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Research article

Socioeconomic drivers of inoculant technology and chemical fertilizer utilization among soybean farmers in the Tolon District of Ghana

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ABSTRACT

Soybean farming is an important source of income for smallholder farmers in Ghana, particularly in the northern savanna ecological zones, where soil infertility is a challenge. To increase soybean production and farm revenue, farmers must adopt improved soybean production technologies. Smallholder soybean farmers' decisions to embrace high-yielding technology are influenced by various socioeconomic factors. The factors driving the adoption of rhizobium inoculant and mineral fertilizer technologies in Ghana's Tolon district were evaluated using a multinomial logit model with 200 smallholder soybean farmers. According to the findings, the likelihood of using inoculants and inorganic fertilizers increased with herd size, farm size, and access to extension services. In addition, female soybean producers were more likely than their male counterparts to use inoculants and chemical fertilizers. The study also found that soybean producers were less likely to use inoculants and chemical fertilizers because of their distance from the local market. To encourage technology adoption, the study recommends that agricultural extension services to farmers be increased. Farmers should also be encouraged to join farmer-based groups to increase inoculant technology uptake.

1. Introduction

Improved agricultural technology is critical for increasing farm production and achieving food and nutrition security (FNS), particularly among rural producers. Developing and disseminating improved agricultural technologies has the potential to enhance farm performance and job creation for the youth. Agriculture contributes to Ghana's gross domestic product (GDP) and improves the socioeconomic indices of smallholder farmers in rural areas. Agriculture contributed about 20% to the Ghana's GDP in 2019 (Nyamekye et al., 2021). Agriculture has a lot of potential to reduce unemployment by creating jobs because it employs over 75% of the labor force in rural areas of the country (MoFA, 2017; Yeboah and Flynn, 2021). Farm production and productivity are boosted by farmers' access to production capital, improved farming technologies, and market access (Kuhl, 2020; Yeboah and Flynn, 2021).

Ghana's government spends GH¢ 362.981 million (about US$ 58 million) to increase agricultural production and farm yields (MoFA, 2019). The majority of the funds have gone toward the promotion and use of better agricultural technologies. Improved agricultural technologies, such as agrochemicals and biological fertilizers, have been shown in the literature to be critical for increasing agricultural productivity (Sheahan et al., 2016; Danso-Abbeam and Baiyegunhi, 2017); thus, their importance in achieving FNS cannot be neglected. However, due to limited adoption of modern production technology in developing nations such as Ghana, the agricultural industry's full potential has yet to be realized (Afolami et al., 2015; Martey et al., 2020). According to Anang et al. (2021), low adoption of improved farming technologies such as agrochemicals and bio-fertilizers can be attributed to high input costs, limited market access, poor road networks, socio-cultural hurdles, and a lack of farmer awareness of the benefits of such improved technologies.

Soybean production has attracted global attention due to the food crop's economic benefits and its multipurpose nature (Hartman et al., 2011; Sinclair et al., 2014). Currently, Brazil is the leading producer of soybean with an output of 126 million metric tons in 2020/2021, followed by the United State of America. Since the 1970s, the area under soybean cultivation in Sub-Saharan Africa has increased (Khojely et al., 2018). Despite this, SSA only contributes 0.7% of world soybean production, making it a net importer of soybean products and oil (OECD-FAO, 2016; FAOStat, 2019). South Africa and Nigeria lead in the production of soybean in SSA, representing about 70% of total soybean production in Africa (Foyer et al., 2018; Cornelius and Goldsmith, 2019).

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The contribution of soybean production to Ghana's food basket cannot be overlooked. Production has increased from 112,800 metric tonnes in 2009 to 176,670 metric tonnes in 2018 (MoFA, 2019). This implies that within this period, Ghana's soybean production increased by 36.2%. Domestic demand for soybeans, however, has not been met because the average yield (1.72 Mt/Ha) is still below the feasible yield (3.0 Mt/Ha) (MoFA, 2019). The low yield achieved can be attributed to a lack of adoption of improved technology such as inoculants and chemical fertilizers. The introduction of bio-fertilizers such as rhizobium inoculants has become one of the breakthrough initiatives in recent times to enhance soybean productivity. Tefera et al. (2010) found that inoculating soybeans with rhizobium and other strains of inoculants helps to fix nitrogen in the root nodules of the plant, which may then be used by other crops, and enhances cultivation on the same piece of land in subsequent years. In order to boost soybean production and productivity, small-scale farmers in rural areas should be encouraged to use inoculants and chemical fertilizers. This is especially true because inoculants and chemical fertilizers are complementary inputs in soybean production (Anang et al., 2021). Chemical fertilizers contribute critical elements such as phosphorus and potassium to boost soil fertility and soybean yield, while inoculants aid to fix atmospheric nitrogen to the soil through the root nodules of crops. To the best of the researchers' knowledge, however, knowledge of the factors that influence inoculant and chemical fertilizer adoption, particularly joint adoption decisions, is sparse. As a result, the goal of this study is to fill that information gap by examining the socioeconomic determinants that drive individual and joint adoption of inoculant technology and inorganic fertilizer in soybean production in Ghana's Tolon district.

Several studies have highlighted the adoption of enhanced soybean technologies. Peshin et al. (2018) studied the effects of soybean production technology adoption in India and discovered that education, family size, income, and extension service all influenced adoption positively, whereas age and farm area had the opposite effect. To increase farmers' use of enhanced soybean production technology, the study proposed improving the linkages between research and development and agricultural extension services (Peshin et al., 2018). Wawire et al. (2021) examined the inter-relationship between adoption of integrated soil fertility management strategies using a hierarchical clustering approach in Kenya. Farmers' adoption decisions were influenced by age, education, extension service, and access to crop information. In addition, the study found that using chemical fertilizer was linked to manure use, adoption of agroforestry, and minimum/zero tillage. Adebayo et al. (2018) investigated the factors affecting uptake of soybean innovations in Nigeria. The cost of soybean innovations, access to extension services, household size, educational attainment, experience in soybean farming, farmer affiliation to an association, and soybean output per hectare were all found to be determinants of adoption. The study recommended that farmers should join active associations to access production technologies and extension services to enhance soybean production (Adebayo et al., 2018).

In Ghana, Mahama (2020) used the generalized Poisson model to empirically quantify the factors that influence farmers' decision to embrace improved soybean technologies. Farmers' decision to embrace soybean production technology was positively influenced by their age, years of schooling, extension visits, and use of social media. Similarly, Anang et al. (2021) employed multivariate and Tobit models to examine factors enhancing farmers' decisions to practice crop protection and soil management mechanisms in Ghana. The study concluded that the farmer's gender, age, herd size, farm capital, and farm size all influenced adoption and extent of using crop protection and soil management mechanisms.

Several socioeconomic factors influence farmers' decisions to adopt new agricultural technology, particularly joint adoption decisions like inorganic and biological fertilizer adoption. However, not much is known especially about the determinants of farmers' joint adoption decisions, which has received little attention in the literature. This study therefore examined the socioeconomic variables driving soybean farmers' decision to adopt inoculant technology and chemical fertilizer in Ghana's Tolon district, using a multinomial regression approach. This research will help scientists and policymakers develop and spread efficient technologies to farmers in order to boost soybean productivity and farm income.

2. Research materials and methods

2.1. Study area

The study was carried out in the Tolon District of northern Ghana. The district is located in the Guinea savanna, between latitudes $9^0$15 and $10^0$02 to the North and longitudes $0^0$53 and $1^0$25 to the West. The district's overall landmass is estimated to be 1353.66 sq. km (Tolon district, 2020). Majority of the labour force are peasant farmers. The district has soil characteristics suitable for soybean production. Soybean production helps to create jobs and improves the socioeconomic conditions of the soybean producers in the district. The soybean value chain is broad, and jobs are created at many stages of the industry, including production, assembly, marketing, transportation, and processing. Soybean is also an important cash crop that improves household income and food security level. The district has an agricultural service department that is responsible for promoting and disseminating agricultural technologies to farmers. The map showing the Tolon district is shown in Figure 1.

2.2. Sampling procedure, sample size, and data collection

A multi-stage random sampling strategy was used to acquire data for the study. The first stage involved purposive sampling of the study district, followed by the selection of five (5) communities in the district namely Kpalsogu, Tingoli, Nafarang, Dimabi, and Bilisi. Simple random approach was employed to selected forty (40) soybean farmers in each community in the final stage to give a total of 200 respondents. A pretested questionnaire was used to interview the respondents. Three

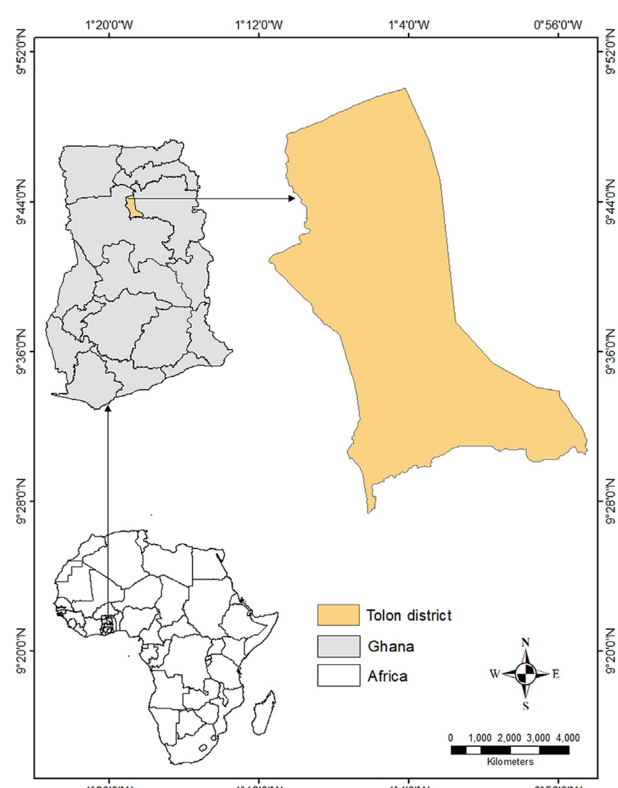

Figure 1. Map showing the Tolon district.

undergraduate students were employed and trained for the data collection which took place between January–March, 2019 and covered the 2018/2019 farming season. Farmer participation in the interviews was voluntary. Informed consent was obtained from each respondent, and the purpose of the research was clearly explained to the participants who offered information to the enumerators on their own volition. The interviews were done in the local dialect of the respondents because majority of them could not read or write.

2.3. Conceptual framework and data estimation approach

This research is based on the random utility theory, which states that a soybean farmer will embrace soybean production technology if the benefits outweigh the negatives. There is no adoption or dis-adoption when a soybean farmer perceives that soybean production technology offer less or no benefits. Hence, adoption of soybean inoculants and chemical fertilizer technologies occurs if and only if a farmer's utility for such production technologies is high. There are several methods available for estimating the determinants of farmers' decisions to adopt improved agricultural technologies. When adoption is measured as a dummy variable (yes or no), binary logit/probit model is preferred for the estimation (Wooldridge, 2012). In a situation where the dependent variable is a count variable, the Poisson regression model is appropriate (Terza, 1998; Miranda, 2004). Since a soybean farmer can adopt inoculants and chemical fertilizer individually or jointly, using the logit/probit model, Poisson regression, or ordered probit/logit model will result in biased estimates. As a result, the multinomial logit model was utilized in this research since it can handle both individual and combined inoculant and chemical fertilizer adoption decisions. The multinomial logit model can fit categorical dependent variables when there is no natural ordering of the outcome variables (Long and Freese, 2014). Following the works of Greene (2000), the utility function can be expressed as:

$$U_{ik} = G_i \sigma_k + \tau_{ik} \tag{1}$$

where U denotes the latent variable (adoption) with K alternatives; $K = 1, 2, 3\ldots\ldots k$, available to a farmer. G_i denotes socioeconomics factors expected to influence adoption, σ_k represents coefficients to be estimated, and τ_{ik} is the error term. A soybean farmer decides to adopt K-alternatives (soybean production technologies) such that $U_{ik} \geq U_{im}$ for $k \,/\!= m$. Based on the utility theory, the multinomial logit model for a soybean farmer's decision to adopt an individual technology or jointly adopt inoculant and chemical fertilizer technologies can be presented as:

$$Prob.\left(Y_k = \frac{e^{\beta_k' X_k'}}{\sum_{k=1}^{k} e^{\beta_k' X_k'}}\right), K = 1, 2\ldots\ldots\ldots\ldots k \tag{2}$$

The theoretical model can be translated into an empirical model as:

$$Adoption(A) = \beta_0 + \sum_{i=1}^{11} \beta_i X_i + \varepsilon_i \tag{3}$$

where A denotes adoption, X represents socioeconomic factors (see Table 2), β denotes unknown coefficients, and ε_i is the error term.

2.4. Typology of modeling agricultural technologies adoption decision

As previously mentioned, improved technology adoption is categorical. As a result, a farmer can use a variety of production technology combinations to boost soybean yields. A soybean farmer, for example, can choose to use inoculant and chemical fertilizer separately or combine the technologies in production. The possible adoption combinations of the inoculant and chemical fertilizer technologies is presented in Table 1. Each combination is a binary decision and zero (0) denotes non-adoption; one (1) stands for the adoption of inoculant only, two (2) stands for the adoption of inorganic fertilizer only, while three (3) stands for joint adoption.

Table 1. The typology of soybean technologies adopted by farmers.

Decision to adopt	Binary choice	Inoculant (I)		Chemical fertilizer (F)	
		I_1	I_0	F_1	F_0
0	I_0F_0		√		√
1	I_1F_0	√			√
2	I_0F_1		√	√	
3	I_1F_1	√		√	

Source: Field Data, 2019.

2.5. Variable description and expected signs

Table 2 lists the variables and their meanings, as well as a priori expectations and literature references. Most of the variables are hypothesized to increase adoption in line with economic/utility theory. Increased market distance, on the other hand, raises the cost of adoption, lowering the chance of adoption. Producers with larger farms may be more innovative and technology adopters. However, the cost of adoption may be too high for certain farmers with large acreages, resulting in decreased adoption.

3. Results

3.1. Farmer socioeconomic characteristics

Table 3 shows the findings of the farmer's attributes. The soybean growers are on average 38 years old which means that they are in their productive ages for farming. About 62% of the soybean farmers are men, indicating that soybean farming in the area is dominated by men. The result could be attributed to men having more access to production resources like land and credit, and higher participation in training programmes compared to females. With regards to access to production credit, about 20% of the soybean farmers had access to credit for soybean production. The soybean farmers travelled an average of 2.92 km to the

Table 2. Description of the variables.

Variable	Definition	Sign	Selected cases of literature
Age	Farmer's age in years	+/-	Beshir et al. (2012); Miheretu and Yimer (2017).
Sex	Dummy: 1 if male; otherwise	+/-	Yirga et al. (2015); Issahaku and Abdulai (2020);
Education	Years of formal education	+	Šūmane et al. (2018)
Farm size	Farm size in hectares	+/-	Kuwornu et al. (2017), Abdul-Hanan (2016)
Herd size	Number of cattle owned	+	Kahenge et al. (2020); Gebre et al. (2021)
Capital	Value of farm capital in Ghana cedi	+	Gebeyehu (2016)
Market distance	Distance to market in kilometers	-	Iticha (2020)
Credit	Dummy: 1 for credit users; 0 otherwise	+	Mohammed et al. (2018); Dagunga et al. (2021)
Off-farm work	Dummy: 1 for off-farm work; 0 otherwise	+	Wassihun et al. (2020)
Extension visits	Number of extension visits	+	Anang (2019); Ahmed and Anang (2019); Kahenge et al. (2020)
Farmer group membership	Dummy: 1 for group member; 0 otherwise	+	Danso-Abbeam et al. (2017)

Source: Field Data, 2019.

Table 3. Farmer characteristics.

Variable	Mean	Std. Dev.	Minimum	Maximum
Age	38.13	10.63	20	75
Sex	0.620	0.487	0	1
Herd size	3.540	5.160	0	30
Distance to market	2.916	1.386	0.81	4.83
Credit	0.200	0.401	0	1
Off-farm work	0.300	0.459	0	1
Extension visits	1.085	1.124	0	4
Farmer association	0.345	0.477	0	1
Years of education	1.100	2.930	0	12
Capital	68.23	45.88	10	320
Farm size (hectares)	0.638	0.324	0.40	2.43

Source: Field Data, 2019.

nearest market implying that the study communities are close to markets, which can assist farmers in obtaining production inputs such as improved soybean seeds, fertilizers, and weedicides/herbicides to boost soybean productivity. The study found that about 30% of the sampled soybean cultivators engaged in off-farm work. Off-farm income generation activities aid producers to absorb seasonal shocks in production. Agricultural extension services are essential for boosting technological uptake. Soybean producers had on average a single extension visit for the entire cropping season which is inadequate and could have an adverse effect on technology adoption.

Furthermore, around 35% of soybean growers belonged to a farmer group. Farmer group membership provides various benefits, including access to labour, information sharing about soybean production, access to production credit and farm inputs, and participation in agricultural capacity-building programmes. Farmers may be encouraged to use high-yielding soybean farming systems as a result of these factors. The average years of education was 1.1, meaning that soybean farmers who had formal education, only attained the minimum level of primary school education. The average farm capital of a soybean farmer was valued at GHS 68.23 while the average land size allocated to soybean cultivation was 0.638 ha. Farm capital was estimated as the market value of farm assets namely hoes, cutlasses, oxen ploughs, and knapsack sprayers.

3.2. Adoption status and soybean yield differentials

The goal of research scientists who develop and disseminate modern production technology to farmers is to increase agricultural productivity and hence reduce food insecurity and poverty. Table 4 presents the adoption status and yield differentials of the respondents. The study revealed that about 21% of the soybean farmers adopted none of the production technologies. Failure of such farmers to adopt the soybean production technologies could be due to several factors which are beyond the scope of this study. About 24.5% of the soybean farmers adopted soybean inoculants only while about 36% adopted chemical fertilizer only. The low adoption of inoculant technology could be attributed to the complicated management requirements and conditions for using the technology, and the fact that most of the farmers are illiterates (Asodina et al., 2021). This could lead to low yield of soybean at the farmer level since many farmers lack the technical ability to meet the technical and procedural requirements to utilize the technology. In terms of joint adoption, about 18.5% of the farmers adopted both soybean inoculants and chemical fertilizer to enhance soybean productivity. The majority of soybean farmers used inorganic fertilizer, which could be attributed to deteriorating soil fertility. To enhance productivity, farmers need to improve the soil mineral content with chemical fertilizer application.

Table 4. Adoption status of farmers and soybean yield differentials.

Adoption status	Frequency	Percent	Mean yield (kg/ha)	Standard deviation
Non-adoption	42	21.0	1509.3	650.9
Adopt inoculant only	49	24.5	1472.3	555.2
Adopt fertilizer only	72	36.0	1789.1	779.5
Adopt both fertilizer and inoculant	37	18.5	1811.7	701.8
Total	200	100.0	-	-

Source: Field Data, 2019.

The soybean yield (productivity) was also calculated for each category of inoculant and chemical fertilizer users (See Table 4). The study revealed that non-adopters achieved a mean soybean yield of 1509.3 kg/Ha, representing 1.509 Mt/Ha. Farmers who adopted only soybean inoculant had a mean yield of 1472.3 kg/Ha (1.472 Mt/Ha) while those who adopted only chemical fertilizer recorded a mean yield of 1789.1 kg/Ha (1.789 Mt/Ha). Joint adopters had a mean soybean yield of 1811.7 kg/Ha representing 1.812 Mt/Ha. Generally, the adoption of soybean inoculant and chemical fertilizer led to higher soybean productivity. Chemical fertilizer and inoculants may be complementary inputs because soybean productivity is higher for joint adoption. As a result, soybean farmers who use inoculants and chemical fertilizers at the same time may be able to boost soybean yields, reducing food insecurity and increasing farm income. However, the average soybean yield is still below the national potential yield of the crop which is 3.0 Mt/Ha (MoFA, 2019).

3.3. Determinants of adoption: multinomial logit model estimates

The goal of the study was to determine the socioeconomic factors influencing soybean farmers' adoption of inoculant and inorganic fertilizer technologies individually and jointly. Table 5 depicts the results of the multinomial logit regression model.

Turning to the socioeconomic drivers of adoption, age was found to positively correlate with chemical fertilizer adoption at 10% significance level. This shows that as soybean producers get older, they are more likely to use chemical fertilizers. However, age did not influence inoculant adoption or joint adoption of inoculants and chemical fertilizer.

The study demonstrated that sex had a positive relationship with adoption of inoculant technology and an inverse relationship with joint adoption of inoculants and chemical fertilizer at 5% and 10% levels, respectively. The intuition from this result is that female soybean producers have a higher likelihood to jointly adopt inoculants and chemical fertilizer compare to their male counterparts. Male farmers, on the other

Table 5. Multinomial logit estimates of the determinants of adoption.

Variable	Inoculant only (I_1F_0)		Fertilizer only (I_0F_1)		Both inputs (I_1F_1)	
	Marg. Eff.	S.E.	Marg. Eff.	S.E.	Marg. Eff.	S.E.
Age	-0.145	0.117	0.238*	0.132	0.050	0.101
Sex	0.150**	0.072	-0.119	0.083	-0.112*	0.066
Education	-0.010	0.011	0.012	0.012	-0.007	0.009
Farm size	-0.334***	0.090	-0.024	0.089	0.230***	0.061
Farm capital	0.002	0.056	0.166***	0.063	0.003	0.049
Herd size	-0.008	0.007	0.007	0.007	0.012**	0.005
Access to credit	0.052	0.074	0.091	0.087	0.048	0.060
Off-farm work	-0.135**	0.065	0.073	0.071	-0.003	0.050
Extension visits	0.029	0.029	-0.022	0.032	0.042*	0.024
Farmer association	0.202***	0.057	-0.101	0.074	0.043	0.052
Market distance	0.041*	0.023	0.046*	0.025	-0.107***	0.025

***, ** and * signify significance at 1%, 5%, and 10% respectively. Base group: non-adoption. Source: Field Data, 2019.

hand, have a higher probability to adopt inoculant technology, which is still a relatively new technology among the farmers.

Furthermore, farm size was inversely related to adoption of inoculants at 1% significance level. The result implies that soybean producers with smaller farms had a higher likelihood to adopt inoculants. However, farm size was positively associated with joint adoption of inoculants and chemical fertilizer at 1% significance level.

Farm capital demonstrated a positive and significant relationship with chemical fertilizer adoption at 1% level. The result means that soybean producers endowed with farm capital have a higher likelihood to use chemical fertilizer. The results further revealed that at 5% level, herd size was significantly related to the adoption of inoculants and inorganic fertilizer together. Farmers with larger herds are more likely to use inoculants and inorganic fertilizer in tandem to boost soybean yield. Off-farm work had an inverse relationship with the adoption of inoculant technology at 5% significance level. Thus, farmers without engagement in off-farm work are more likely to adopt inoculant technology which does not meet the study's *a priori* expectation.

The results further portrayed a positive relationship between access to extension service and joint adoption (at 10%), meaning that access to agricultural extension services increases farmers' likelihood to adopt soybean production technologies. At a 1% significance level, farmer group participation demonstrated a positive relationship with inoculant technology adoption. This indicates that members of farmer associations have a high probability to adopt soybean production technologies. Market distance demonstrated a direct association with producers' choice to adopt soybean production technologies. The study found that, at a 1% significance level, market distance influenced the combined adoption of chemical fertilizer and inoculant technology adversely, but, unexpectedly, positively influenced the adoption of both inoculant technology and chemical fertilizer.

4. Discussions

4.1. Farmer characteristics

Soybean production in the study area was undertaken by an active, young farming population, which may facilitate the introduction of technological innovations to enhance productivity. The relatively youthful age group may be relied upon to transfer technologies to young and able farmers. The high involvement of male farmers in the cultivation of soybean reflects land ownership patterns and access to resources in most rural areas of Ghana and other developing countries. Policies to promote women's access to production resources in developing countries are needed to ensure equity in resource accessibility and utilization at the household level (Fonjong, 2008; Norton et al., 2021; Lawless et al., 2021). A major constraint to smallholder farming is access to credit. Farmers in most developing countries do not have access to production credit and hence are unable to acquire critically needed inputs to expand production and improve upon their level of productivity (Ololade and Olagunju, 2013; Owusu, 2017). Farmers' inability to access credit is a major drawback to adoption of productivity-enhancing technologies such as inoculants and chemical fertilizer. This is supported by Nordjo and Adjasi (2020). Farmers' engagement in off-farm work is reflective of the urge to diversify income sources in the face of risks and uncertainties associated with rain-fed agriculture. About 30% of the respondents took part in off-farm work to supplement income from the farm. Farmers were constrained in their farm capital endowment, which could hinder productivity at the farm level. Farmers also had limited access to agricultural extension services, with an average of one visit for the cropping season. This is insufficient to permit effective knowledge and technology transfer to farmers. This is further compounded by the low level of education of the respondents, which is likely to slow down uptake of innovations. The respondents were typically smallholders and operated crop lands averaging less than one hectare.

4.2. Adoption status and soybean yield differentials

Soybean production is relatively new in Ghana and most developing countries and its contribution to food security, incomes, and jobs creation cannot be overlooked. Soybean cultivation helps to achieve food security and poverty reduction, which has increased its appeal among stakeholders and farmers in Sub-Saharan Africa, including Ghana (Asodina et al., 2021). To enhance soybean output and productivity, there are several yield-enhancing innovations including inoculant and chemical fertilizer technologies developed and disseminated to soybean farmers (Chianu et al., 2009; Asodina et al., 2021). Farmers face a number of challenges that make it difficult for them to adopt soybean yield-enhancing technologies that are needed to increase output. Lack of knowledge and awareness of inoculant technology is one of the reasons for its low level of adoption compared to chemical fertilizers (Alori and Babalola, 2018), which could explain why inoculants have a smaller impact on soybean yields. Inoculants are biofertilizers that require certain minimum conditions to be effective. For example, inoculants must be stored at low temperatures (Pathak and Kumar, 2016), whereas in northern Ghana temperatures are generally high and may exceed 30 degrees Celsius during the cropping season. Improper management and high temperatures could affect the efficacy of the bio-fertilizer thus reducing its impact on crop yields (Raimi et al., 2021; Fasusi et al., 2021; Mahmud et al., 2021). As a result, soybean farmers will benefit from capacity-building programmes that teach them how to handle inoculants for increased productivity.

Inoculant technology and chemical fertilizer are expected to complement each other in the production of soybean in the savanna ecological zone of Ghana where soil fertility is low. While inoculants add atmospheric nitrogen to the soils, phosphorus fertilizers add much-needed phosphorus to enrich the soils in the ecological zone, which is necessary to enhance the yield of soybean. The significance of inoculant and chemical fertilizer technologies for improving soil fertility and farm production buttresses calls for policymakers to design environmentally-friendly technologies for farmers to adopt in order to increase the yield of soybean and other major food crops.

4.3. Socioeconomic drivers of individual and joint adoption

Age is a key determinant of technology adoption in the extant literature (Anang 2018; Danso-Abbeam et al., 2017). Farmers are likely to become more aware about productivity-enhancing technologies as they get older. However, the effect of age on adoption usually depends on farmers' experience with the technology as well as other factors. Hence, in the extant literature, age has exhibited conflicting effects on technology adoption. The result of this study suggests that older farmers have higher adoption of chemical fertilizer, albeit age did not affect inoculant technology adoption and joint adoption of the soil fertility management practices. Older farmers in this study may have a better understanding of the technology, and possibly higher income, to support chemical fertilizer adoption.

Gender differences in access to production resources are also crucial in the adoption decisions of smallholder farmers. The existing literature is replete with studies indicating that men are more likely to adopt technology as a result of unequal access to and ownership of production resources within the home, which favors men in most developing nations (Anang, 2019; Tesfaye et al., 2016). Contrary to this assertion, the study found female producers to have higher joint adoption of inoculants and chemical fertilizer than their male counterparts (Issahaku and Abdulai, 2020). The study, however, pointed out that male farmers had higher adoption of inoculant technology compared to female farmers. Inoculant technology is relatively new to smallholder farmers in the study area and the result could imply that male farmers are more likely to readily adopt new technologies than female farmers.

It has also been shown that the farm capital level of the household plays a critical role in production decisions. The finding of this study revealed that farm capital had a positive effect on the adoption of chemical fertilizers. This corroborates the finding of Gebeyehu (2016) in Ethiopia. Households with low level of farm assets (in terms of market value) are expected to face more production constraints since farm capital combines with other inputs to facilitate production.

The study further revealed that farm size had an inverse relationship with the adoption of soybean inoculants, implying that farmers with smaller farm area are more likely to adopt inoculant technology compare to their counterparts with larger acreages. As farm size increases, the cost of adopting inoculants may become prohibitive thus decreasing adoption. The negative effect of farm size on inoculant adoption is consistent with Gebeyehu (2016). Farm size however positively correlated with joint adoption of inoculant technology and chemical fertilizer in sync with the findings of Kuwornu et al. (2017).

Herd size (as well as capital stock) is a proxy for wealth status and plays an important role in the adoption decisions of farm households (Anang, 2019). Wealthier households are expected to have higher adoption of agricultural technologies such as inoculant-based technology and chemical fertilizer. As shown by this study, joint adoption of inoculant technology and chemical fertilizer increased with herd size. The positive effect of herd size on technology adoption is in line with the findings of other authors (Anang, 2019; Tesfaye et al., 2016).

Agricultural extension agents are often the source of production information for farmers. Extension agents' advice and services to farmers aid in the technical and capacity-building of producers, as well as providing support to farmers, which tends to encourage agricultural technology adoption. This study found that having access to agricultural extension services promotes the joint adoption of soybean inoculants and chemical fertilizer. This is in line with the study's expectation which is also in consonance with the findings of Anang (2019), Ahmed and Anang (2019), and Kahenge et al. (2020). To enhance rural farmers' access to technology and adoption of innovations, there is the need to improve the rural agricultural extension service delivery system.

The extant literature indicates that farmer-based organizations are essential institutions for farmer-learning and dissemination of information and services, and facilitates access to extension service and farm credit (Stockbridge et al., 2003; Chang, 2012). Farmer associations promote technology adoption of their members through training and extension services delivered through these groups. Consequently, technology adoption has increased with group membership according to several findings that support the result of this study. However, other studies have reported an inverse relationship between belonging to a farmer group and technology adoption (Anang et al., 2020; Ahmed and Anang, 2019). This has been attributed to factors such as excessive politicization of some groups and failure to abide by the groups' core mandates.

Smallholder farm households usually engage in off-farm work as an income diversification strategy to supplement income from farming. Participation in off-farm work is expected to increase farm households' ability to finance the acquisition of farm inputs, including inoculants and chemical fertilizers (Anriquez and Daidone 2010; Maertens 2009). However, for very poor households, on-farm investments may not increase and may probably decrease because the emphasis is usually on survival. In other words, the quest to meet essential household needs may be prioritized above on-farm investment decisions, leading to lower adoption. This assertion aligns with the result of this study; inoculant adoption decreased with off-farm employment. Thus, income from off-farm employment may be too little to finance on-farm investments or may be diverted to meet household food needs instead of acquiring farm inputs. This is typically the case with very poor households for whom survival is prioritized above other decisions.

In line with other studies, distance to market had a negative relationship with joint adoption decision. The inverse relationship between technology adoption and market distance is plausible (Ayenew et al., 2020) since the longer the distance to the local market, the higher the transaction cost thus reducing the ability of farmers to acquire and use a particular technology. Market access, as indicated by proximity to a market, influences technology adoption and has been found to have a negative association with adoption (Iticha, 2020). Uncharacteristically, however, inoculant technology adoption and chemical fertilizer adoption increased with market distance, albeit only at 10% level.

5. Conclusions and policy implications

Agriculture and improved technology adoption will continue to shape and enhance socioeconomic development in the rural areas of Ghana. Agriculture creates jobs for rural folks through the adoption of high-yielding technologies to increase farm productivity, reduce extreme hunger and poverty, and improve the living standards of rural farmers and other value chain actors. The study's main aim was to assess the socioeconomic factors affecting soybean farmers' adoption of inoculant and chemical fertilizer in Ghana, using Tolon district as a case study. Using a multinomial logit model, the study found that herd size, farm size and access to agricultural extension service exerted positive and significant effects on joint adoption of inoculant and chemical fertilizer. Gender of the farmer and market distance on the other hand exerted negative and significant effects on joint adoption. The study, therefore, concludes that soybean farmers have a higher probability to adopt improved soybean production technologies if they have larger farm and herd sizes, and have access to extension services. Also, age and farm capital endowment are critical to chemical fertilizer adoption decision among soybean producers, while gender and farmer group membership are important to inoculant technology adoption.

There are several policy implications from the findings of this study. Farmer associations are critical to technology adoption as evidenced by farmers' inoculant adoption decision in this study. Farmers should therefore be encouraged to join groups to enhance their knowledge and adoption of modern technologies. Also, access to agricultural extension service enhances farmers' ability to access and utilize production information. It helps farmers to embrace improved soybean production technologies regardless of their low level of formal education. It is there prudent for stakeholders to intensify agricultural services to soybean farmers through capacity building programmes, workshops and field visits to empower them to adopt modern soybean production technologies. Long distance to markets to purchase farm inputs leads to poor market access and lowers the adoption rate of modern production technologies. To increase soybean technology adoption, soybean value chain operators must bring input and output markets within reach of rural communities.

Declarations

Author contribution statement

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

Abraham Zakariah: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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