanaian farmers (Dittoh, 2006). Smallholders usually lack access to formal credit due to several challenges that include identifying eligible borrowers, high transaction costs, high lending risks, lack of collateral, poor repayment, among others. As a result, many smallholders rely on informal financial service providers, even where the interest rates are arbitrarily high. Government's effort to alleviate the plight of farmers has come through government social intervention measures that provide soft loans to farmers. These programs are not widespread and do not reach many farmers. Increasing number of farmers, especially those with some level of education, rely on commercial sources such as the Rural Banks to access credit for farming. Non-governmental organizations working with farmers also provide agricultural credit to farmers, with the mode of operation depending on the organization involved. In some instances, farmers are provided with credit in kind (in the form of farm inputs) to avoid fungibility. The mode of repayment varies from cash repayment to repayment with harvested crop. In this study, the credit market was not segregated. Both formal, semi-formal and informal sector credit providers were included to define the market for credit. This approach is commendable because the credit market is liberalized and farmers typically do not rely on one source of credit to farm.

Another agricultural service which is important to smallholders in Ghana is mechanization (usually tractorization) services. Agricultural mechanization centers have been established across the country to provide tractor services to farmers. Due to the limited number of these centers, many farmers rely on private mechanization service providers. The study did not differentiate between private and public service providers. Access to mechanization was taken to mean access to tractor services to carry out land preparation.

3. Methodology

3.1. Study area and data collection

Northern Ghana covers approximately one-third of the country's land area, and is predominantly agrarian. Smallholder farmers were sampled from three districts in two regions in northern Ghana using multi-stage sampling technique. The districts included Tolon-Kumbungu district (now separated into Tolon and Kumbungu) in the Northern Region, and Kassena-Nankana and Bongo districts located in the Upper East Region. The choice of districts was influenced by the presence of large-scale public irrigation facilities for agricultural purposes. Hence, Tolon-Kumbungu in the Northern Region was selected because of the Bontanga Irrigation Scheme, Kassena-Nankana was selected because of the Tono Irrigation Scheme, while Bongo District was selected because of the Veia Irrigation Scheme. Thereafter, five communities were chosen at random from each of the selected districts, after which 20 respondents were randomly chosen from each of the selected communities to give a fairly representative sample of 300 farmers for the econometric analysis. Data collection was carried out from January to March 2014.

3.2. The MVP model

The MVP model is a series of probit models that are estimated together. The rationale behind the MVP model is that agricultural services comprise a mix of services which are accessible to farmers. A farmer may have access to any of the services with a different probability of access to each of them. Access to one service does not exclude the farmers from accessing other services. Access to the total number of services, especially if they are perfectly complementary, is essential to promote farm yield.

For the individual probit model, we can specify a linear function for the latent continuous variable D_i^* as follows.

$$D_i^* = \beta W_i + \varepsilon_i \tag{1}$$

where β denotes unknown parameters, and W_i represents independent variables. The observed dummy variable is defined as

$$D_i^* = \begin{cases} 1 & \text{if } D_i^* > 0 \text{ (access)} \\ 0 & \text{if } D_i^* \leq 0 \text{ (no access)} \end{cases} \tag{2}$$

The probability that we obtain the outcome of interest is

$$\Pr(D_i = 1) = \Pr(\varepsilon_i > -\beta W_i) = 1 - F(-\beta W_i) \tag{3}$$

where $F(\cdot)$ represents the cumulative distributive function of ε_i .

The MVP model has the general form

$$D_{ik}^* = W_{ik}\beta_k + \varepsilon_i, D_{ik} = 1 \text{ if } D_{ik}^* > 0 \text{ and } 0 \text{ otherwise.} \tag{4}$$

The empirical MVP model is presented as

$$D_{ik}^* = \beta_0 + \sum_{i=1}^{11} \beta_{ik} W_{ik} + \varepsilon_i \tag{5}$$

where W_{ik} are the independent variables hypothesized to influence access to services namely respondent's sex, education, household size, farming experience, farm size, household income, participation in off-farm employment, farmer group membership, degree of specialization in farming, and location of the household. The choice of the variables was based on the existing literature and a priori expectation.

As indicated by the extant literature, a number of factors affect farmers' access to agricultural services in developing countries. These factors include socio-economic, demographic, geographical and institutional factors. Some of the influential factors include respondent's sex (Dontsop-Nguezet et al., 2016; Kuwornu et al., 2017), education (Wossen et al., 2017; Gebrehiwot, 2015), household size (Khonje et al., 2015; Sodjinou et al., 2015), farming experience (Bidzakin et al., 2018; Danso-Abbeam et al., 2018), farm size (Danso-Abbeam et al., 2018; Kuwornu et al., 2017), household income (Anang et al., 2016), participation in off-farm work (Awunyo-Vitor et al., 2014), farmer group membership (Danso-Abbeam et al., 2018; Anang et al., 2017), degree of specialization in farming (Anang, 2018), location of the household (Anang, 2018) and wealth of farmer (Bidzakin et al., 2018).

3.3. The generalized Poisson regression model

Poisson regression is applied to model dependent variables that consist of count data. The standard Poisson model assumes that there is equidispersion of the data, implying that the mean and variance of the regressand do not differ. However, most data are either overdispersed (the variance exceeds the mean) or underdispersed (the mean exceeds the variance). Overdispersed count data cannot be estimated consistently using Poisson regression. Other models such as negative binomial regression, zero-inflated Poisson and zero-inflated negative binomial models are suited for overdispersed count data. On the other hand, few models exist that can be used to estimate underdispersed count data. Whereas the standard Poisson model

cannot account for underdispersed data, the generalized Poisson model can account for both underdispersed and overdispersed data. For the current study, the data displayed underdispersion, hence the choice of the generalized Poisson model (Awuni et al., 2018; Harris et al., 2012; Aker, 2011; Cui et al., 2006).

If we denote the response variable by Y_i , then the probability mass function (PMF) is given as

$$f(y_i, \theta_i, \delta) = \frac{\theta_i(\theta_i + \delta y_i)^{y_i-1} e^{-\theta_i - \delta y_i}}{y_i!}; \quad (y_i = 0, 1, 2, \dots) \tag{6}$$

where $\theta_i > 0$, and $\max(-1, -\theta_i/4) < \delta < 1$. The generalized Poisson model has mean (μ_i) and variance ($\text{var}(y_i)$) given as

$$\mu_i = E(Y_i) = \frac{\theta_i}{1-\delta}, \quad \text{var}(Y_i) = \frac{\theta_i}{1-\delta^3} = \frac{\theta_i}{1-\delta} E(Y_i) = \phi E(Y_i) \tag{7}$$

where the term $\phi E(Y_i)$ serves as a dispersion factor. When $\delta = 0$, we have equidispersion and the generalized Poisson reduces to the standard Poisson model. The data shows overdispersion when $\delta > 0$ and underdispersion when $\delta < 0$.

The generalized Poisson model has the following log-likelihood function

$$L = \sum_{i=1}^n L(\theta_i, \delta, y_i) = \sum_{i=1}^n \ln L(\theta_i, \delta, y_i) \tag{8}$$

$$= \sum_{i=1}^n \{ \ln \theta_i + (y_i - 1) \ln(\theta_i + \delta y_i) - (\theta_i + \delta y_i) - \ln y_i! \}$$

The study measured access to services as the number of services that farmers were able to access for the cropping season, which is non-negative, with a value of 0–5. The count data response variable is regressed on a set of covariates. The covariates are introduced into the regression model as follows (Consul and Famoye, 1992; Consul, 1989):

$$\log \frac{\theta_i}{1-\delta} = \sum_{r=1}^p x_{ir} \gamma_r \tag{9}$$

where x_{ir} denotes the i th observation of the r th covariate, p indicates the number of covariates, and γ_r represents the r th parameter.

Empirically, the generalized Poisson regression model is represented by the following equation

$$Y_i = \gamma_0 + \sum_{r=1}^{11} \gamma_r x_{ir} + v_i \tag{10}$$

where x_{ir} are independent variables including respondent's sex, education, household size, farming experience, farm size, household income, participation in off-farm work, farmer group membership, degree of specialization in farming, and location of the household. The choice of the variables was based on the existing literature and a priori expectation as previously explained.

4. Results

4.1. Descriptive statistics of the sample

Most of the sampled farmers are males and possessed up to 4 years of formal education with sufficient experience in farming (Table 1). Each respondent had an additional 9 household members and cultivated less than one hectare of farmland. Majority of the farmers participated in a farmer group while a little below half of the respondents took part in off-farm work. Household income averaged 2364 Ghana cedis. The respondents devoted a little below half of their total farmland to rice production, indicating that rice is an important crop in the area. Most of the farmers were sampled from the Upper East Region.

4.2. Factors determining access to agricultural services

The agricultural services that producers were able to access are presented in Table 2. The most accessed service was agricultural mechanization (65%), involving the hiring of tractor services for major land preparation prior to cultivation. Agricultural extension service was accessed by 63% of the respondents followed by agricultural input subsidies (60%) and irrigation (50%). The least accessed agricultural service was farm credit. This highlights the challenges smallholder farmers face in accessing finance for crop production.

Table 3 presents the tetrachoric correlation estimates of agricultural services. The results indicate that all the tetrachoric correlation coefficients are below 0.5 ($r < 0.50$). According to Sharma et al. (2011) and Mensah-Bonsu et al. (2017), correlation coefficients above 0.5 are classified as high, while values between 0.25 and 0.5 are considered to be medium. Correlation coefficients below 0.25 are deemed to be low. Positive and significantly correlated coefficients indicate that the two services are accessed simultaneously by farmers, while a negative and significant correlation coefficient shows that the two services are mutually exclusive (Sharma et al., 2011).

Agricultural extension is moderately and positively correlated with farm credit but minimally correlated with access to irrigation and subsidy. Also, access to subsidy has a minimal and positive correlation with farm credit. On the other hand, farm credit and agricultural mechanization exhibited a minor and negative correlation suggesting that the two services are aligned towards mutual exclusiveness.

The positive correlation between credit and extension means that these services are complementary or linked hence, they are accessed jointly or simultaneously by profit maximizing farmers (Smith, 2004). Access to extension services facilitates farmer group membership, hence increases the likelihood to access farm credit because of the collective bargaining power and strong social capital of farmer groups (Asante et al., 2011). Farmers' decision to use these services either jointly or separately is influenced by several factors including cost, farming objectives and profit maximizing behavior of the farmer. Profit maximizing

Table 1. Description of the variables.

Variable	Expected sign	Mean	Std. Dev.
Sex (1 = male; 0 otherwise)	+	0.783	0.413
Education (years)	+	3.933	5.350
Household size (number)	+	9.650	7.204
Experience (years)	+	20.60	12.24
Farm size (hectare)	+	0.857	0.682
Off-farm work (1 = if participant; 0 otherwise)	+	0.440	0.497
Region (1 = Northern; 0 otherwise)	+/-	0.333	0.472
Specialization (proportion of land for rice)	+	45.37	25.11
Income (Ghana cedis)	+	2364	2030
Farmer group (1 = member; 0 otherwise)	+	0.667	0.475

Table 2. Agricultural services accessed by farmers.

Agricultural services	Frequency (No. of farmers who had access)	Percent
Credit	121	40.3
Irrigation	150	50
Mechanization	195	65
Subsidy	180	60
Extension	190	63.3

Table 3. Tetrachoric correlation estimates of agricultural services accessed by farmers.

Agricultural Service	Credit	Irrigation	Mechanization	Subsidy	Extension
Credit	1.00				
Irrigation	-0.086	1.00			
Mechanization	-0.217**	-0.003	1.00		
Subsidy	0.206**	0.091	0.133	1.00	
Extension	0.311***	0.234**	0.015	0.203**	1.00

*p < 0.1; **p < 0.05; ***p < 0.01.

farmers are expected to have a higher likelihood of adopting complementary technologies to maximize profit. The weak correlation between credit and mechanization is surprising because farm credit is an essential prerequisite for assessing agricultural mechanization especially within the context of resource-poor or smallholder farming in Ghana. Farmers require credit to meet the cost of adopting agricultural mechanization. However, the weak correlation between credit and mechanization could also be attributed to the type and scale of mechanization required. This is because the cost associated with mechanization may be such that farmers are able to internalize this cost in their production process and hence do not require credit to adopt same.

Table 4 presents the multivariate probit model estimates of the determinants of smallholders' access to agricultural services. The services were accessed simultaneously by the respondents, hence the choice of the MVP model. The Chi square test was significant at 1% level suggesting that the MVP model adequately represents the data and the regressors included in the MVP model jointly explained access to agricultural services in the northern regions of Ghana. From the MVP model estimates, access to farm credit increased with farming experience, household income and farmer group membership. Also, the likelihood of female farmers accessing credit was higher than that of male farmers. In

addition, farm households located in the Northern Region had higher likelihood of accessing credit relative to producers in the Upper East Region.

4.2.1. Access to farm credit

Access to credit depends on the credit worthiness of the borrower, socioeconomic, technical, institutional and sometimes cultural factors. Rural financial institutions are unwilling to lend to farmers largely due to the inherent risks associated with agricultural production. The abilities of the farmer to pay back the borrowed money is the most crucial factor determining access to farm credit. The credit worthiness of farmers depends on their worth measured as value of assets legally owned by the farmer, payment history, savings history, social capital and other socioeconomic factors (Chandio et al., 2020; Asante-Addo et al., 2017; Abdul-Jalil, 2015). Income is normally used as proxy for worth in econometric models. Access to credit is expected to be higher for farmers with higher incomes because of their credit worthiness. Moreover, financial institutions also consider worth indicators when appraising the credit worthiness of applicants. The influence of income on access to credit is therefore not surprising at all. The empirical relationship between access to credit and income has been well researched and

Table 4. MVP model estimates of the determinants of smallholders' access to agricultural services.

Variable	Farm Credit		Irrigation		Mechanization		Input Subsidy		Extension	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Sex	-0.669***	0.216	0.212	0.215	0.298	0.211	0.169	0.205	-0.260	0.233
Farm size	-0.189	0.333	-0.695	0.500	-0.062	0.390	-0.199	0.326	-0.676*	0.409
Farm size sq.	0.037	0.090	0.323*	0.188	0.147	0.127	0.032	0.091	0.301**	0.132
Household size	-0.016	0.014	0.005	0.017	-0.063***	0.016	-0.017	0.013	-0.028*	0.016
Experience	0.014**	0.007	-0.002	0.007	0.012*	0.007	0.017**	0.007	0.021***	0.007
Education	0.012	0.016	-0.025	0.016	-0.018	0.016	0.003	0.015	0.008	0.017
Off-farm work	-0.147	0.170	-0.478***	0.175	-0.190	0.176	-0.040	0.164	0.108	0.180
Region	0.727***	0.199	-0.231	0.206	1.061***	0.230	0.337*	0.199	-0.949***	0.218
Specialization	-0.004	0.003	0.014***	0.003	0.003	0.003	-0.003	0.003	-0.001	0.003
Income	0.328***	0.113	0.359***	0.107	0.027	0.113	0.184*	0.107	-0.066	0.114
Farmer group	0.337**	0.168	0.529***	0.169	0.319*	0.171	-0.015	0.163	1.122***	0.183
Constant	-0.351	0.327	-0.871**	0.381	-0.100	0.358	-0.071	0.320	0.255	0.368

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 33.8045, Prob > chi2 = 0.0002. *p < 0.1; **p < 0.05; ***p < 0.01.

documented in development economic literature especially for developing countries. Due to the risks associated with farming especially in the northern regions, farmers are often reluctant to access formal credit facilities because of fear of potential default. Risk and uncertainties in agriculture makes farm credit very risky for smallholders. Risk aversion is a common behavior among smallholders. Experienced farmers have lower risk aversion and therefore likely to take the risk to access farm credit. Experienced farmers have better understanding of the inherent agricultural systems and therefore likely to have a better appreciation of the underlying risks and uncertainties involved in using formal credit in agriculture. Hence, the positive association between credit access and farmers' experience was expected. Surprisingly, women had a higher likelihood to access credit. This finding is surprising because in most regions of Ghana men rather than women own and control productive resources. Women in most regions of Ghana have little access to and control over resources as a result of sociocultural constraints and therefore have limited access to credit because they are unable to meet the eligibility requirements for formal credit. Without the guarantee, approval or support of their husbands, it is very difficult for female spouses to secure formal loans for agricultural production. However, in the credit literature, women are described as good or honest borrowers; when they access credit, they pay their loans in time and have lower default rates compared to their male counterparts (Weber and Musshoff, 2012). This could explain why rural financial institutions in the northern regions were likely to lend to women in agriculture.

4.2.2. Access to irrigation

Access to irrigation was positively influenced by household income, degree of specialization in farming and farmer group membership. Irrigation access however decreased with land area and engagement in off-farm employment. The second order land area variable returned a positively significant value indicating that as farms become larger, the probability of access to irrigation increases. Ghana's agriculture is predominantly rain fed. Less than 5% of arable land is under irrigation. Scarcity of irrigation water especially during the minor seasons means that majority of farmers require irrigation water to embark on farming throughout the year in northern Ghana. Access to irrigation is affected by the cost and availability of alternative sources of irrigation water, irrigation water needs of the farmer, scale of production, type of cropping system, geographical location, household income, household size, environmental factors and other socioeconomic factors. The northern parts of the country experience unimodal rainfall. The scarcity of water for crop irrigation especially during the minor season means that majority of farmers may want to consider alternative sources of water for year-round farming but the cost of irrigation water is a major constraint to smallholders' access to irrigation. Households having large land holdings have a higher likelihood to meet the cost component of modern irrigation facilities and use same for agricultural production. The positive influence of income on access to irrigation aligns with previous studies (Abdulai et al., 2011; Bacha et al., 2011). Off-farm income had negative influence on access to irrigation because farmers who are engaged in the non-farm sector are less dependent on farm income, especially if the off-farm job is more lucrative and competitive than farming. The farming objectives and profit-maximizing behavior of farmers with diversified sources of income is completely different from farmers whose livelihoods are solely reliant on farm income. Farm households reliant on the farm sector for their livelihoods are expected to have a higher likelihood to adopt irrigation in order to enhance production, expand farm income and smooth consumption (Sikwela, 2008; Postel et al., 2001). The negative relationship between access to irrigation and farm size implies that smallholders have limited access to irrigation. The quadratic term for land area is positive indicating that producers having large farm holdings have a higher likelihood to access irrigation relative to farmers with small land holdings. Farmers with large farm holdings may also adopt irrigation because of economics of scale. The overhead cost of operating an irrigation facility on large farms may be comparatively lower than for small farms.

Modern irrigation facilities are suitable and efficient for commercial farming. The positive influence of farm size on access to irrigation could also mean that the irrigation needs of large scale or commercial farming is higher than small scale farming and the willingness to access irrigation water could be higher for farmers having large farm holdings as opposed to producers with small farm holdings. Smallholders are more likely to rely on rainfall water for irrigation due to cost constraint, unless the irrigation comes at no explicit cost to the farmer. Commercial farming is associated with high degree of specialization. Mono cropping is predominant in the northern parts of the country. It is therefore not surprising that farmers with high degree of specialization had access to irrigation. Large farms under irrigation are mostly mono cropped as commercial farming is not synonymous with mixed farming system. Farmer groups act as social networks in the agriculture sector. Members of FBOs are more connected and have better access to agricultural services than farmers who are not members of any farmer group, hence the positive influence of FBO membership on access to irrigation. Members of farmer groups may adopt irrigation facilities as a group in which case the overhead cost and risk of investment is spread among group members. The investment risk of adopting modern irrigation facilities is higher for individual farmers than those in groups.

4.2.3. Access to mechanization

Access to mechanization services increased with farming experience and farmer group membership but decreased with household size. Also, respondents in the Upper East Region had a lower probability of accessing mechanization services. A positive influence of farming experience on access to mechanization is not surprising because experience increases farmers' understanding of the prevailing farming system making them more likely to appreciate the compatibility of mechanization with existing practices according to Rogers diffusion of innovation theory (Rogers, 2003). Also, experience farmers have better understanding of the cost implications of mechanization (Kuwornu et al., 2017; Benin, 2015; Julius, 2014). The risks and uncertainties involved in adopting modern agricultural technologies and practices are minimized for experience farmers. In the same vein, members of FBOs have better access to agricultural services because they are well connected to agricultural service providers through social networks (Houssou and Chapoto, 2014). The food security needs of smaller households are relatively lower compared to large households (Houssou & Chapoto, 2014, 2015; Houssou et al., 2013). Large households are more likely to depend on family labor to expand agricultural production hence the negative influence of household size on access to mechanization. Households in Upper East region were less likely to have access to mechanization indicating that there are geographical specific and ecological barriers to access to mechanization in the northern parts of the country (Julius, 2014). This could also mean that mechanization services are not evenly distributed across the northern regions of Ghana. The irrigation water needs and farming system in Upper East could be slightly different from the rest of the northern regions hence the negative influence of the regional dummy on access to mechanization.

4.2.4. Access to input subsidies

Access to input subsidy was positively influenced by farming experience and household income while farm households in the Upper East Region had a lower likelihood to access subsidy. Input subsidies are packages of agricultural technologies. Factors influencing agricultural technology adoption are expected to affect access to input subsidies. The positive influence of farming experience and income on input subsidies is therefore not surprising because progressive farmers who are experience with high incomes have a higher likelihood to adopt improved technologies (Fisher and Kandiwa, 2014; Bezu et al., 2014; Ogada et al., 2010). It is noteworthy to stress that access to input subsidies is a two-hurdle process. First, farmers have to demand

the inputs before they can receive subsidies. Hence farmers with access to input subsidies have high demand for inputs. Again, farmers in Upper East Region have lower probability to access input subsidies reemphasizing the fact that there are geographical specific factors influencing access to services in northern Ghana.

4.2.5. Access to agricultural extension services

Access to agricultural extension services was positively related to farming experience and farmer group membership but negatively associated with farm size and number of household members. Also, farm households in the Northern Region had lower access to extension services. The second order term of the farm size variable assumed a positively significant value implying that as farm size increases, the probability to access agricultural extension increases. Extension is meant to complement other agricultural services. The role of extension agents among other things is to assist farmers in the use of modern agricultural technologies and practices. Highly experienced producers participating in farmer groups are anticipated to have higher demand for agricultural extension services because they are likely to use improved agricultural technologies and seek agricultural information on how to use these technologies (Mugunieri and Omiti, 2007). The Northern Region has a wide geographical spread and low population density. The large geographical spread is expected to lead to low extension worker to farmer ratio and difficulty in reaching farmers in remote farming communities. Extension coverage is thus lower in the Northern Region and this could explain why farm households in that region had lower access to extension services. The quadratic term for farm size was positive because progressive farmers who cultivate large acreages have a higher propensity to use modern agricultural technologies and seek extension advice (Abdallah and Abdul-Rahaman, 2016).

4.3. Factors determining the degree of access to agricultural services

Next, we examine the extent (or degree) to which farm households were able to access agricultural services. The findings indicate that 14.3% of farm households had access to just one service, 16.7% accessed two services while 35% were able to access three services (Table 5). Twenty-four (24) percent of the respondents had access to four out of the five agricultural services. The results further indicate that 65% of farmers had access to not less than three services while 31% had access to not more than two services. Only 4% of the farmers interviewed could not access any of the five types of agricultural services whereas 6% were able to access all the services.

To gain insight into the factors affecting producers' access to agricultural services, this section investigates the factors determining the degree of access to these services. First, we discuss the choice of the generalized Poisson (GP) model for the estimation. Usually, a test of overdispersion is needed to choose between the Poisson regression and other count models. A close examination of the data indicates that there are not many zeros for the dependent variable (number of

services accessed by farmers); hence the data is not expected to show overdispersion. The zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB) models were deemed unsuitable for the analysis since they apply to data with several zeros. We however tested the adequacy of the standard Poisson against the negative binomial. The likelihood ratio test of overdispersion led to rejection of the negative binomial regression model in favor of the Poisson model. However, since examination of the data signaled the likelihood of underdispersion, we tested the adequacy of the GP against the standard Poisson. The mean and variance of the dependent variable (Table 5) show that the data displays underdispersion supporting the choice of the GP regression model. Furthermore, the test of hypothesis regarding the choice of the GP over the standard Poisson enabled us to reject the null hypothesis of equidispersion since the dispersion parameter is less than zero as indicated in Table 6. Hence, the data is underdispersed and the generalized Poisson model is preferred.

The generalized Poisson model estimates are shown in Table 6. The Chi square test is significant at 1% probability level implying that this model adequately represents the data and the regressors jointly explained the degree of access to agricultural services in the northern regions of Ghana. The factors influencing the degree of access to agricultural services were not very different from the factors influencing access to the individual services. With the exception of sex and degree of specialization, almost the same set of factors influenced both access and the degree of access to services. Farm income, farmer group membership, farming experience and the quadratic term for farm size were positive determinants of degree of access to agricultural services. Off-farm income and number of household members were negative factors affecting the degree of access to agricultural services. Farmers cultivating large farm holdings have a higher propensity to adopt modern production technologies and other complementary services (Nederlof et al., 2011; Wennink et al., 2007; Stringfellow et al., 1997).

The degree of access is an indication of the degree of complementarity between the agricultural services. Commercial agriculture is associated with high degree of access to agricultural services due to agricultural intensification. The degree of access to agricultural services increases with degree of agricultural intensification. Highly experienced farmers have a higher probability to adopt modern agricultural technologies as well as demand more agricultural services to complement other farm inputs. Wealthy households with high incomes are expected to demand more agricultural services because they have the financial muscles to meet the costs of agricultural service provision especially in rural areas. Farmers who have diversified and additional sources of income are less dependent on the farm sector for livelihood and therefore have low willingness to expand agricultural production through improved access to agricultural services. Farm households whose livelihoods depend solely on the farm sector have a higher likelihood to access agricultural services

Table 5. Degree of access to agricultural services by farm households.

Number of services accessed	Frequency	Percent
0	12	4.0
1	43	14.3
2	50	16.7
3	105	35.0
4	72	24.0
5	18	6.0
Total	300	100
Mean	2.79	
Variance	1.54	

Table 6. Factors determining the degree of access to agricultural services.

Variable	Generalized Poisson model		Standard Poisson model	
	Coefficient	Std. Error	Coefficient	Std. Error
Sex	-0.032	0.061	-0.009	0.927
Farm size	-0.085	0.087	-0.106	0.450
Farm size squared	0.039*	0.022	0.048	0.170
Household size	-0.010***	0.004	-0.013**	0.029
Experience	0.007***	0.002	0.007**	0.013
Education	-0.002	0.004	-0.003	0.719
Off-farm work	-0.099**	0.048	-0.089	0.252
Region	0.098*	0.055	0.103	0.253
Specialization	0.001	0.001	0.001	0.403
Income	0.085***	0.030	0.096**	0.034
Farmer group membership	0.264***	0.048	0.298***	0.000
Constant	0.719***	0.090	0.688***	0.000
<i>Diagnostic statistics</i>				
LR Chi ² (11)	72.92		38.11	
Prob > Chi ²	0.000		0.000	
Pseudo R ²	0.074		0.037	
Log-likelihood	-453.7		-497.9	
Dispersion	-0.569		-	
LR test of delta = 0: Chi ² (1)	88.59***		-	

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

to increase agricultural productivity and expand income. This however depends on the stability or reliability of off-farm income.

5. Concluding remarks

Access to agricultural services is a prerequisite for agricultural modernization in Ghana. The extent to which agricultural transformation agenda will be achieved will depend on the degree to which smallholders have access to modern agricultural services such as extension, inputs, credit, irrigation and mechanization. This paper assessed factors influencing access and degree of access to agricultural services in the northern regions of Ghana using the multivariate probit and generalized Poisson regression models respectively. Household income, off-farm income, number of household members and land area were the main determinants of both access and degree of access to agricultural services in the northern regions of Ghana. There were regional differences in access to agricultural services; while households in the Upper East Region had lower access to irrigation water, those in the Northern Region had lower access to extension services. Policy makers are therefore encouraged to take cognizance of these factors in the design of agricultural service policies and interventions in the northern regions of Ghana.

Declarations

Author contribution statement

Benjamin Tetteh Anang: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Bright Owusu Asante: Analyzed and interpreted the data; Wrote the paper.

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References

- Abdallah, A.-H., 2016. Agricultural credit and technical efficiency in Ghana: is there a nexus? *Agric. Finance Rev.* 76 (2), 309–324.
- Abdallah, A.-H., Abdul-Rahaman, A., 2016. Determinants of access to agricultural extension services: evidence from smallholder rural women in Northern Ghana. *Asian J. Agri. Exten. Econom. Socio.* 1–8.
- Abdulai, A., Owusu, V., Bakang, J.E.A., 2011. Adoption of safer irrigation technologies and cropping patterns: evidence from Southern Ghana. *Ecol. Econ.* 70 (7), 1415–1423.
- Abdul-Jalil, M.A., 2015. Determinants of Access to Credit and its Impact on Household Food Security in Karaga District of the Northern Region of Ghana. Master of Philosophy dissertation submitted to the Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology, Ghana. Available at: <http://ir.knust.edu.gh/bitstream/123456789/8049/1/ma-Az%20Abdul-Jalil.pdf>. (Accessed 15 May 2020).
- Aker, J.C., 2011. Dial “A” for agriculture: a review of information and communication technologies for agricultural extension in developing countries. *Agric. Econ.* 42 (6), 631–647.
- Anang, B.T., 2018. Farm technology adoption by smallholder farmers in Ghana. *Rev. Agri. Appl. Econom.* XXI, 41–47 (Number 2, 2018).
- Anang, B.T., Bäckman, S., Rezitis, A., 2017. Production technology and technical efficiency: irrigated and rain-fed rice farms in northern Ghana. *Eurasian Econom. Rev.* 7, 95–113.
- Anang, B.T., Bäckman, S., Sipiläinen, T., 2020. Adoption and income effects of agricultural extension in northern Ghana. *Scientific African* 7 (2020), e00219.
- Anang, B.T., Sipiläinen, T., Bäckman, S., Kola, J., 2015. Factors influencing smallholder farmers’ access to agricultural microcredit in Northern Ghana. *Afr. J. Agric. Res.* 10 (24), 2460–2469.
- Anang, B.T., Bäckman, S., Sipiläinen, T., 2016. Agricultural microcredit and technical efficiency: the case of smallholder rice farmers in Northern Ghana. *J. Agric. Rural Dev. Tropics Subtropics* 117 (2), 189–202.

- Asante, B.O., Afari-Sefa, V., Sarpong, D.B., 2011. Determinants of small-scale farmers' decision to join farmer-based organizations in Ghana. *Afr. J. Agric. Res.* 6 (10), 2273–2279.
- Asante-Addo, C., Mockshell, J., Zeller, M., Siddig, K., Egyir, I.S., 2017. Agricultural credit provision: what really determines farmers' participation and credit rationing? *Agric. Finance Rev.*
- Asfaw, S., Shiferaw, B., Simtowe, F., Lipper, L., 2012. Impact of modern agricultural technologies on smallholder welfare: evidence from Tanzania and Ethiopia. *Food Pol.* 37 (3), 283–295.
- Awuni, J.A., Azumah, S.B., Donkoh, S.A., 2018. Drivers of adoption intensity of improved agricultural technologies among rice farmers: evidence from northern Ghana. *Rev. Agri. Appl. Econom.* 21 (1340-2018-5180), 48–57.
- Awunyo-Vitor, D., Al-Hassan, R.M., Sarpong, D.B., Egyir, I., 2014. Agricultural credit rationing in Ghana: what do formal lenders look for? *Agric. Finance Rev.* 74 (3), 364–378.
- Bacha, D., Namara, R., Bogale, A., Tesfaye, A., 2011. Impact of small-scale irrigation on household poverty: empirical evidence from the Ambo district in Ethiopia. *Irrigat. Drain.* 60 (1), 1–10.
- Benin, S., 2015. Impact of Ghana's agricultural mechanization services center program. *Agric. Econ.* 46 (1), 103–117.
- Bezu, S., Kassie, G.T., Shiferaw, B., Ricker-Gilbert, J., 2014. Impact of improved maize adoption on welfare of farm households in Malawi: a panel data analysis. *World Dev.* 59, 120–131.
- Bidzakin, J.K., Fialor, S.C., Awunyo-Vitor, D., Yahaya, I., 2018. Impact of irrigation ecology on rice production efficiency in Ghana. *Adv. Agric.* 2018, 1–10.
- Boniphace, N.S., Fengying, N., Chen, F., 2015. An analysis of smallholder farmers' socio-economic determinants for inputs use: a case of major rice producing regions in Tanzania. *Russ. J. Agric. Soc. Econ. Sci.* 2 (38), 41–55.
- Chandio, A.A., Jiang, Y., Rehman, A., Twumasi, M.A., Pathan, A.G., Mohsin, M., 2020. Determinants of demand for credit by smallholder farmers: a farm level analysis based on survey in Sindh, Pakistan. *J. Asian Business Econom. Stud.*
- Clarke, L.J., 2000. Strategies for Agricultural Mechanization Development: the Roles of the Private Sector and the Government. Agricultural Engineering Branch. Agricultural Support Systems Division FAO, Rome, Italy.
- Consul, P.C., 1989. Generalized Poisson Distributions: Properties and Applications. Dekker, New York.
- Consul, P.C., Famoye, F., 1992. Generalized Poisson regression model. *Commun. Stat. Theor. Methods* 21, 89–109.
- Cui, Y., Kim, D.Y., Zhu, J., 2006. On the generalized Poisson regression mixture model for mapping quantitative trait loci with count data. *Genetics* 174 (4), 2159–2172.
- Danso-Abbeam, G., Ehiakpor, D.S., Aidoo, R., 2018. Agricultural extension and its effects on farm productivity and income: insight from Northern Ghana. *Agri. Food Security* 7, 74.
- Davis, K., Nkonya, E., Kato, E., Mekonen, D.A., Odendo, M., Miro, R., Nkuba, J., 2012. Impact of farmer field schools on agricultural productivity and poverty in East Africa. *World Dev.* 40 (2), 402–413.
- Diao, X., 2010. Economic importance of agriculture for sustainable development and poverty reduction: findings from a case study of Ghana. In: *Global Forum on Agriculture, 29–30 November 2010. Policies for Agricultural Development, Poverty Reduction and Food Security*. OECD Headquarters, Paris available at: <http://www.oecd.org/agriculture/agricultural-policies/46341169.pdf>. (Accessed 15 May 2020).
- Diao, X., Cossar, F., Houssou, N., Kolavalli, S., 2014. Mechanization in Ghana: emerging demand and the search for alternative supply models. *Food Pol.* 48, 168–181.
- Dillon, A., 2008. Access to Irrigation and the Escape from Poverty: Evidence from Northern Mali. IFPRI Discussion Paper 00782. July 2008, available at: <http://www.ifpri.org/publication/access-irrigationand-escape-poverty>. (Accessed 15 May 2020).
- Dittoh, S., 2006. Effective aid for small farmers in sub-saharan Africa: Southern civil society perspective. Ghana Case Study.
- Dontsop-Nguezet, P.M., Manyong, V., Abdoulaye, T., Arega, A., Amato, M.S., Ainembabazi, J.H., Mignouna, D.A.D., Okafor, C., 2016. Non-farm activities and adoption of improved cassava and beans varieties in Southern Kivu, DR Congo. *Tropicultura* 34 (3), 262–275.
- Dorward, A., Chirwa, E., 2011. The Malawi agricultural input subsidy program: 2005/2006 to 2008/2009. *Int. J. Agric. Sustain.* 1 (9), 232–247.
- Fisher, M., Kandiwa, V., 2014. Can agricultural input subsidies reduce the gender gap in modern maize adoption? Evidence from Malawi. *Food Pol.* 45, 101–111.
- Gebrehiwot, K.G., 2015. The impact of agricultural extension on households' welfare in Ethiopia. *Int. J. Soc. Econ.* 42 (8), 733–748.
- Ghimire, R., Wenchi, H., Shrestha, R.B., 2015. Factors affecting adoption of improved rice varieties among rural farm households in central Nepal. *Rice Sci.* 22 (1), 35–43.
- Harris, T., Yang, Z., Hardin, J.W., 2012. Modeling underdispersed count data with generalized Poisson regression. *STATA J.* 12 (4), 736–747.
- Houssou, N., Chapoto, A., 2015. Adoption of farm mechanization, cropland expansion, and intensification in Ghana. In: Paper Prepared for the 29th International Conference of Agricultural Economists, Milan, Italy. August 8-14, 2015.
- Houssou, N., Chapoto, A., 2014. The Changing Landscape of Agriculture in Ghana: Drivers of Farm Mechanization and its Impacts on Cropland Expansion and Intensification.
- Houssou, N., Diao, X., Cossar, F., Kolavalli, S., Jimah, K., Aboagye, P.O., 2013. Agricultural mechanization in Ghana: is specialized agricultural mechanization service provision a viable business model? *Am. J. Agric. Econ.* 95 (5), 1237–1244.
- ISSER, 2006. The state of the Ghanaian economy 2005. In: Institute of Statistical, Social and Economic Research (ISSER). University of Ghana, Legon, Accra.
- Jayne, T.S., Mather, D., Mason, N.M., Ricker-Gilbert, J., 2013. How do fertilizer subsidy programs affect total fertilizer use? Crowding out, diversion, and benefit/cost assessments. *Agric. Econ.* 44 (6), 687–703.
- Julius, A., 2014. Factors limiting small-scale farmers' access and use of tractors for agricultural mechanization in Abuja, North Central Zone, Nigeria. *Eur. J. Sustain. Dev.* 3 (1), 115–115.
- Khonje, M., Manda, J., Alene, A.D., Kassie, M., 2015. Analysis of adoption and impacts of improved maize varieties in Eastern Zambia. *World Dev.* 66, 695–706.
- Kuwornu, J.K., Apiors, E.K., Kwadzo, G., 2017. Access and intensity of mechanization: empirical evidence of rice farmers in southern Ghana. *Braz. Arch. Biol. Technol.* 60.
- Kuwornu, J.K.M., Owusu, E.S., 2012. Irrigation access and per capita consumption expenditure in farm households: evidence from Ghana. *J. Dev. Agric. Econ.* 4 (3), 78–92.
- Lunduka, R., Ricker-Gilbert, J., Fisher, M., 2013. What are the farm-level impacts of Malawi's farm input subsidy program? A critical review. *Agric. Econ.* 44, 563–579.
- McNamara, P., Dale, J., Keane, J., Ferguson, O., 2014. Strengthening Pluralistic Agricultural Extension in Ghana, Modernizing Extension and Advisory Services Discussion Paper, USAID.
- Mehta, C.R., Chandel, N.S., Senthilkumar, T., 2014. Status, challenges and strategies for farm mechanization in India. *Agri. Mechanization Asia Afr. Latin Am.* 45 (4), 43–50.
- Mensah-Bonsu, A., Sarpong, D.B., Al-Hassan, R., Asuming-Brempong, S., Egyir, I.S., Kuwornu, J.K.M., Osei-Asare, Y.B., 2017. Intensity of and factors affecting land and water management practices among smallholder maize farmers in Ghana. *Afr. J. Agri. Res. Econ.* 12 (2), 142–157.
- Morris, M., Kelly, V., Kopicki, R., Byerlee, D., 2007. Fertiliser Use in African Agriculture: Lessons Learned and Good Practice Guidelines. Agriculture and Rural Development Division, World Bank, Washington, DC, p. 203.
- Mugunier, G.L., Omiti, J.M., 2007. Decentralization, Community-Based Organizations and Access to Agricultural Extension Services in Eastern Kenya. *Decentralization and the Social Economics of Development: Lessons from Kenya*, pp. 64–83.
- Nederlof, E.S., Wennink, B., Heemskerck, W., 2011. Access to Agricultural Services. Background Paper for the IFAD Rural Poverty Report.
- Nkegbe, P.K., 2018. Credit access and technical efficiency of smallholder farmers in Northern Ghana: double bootstrap DEA approach. *Agric. Finance Rev.* 78 (5), 626–639.
- Obi, A., Chisango, F.F., 2011. Performance of smallholder agriculture under limited mechanization and the fast track land reform program in Zimbabwe. *Int. Food Agribus. Manag. Rev.* 14 (4), 85–104. Retrieved from: <http://ageconsearch.umn.edu/record/117605>.
- Ogada, M.J., Nyangena, W., Yesuf, M., 2010. Production risk and farm technology adoption in the rain-fed semi-arid lands of Kenya. *Afr. J. Agri. Res. Econ.* 4, 159–174, 311-2016-5543.
- Postel, S., Polak, P., Gonzales, F., Keller, J., 2001. Drip irrigation for small farmers: a new initiative to alleviate hunger and poverty. *Water Int.* 26 (1), 3–13.
- Roger, E.M., 2003. Diffusion of Innovations, fifth ed. Free Press, New York.
- Sellamuttu, S.S., Aida, T., Kasahara, R., Sawada, Y., Wijerathna, D., 2013. How Access to Irrigation Influences Poverty and Livelihoods: A Case Study from Sri Lanka. Impact Assessment of Infrastructure Projects on Poverty Reduction. JICA Research Institute (JICA-RI) Working Paper. No. 59, 19 May 2020, available at: http://jica-ri-jica.jp/publication/assets/JICA-RI_WP_No.59_2013.pdf. (Accessed 15 May 2020).
- Sharma, A., Bailey, A., Fraser, I., 2011. Technology adoption and pest control strategies among UK cereal farmers: evidence from parametric and nonparametric count data models. *J. Agric. Econ.* 62 (1), 73–93.
- Sims, B.G., Kienzle, J., 2016. Making mechanization accessible to smallholder farmers in Sub-Saharan Africa. *Environments* 3 (11), 1–18.
- Stringfellow, R., Coulter, J., Lucey, T., McKone, C., Hussain, A., 1997. Improving the access of smallholders to agricultural services in sub-Saharan Africa: farmer cooperation and the role of the donor community. *Nat. Res. Perspect.* 20, 1–10.
- Sikwela, M.M., 2008. Determinants of Household Food Security in the Semi-arid Areas of Zimbabwe: A Case Study of Irrigation and Non-irrigation Farmers in Lupane and Hwange Districts (Doctoral Dissertation. University of Fort Hare).
- Smith, M.Y., 2004. A model of the linked adoption of complementary technologies. *Econ. Innovat. N. Technol.* 13 (1), 91–99.
- Sodjinou, E., Glin, L.C., Nicolay, G., Tovignan, S., Hinvi, J., 2015. Socioeconomic determinants of organic cotton adoption in Benin, West Africa. *Agric. Food Econ.* 3, 1–22.
- UNCTAD, 2015. The role of smallholder farmers in sustainable commodities production and trade. United Nations Conference on Trade and Development. URL: http://unctad.org/meetings/en/SessionalDocuments/tdb62d9_en.pdf. (Accessed 21 April 2020).
- van Koppen, B., Namara, R., Safilios-Rothschild, C., 2005. Reducing poverty through investments in agricultural water management: poverty and gender issues and synthesis of Sub-Saharan Africa Case Study Reports. IWMI Working Paper 101, available at: http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR101.pdf. (Accessed 15 May 2020).
- Weber, R., Musshoff, O., 2012. Is Agricultural Microcredit Really More Risky? Evidence from Tanzania. *Agricultural Finance Review*.
- Wennink, B., Nederlof, S., Heemskerck, W., 2007. Access of the poor to agricultural services. *Bulletin* 376.
- Wossen, T., Abdoulaye, T., Alene, A., Haile, M.G., Feleke, S., Olanrewaju, A., Manyong, V., 2017. Impacts of extension access and cooperative membership on technology adoption and household welfare. *J. Rural Stud.* 54, 223–233.
- Xie, H., You, L., Wielgosz, B., Ringle, C., 2014. Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. *Agric. Water Manag.* 131, 183–193.
- You, L., Xie, H., Wood-Sichra, U., Guo, Z., Wang, L., 2014. Irrigation potential and investment return in Kenya. *Food Pol.* 47, 34–45.