



**Credit constraints in adopting rhizobial inoculation
technology among smallholder soybean farmers in
northern Ghana**

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Tiivistelmä – Referat – Abstract <p>Lack of finance is a major constraint for the smallholder soybean farmers in northern Ghana. The area is affected by soil degradation, poverty, and food insecurity, while a majority of the people in the area get their livelihood from agriculture.</p> <p>As a possible solution for the three problems, a natural biofertilizer and biocontrol agent, rhizobium bacteria, can be introduced to the rhizospheres of the soybean. This is usually done by applying rhizobium bacteria to the seeds of a legume prior to planting. This rhizobial inoculation technology improves plant growth, nutrient availability and uptake, as well as yields, thereby increasing the income and food security of the smallholder farmers. A credit to be invested in rhizobium inoculation technology would provide smallholder farmers with the opportunity to improve soil fertility and increase farm productivity, improving their food security and enabling them to earn additional income. The private market for rhizobial inoculants is nascent, but many of the farmers report financial constraints. To create a functioning market and to realise the social and environmental benefits of soybean cultivation and rhizobium inoculation technology, it is important to understand the causes of credit constraints of smallholder farmers and how to reduce them.</p> <p>In this thesis, I study the prevalence and the determinants of credit constraints among smallholder soybean farmers by applying a logistic regression model to a sample of 133 smallholder farmers in northern Ghana. I first define credit constrained status of the farmers and conclude that the prevalence of observable credit constraints in the sample is 57.1%. I conclude that there are two broad categories of variables affecting a farmer's status as credit constrained. The first of these is the type of guarantees that a farmer can offer to the lender. Such guarantees are represented by membership in a farmers' association (and hence access to possible joint guarantees), existing assets such as ownership of cows, and a farmer's experience in soybean production (reflecting knowledge of good investment decisions in the sector). The second category relates to the supply of credit and the factors affecting it. The factors affecting credit supply identified in this study are regional disparities and loans targeted to a certain group, such as women.</p> <p>By influencing the supply and conditions of credit, the financial constraints of smallholder farmers can be alleviated. Such policy interventions, combined with other leverage points such as social learning and access to information, contribute to the adoption of desirable farming practices. Because of the many benefits of rhizobial inoculation in soybean production, its adoption could be promoted by offering credit directed particularly for the adoption of this technology. This would benefit not only the farmers but have broader benefits in the form of climate change adaptation and mitigation.</p>			
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<p>Taloudelliset rajoitteet ovat suuri este pohjoisghanalaisten soijapavun pienviljelijöiden tuotantoa rajoittava tekijä. Suuri osa alueen asukkaista on riippuvaisia maataloudesta ja alue kärsii köyhyydestä, maaperän köyhtymisestä ja ruokaturvan puutteesta.</p> <p>Mahdollisena ratkaisuna näihin kolmeen ongelmaan soijapavun juurakoihin voidaan lisätä Rhizobium-juurinysträbakteereja, jotka toimivat luonnollisena biolannoitteena ja biologisena torjunta-aineena. Tämä soijan kylvösiementen ympääminen Rhizobium-juurinysträbakteereilla parantaa kasvien kasvua, ravinteiden saatavuutta, satoa ja siten viljelijöiden tuloja. Rhizobium-biolannoitteeseen investoitava luotto tarjoaisi pienviljelijöille mahdollisuuden parantaa maaperän hedelmällisyyttä sekä nostaa tilan tuottavuutta, parantaen heidän ruokaturvaansa ja mahdollistaen lisätulojen karttumisen. Rhizobium-biolannoitteiden markkinat ovat kehitymässä alueella, mutta monet potentiaalisista ostajista eli soijapavun pienviljelijöistä raportoivat taloudellisten rajoitteiden olevan pääasiallinen este heidän tuotannolleen. Toimivien markkinoiden luomiseksi sekä soijapavun viljelyn ja Rhizobium-biolannoitteen yhteiskunnallisten ja ympäristöllisten hyötyjen realisoimiseksi on tärkeää ymmärtää, mistä pienviljelijöiden luottorajoitteet johtuvat ja kuinka niitä voisi vähentää.</p> <p>Tässä maisterintutkielmassa tutkin luottorajoitteiden yleisyyttä pohjoisghanalaisten soijapavun pienviljelijöiden keskuudessa sekä luottorajoitteisiin vaikuttavia tekijöitä soveltamalla logistista regressioanalyysiä 133 pienviljelijän otokseen. Käytetyn luottorajoitteisuuden määritelmän mukaan luottorajoitteiden esiintyvyys otoksessa on 57,1 prosenttia. Luottorajoitteisuuteen vaikuttavat muuttujat voidaan jakaa karkeasti kahteen kategoriaan. Ensimmäinen näistä on se, millaisia takuita viljelijä voi tarjota lainantantajalle. Tällaisia takuita edustavat jäsenyys viljelijäyhdistyksessä (ja sitä myötä mahdollisuus yhteistakuisiin), olemassa oleva varallisuus kuten karjan omistus, sekä viljelijän kokemus soijapavun tuotannosta (ilmentäen tuntemusta hyvistä sijoituspäätöksistä). Toinen kategoria liittyy luoton tarjontaan ja sen taustalla vaikuttaviin tekijöihin. Luottojen tarjontaan vaikuttavia tekijöitä ovat tässä tutkimuksessa todetut alueelliset erot ja tietyille ryhmälle, kuten naisille, suunnatut lainat.</p> <p>Vaikuttamalla luoton tarjontaan ja sen ehtoihin, pienviljelijöiden taloudellisia rajoitteita voidaan lieventää. Tällaiset politiikkatoimet yhdistettynä muihin vipuvaikutuksiin, kuten sosiaaliseen oppimiseen ja tiedon saatavuuteen, edesauttavat toivottujen viljelykäytänteiden käyttöönottoa. Koska rhizobiobia inokulaatiotekniikan käytöstä soijapavun tuotannossa on monia etuja, sen käyttöönottoa voitaisiin edistää tarjoamalla erityisesti tämän teknologian käyttöönottoon suunnattuja luottoja. Tämä hyödyttäisi niin pienviljelijöitä itseään kuin laajempaa yhteisöä ilmastonmuutokseen sopeutumisessa ja sen hillitsemisessä.</p>		
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Table of Contents

1	Introduction and aim.....	1
2	Literature review.....	4
2.1	Financial constraints on small-scale agriculture in Ghana.....	4
2.1.1	Terminology related to financial constraint.....	4
2.1.2	Financial constraints on the agricultural sector in Ghana.....	4
2.1.3	Determinants of financial constraints on small-scale agriculture in Ghana.....	5
2.2	Soybean farming and adoption of inoculation technology.....	9
2.3	Financing of rhizobial inoculation.....	10
3	Context of the study.....	11
3.1	PASUSI Project.....	11
3.2	Plans for scaling up the marketplace for biofertilizers.....	12
3.3	Origin of the data and studied area.....	12
4	Data and methodology.....	14
4.1	Data.....	14
4.1.1	Definition of credit constrained farmers.....	14
4.1.2	Explanatory variables.....	16
4.2	Method and model.....	17
4.2.1	Regression theory.....	17
4.2.2	Model.....	19
5	Results and discussion.....	19
6	Conclusions.....	22

References.....	24
Appendices.....	28
Annex I.....	28

1 Introduction and aim

In the world with growing population and increasing soil depletion, environmentally friendly ways of producing larger quantities of nutritional food are highly needed. A Comprehensive Food Security and Vulnerability Analysis (CFSVA) on Ghana showed that, in 2020, 11.7 percent of the population – that is, 3.6 million people – were food insecure. According to the same report, 78 percent of these people live in rural areas, the situation being the worst in the northern regions of the country (Government of Ghana, 2020).

Food insecurity in Ghana is worsened by high rates of soil depletion (Bationo et al., 2018). Adopting environmentally friendly farming practises would, however, require capital that many farmers lack access to. Lack of finance is a major constraint for the agricultural sector in Ghana (Adam, 2018), and this is especially true for the smallholder farmers (Sekyi et al., 2017), who constitute approximately 70% of the farming household population in the country (Peprah et al., 2021).

If farmers have access to credit, they can adopt new production technologies at the farm and increase their production and income. Not having access to credit, on the other hand, leads to a situation, where the farmers are not able to raise production to a level that would allow them to make savings to invest in future production. This means that they remain in a pattern of subsistence production. A credit to be invested in introducing a new production technology, such as rhizobium inoculation, would allow to break this vicious cycle (Ansah et al., 2019).

The introduction of rhizobial inoculants to legume rhizospheres and soils is an environmentally friendly and low-cost alternative for traditional inorganic fertilizers. The use of this technology has many benefits. The bacteria form a symbiosis with the roots of a legume, enabling it to convert atmospheric nitrogen into nitrogen in the soil, both for the use of the legume itself and for the use of other crops in an intercropping or rotational system (Asodina et al., 2020; Asodina et al., 2021; Khojely et al., 2018). Thus, they improve plant growth, nutrient availability and uptake, and yields. Besides this, rhizobial inoculants function as biocontrol agents against plant diseases (Kebede, 2021).

The adoption of inoculation technology is a key strategy for sustainable intensification of agriculture (Oburger et al., 2022).

A legume that benefits from rhizobium inoculation is the soybean (*Glycine max L*). As in many other Sub-Saharan countries, the soybean is largely cultivated by smallholder farmers in Ghana (Asodina et al., 2020). Cultivation of soybean has many benefits. It is a crop with high protein content and a beneficial amino acid pattern, thus improving the nutritional status of the household. The residues of soybean can be used as livestock feed, decreasing the amount of grazing land needed and further contributing to food security. Overall, soybean cultivation has a lot of potential in improving the wealth and nutritional status of farmers in Ghana and other Sub-Saharan African countries with suitable climate for production.

Despite the many benefits of soybean cultivation and rhizobial inoculation, they have not yet met their full potential in Ghana (Asodina et al., 2021; Asodina et al., 2020). The smallholder farmers of soybean and the Ghanaian agricultural sector in general face constraints leading to suboptimal use of resources and inefficiencies in productivity. A major constraint is the lack of access to credit (Adam, 2018). Hence, if the benefits of soybean cultivation and rhizobial inoculation are to be harnessed, the credit constraints of smallholder farmers need to be addressed.

When promoting sustainable intensification of agriculture in the context of smallholder farmers and local value chains, it is vital that the people concerned are being heard. When a sample of smallholder farmers in northern Ghana were asked about their main constraints of soybean production in the past year, a majority of farmers reported financial constraints as their main problem (study conducted as part of the PASUSI Project¹, see chapters 3.1, 4.1.1 and Annex I). In order to address the problem, it is important to understand who are the most affected by these constraints and why.

This study is an empirical analysis of the prevalence and determinants of credit constraints among smallholder soybean farmers in northern Ghana who are interested in adopting rhizobial inoculation technology. It builds on the learnings of other scholars regarding credit constraints of Ghanaian farmers but is applied to a concrete case of a nascent farm input market, that is, the market for rhizobial inoculants. The analysis is carried out by applying a logistic regression model to a dataset of 133 smallholder soybean farmers who are classified as either credit constrained or credit

¹ Participatory Pathways to Sustainable Intensification. Innovation platforms to integrate leguminous crops and inoculants into small-scale agriculture and local value chains (LEAP-Agri project financed by the European Union). More information at: https://knowledge4policy.ec.europa.eu/projects-activities/pasusi-participatory-pathways-sustainable-intensification-innovation-platforms_en, and at University of Helsinki Research Portal (n.d.).

unconstrained. The rest of the study is organised as follows: chapter 2 provides an overview on existing literature on financial constraints in the context of smallholder farmers in Ghana, as well as on soybean farming and rhizobial inoculation technology and its financing. Chapter 3 provides a context for the empirical part of the study. Chapter 4 presents the data, method, and model used. Chapter 5 discusses the results and lastly, chapter 6 concludes.

2 Literature review

2.1 Financial constraints on small-scale agriculture in Ghana

2.1.1 Terminology related to financial constraint

There are two related terms to financial constraints: financial inclusion and financial access. Financial inclusion can be defined as delivery of banking services at an affordable cost to disadvantaged and low-income groups. Financially excluded households are those that are denied credit and that are not given access to other financial services such as savings, insurance, payments or remittance facilities (Dev, 2006). In other words, financial inclusion is achieved if there are no price or nonprice barriers in the use of financial services, that is, when everyone has financial access.

Financial access cannot be directly observed, unlike financial use. Financial access refers to the supply of services, whereas use is determined by both demand and supply (World Bank, 2008). People with financial access are not credit constrained, in other words they are credit unconstrained, as they could get credit if they so wished. They might, however, be voluntary nonusers who self-exclude themselves from the financial market by opting not to use the services supplied (World Bank, 2008).

Credit constraints² are felt by people who have demand for credit but insufficient supply. They might apply for credit but get their applications denied, or they might be discouraged from applying due to factors such as high transaction costs or fear of refusal (Cole, 2008). These people lack access to credit and are considered credit constrained.

2.1.2 Financial constraints on the agricultural sector in Ghana

In 2021, the contribution of the agricultural sector to the GDP of Ghana was 20% (World Bank, 2022a) and the sector employed an estimated 30% of the country's labour force (World Bank, 2022b). However, with regard to financing this sector, only 1% of the formal credit of banks on the African continent is channelled into the agricultural sector (Atakli & Agbenyo, 2020). Even when accounting for the informal credit institutions, such as family and friends, produce buyers, or farmers' cooperatives (Etonihu et al., 2013), the agricultural sector remains underfinanced. The lack of finance

² The terms credit constraints and financial constraints are used interchangeably in this study.

has consequences for Ghana's economy as a whole. The people to feel it in the first place, however, are the farmers whose livelihoods are affected by financial constraints and a majority of whom are smallholder farmers (Peprah et al., 2021).

Credit constraints have important implications on productive activities and the possibility to undertake them (Atakli & Agbenyo, 2020). They limit the amount and quality of inputs used as well as the possibilities to adopt improved farming methods. This, in turn, can lead to unsustainable land and environmental management, further decreasing the future yields. Thereby, financial constraints on agriculture have a multiplier effect (Ansah et al., 2016).

Financial inclusion and financial access significantly enhance productivity (Peprah et al., 2021). This finding has been empirically confirmed in the Ghanaian smallholder farmer contexts by scholars such as Akudugu (2016), Ansah et al. (2016), and Nordjo and Adjasi (2020). According to Carter (1989), there are three ways in which access to credit can increase production:

- it allows farmers to enhance their allocative efficiency by optimizing the amount and combination of inputs purchased;
- it allows farmers to purchase new technologies or varieties which in turn enable a shift to a higher production frontier;
- it allows farmers to intensify the use of fixed inputs such as land and family labour through, for example, nutrition-productivity link and acquisition of new skills.

It is noteworthy that a credit for adopting rhizobial inoculation technology increases production through all these three channels, as will be discussed later.

2.1.3 Determinants of financial constraints on small-scale agriculture in Ghana

As agriculture is of great importance to Ghana and financial constraints a main hindrance of the sector, many scholars have studied the factors affecting financial constraints of farmers. This literature review summarizes a sample of relevant studies regarding determinants of financial constraints in Ghana or a subregion of Ghana.

Factors affecting credit constraints of Ghanaian smallholder farmers have been studied by Ansah et al. (2016), Sekyi et al. (2017), and Ankrah Twumasi et al. (2020a). Relatedly, Asiamah et al. (2021) have studied determinants of and trends in credit demand and credit constraints of households in Ghana including separate analysis for rural and urban populations. Further, determinants of smallholder farmers' access to credit have been studied by scholars such as Denkyirah et al. (2016)

and Ankrah Twumasi et al. (2020b). Most of these studies use probit models in the estimation of financial constraints, while Sekyi et al. (2017) utilize conditional mixed process model to jointly determine farmers' credit constraints, access to credit, and productivity.

As credit constraints are linked to production, these dimensions are often combined in studies. Ansah et al. (2016) studied soybean farmers who were denied production credit and whether credit constraints led to lower yield; Denkyirah et al. (2016) researched rice farmers' access to credit and constraints in rice production; Sekyi et al. (2017) jointly examined farmers' access to credit, credit constraint, and productivity. In some cases, scholars are interested in some other factor relevant to credit constraints. For Ankrah Twumasi et al. (2020b), the main focus was the effect of savings mobilization on access to credit and size of loan, and Ankrah Twumasi et al. (2020a) studied factors influencing rural youth farmers' credit constraint status and how the credit constraints affected the intensity of their participation in agriculture. Asiamah et al. (2021) studied not only farmers but the Ghanaian households in general, focusing on the determinants of both credit demand and credit constraints.

Table 1 summarizes the determinants of credit constrained status. The variables are adapted from those deemed significant on at least a 5 percent significance level by the above-mentioned studies. Based on the findings, their *a priori* expected signs are included. Below are reflections on the possible causal paths between the variables and credit constrained status.

Table 1. Determinants of credit constraints and their a priori expected sign as in related literature.

Variable	A priori sign	References
Age	+ / -	Ankrah Twumasi et al. (2020a); Asiamah et al. (2021); Sekyi et al. (2017); Denkyirah et al. (2016)
Married	-	Asiamah et al. (2021); Denkyirah et al. (2016)
Female household head	-	Asiamah et al. (2021)
Household size	+ / -	Ankrah Twumasi et al. (2020b); Asiamah et al. (2021); Sekyi et al. (2017)
Education	-	Ankrah Twumasi et al. (2020); Ankrah Twumasi et al. (2020a); Asiamah et al. (2021)
Literacy	-	Sekyi et al. (2017)
Farmer group membership	-	Ankrah Twumasi et al. (2020b); Ansah et al. (2016); Denkyirah et al. (2016); Sekyi et al. (2017)
Extension visits	-	Denkyirah et al. (2016)
Farming experience	-	Ankrah Twumasi et al. (2020b); Ansah et al. (2016)
Training in soybean production	-	Ansah et al. (2016)
Having access to farm equipment	-	Sekyi et al. (2017)
Income	-	Asiamah et al. (2021); Denkyirah et al. (2016)
Savings	-	Ankrah Twumasi et al. (2020b); Ankrah Twumasi et al. (2020a); Ansah et al. (2016)
Land ownership	-	Ankrah Twumasi et al. (2020b)
Household durable assets	-	Asiamah et al. (2021)
Record keeping on farming activities	-	Denkyirah et al. (2016)
Access to credit information	-	Ansah et al. (2016)
Complicated / costly / long credit process	+	Ankrah Twumasi et al. (2020b); Ankrah Twumasi et al. (2020a)

Age

The age of a person can affect credit constraints in many ways. Young people might have fewer dependants and fewer financial needs but also fewer records to show when applying for credit. Middle-aged people possibly have a greater need for credit as the number of dependants grow, but they also have more experience and records of farming activities. As people grow older, their credit demand for new investments but also capability to pay back the loan can be thought to decrease. For these reasons, age and age squared are often significant explanatory variables for credit constraints, but the findings vary (Asiamah et al., 2021).

Marital status, female household head, and household size

Some studies have found that married people are less likely to be credit constrained. Several factors can explain this correlation. On one hand, being married affects the social network of the credit applicant, increasing both the number of dependants but also possible guarantors. Relatedly, Asiamah et al. (2021) found a link between being widowed or divorced and being credit constrained. The reason behind this was not identified, but it is possible that discrimination against certain groups

exists in credit markets (World Bank, 2008). Sex also plays a role in the status of credit constraints. Somewhat contrary to the common expectation, Asiamah et al. (2021) found that female household heads were less likely to be credit constrained, yet the results were inconclusive for rural population. Household size affects credit demand thereby credit constraints. However, results on the sign of the correlation between household size and credit constraints have been inconclusive.

Education and literacy

People with more education are less likely to experience credit constraints. They have both greater access to credit information and greater ability to conceptualize the information and make economic decisions (see, for example, Sekyi et al., 2017). Same holds for literate versus illiterate people.

Farmer group membership and extension visits

Significantly, all the studies that included farmer group membership to their analysis found it to have a significant negative effect on credit constraints. This can be explained by many factors. Farmer groups provide their members with access to information and credit sources. What is more, the members can offer each other joint guarantees. As farmer groups, extension agents can link farmers to credit information and sources, thus helping to alleviate farmers' credit constraints (see, for example, Denkyirah et al., 2016).

Farming experience and training in soybean production

Farmers with more experience and training are less likely to be credit constrained. They have more track record to show for when applying for credit and are more likely to make viable economic decisions. Also, through experience and training, they have likely acquired knowledge on possible credit sources (see, for example, Denkyirah et al., 2016).

Having access to farm equipment and income

The negative correlation between access to farm equipment and credit constraints could be explained by reverse causality: farmers who have access to equipment have already their demand for it fulfilled, either as they own the equipment or can borrow it from a farmers' group or alike. Also, farmers with higher income are less likely to be credit constrained both as their need for credit is lower and as they from the creditors point of view are more likely to pay back.

Savings, land ownership, household durable assets, and record keeping

The negative relationship between savings or land ownership and credit constraints is understandable, as those can be used as collaterals for credit. The same holds for household assets. As financiers need to have information on performance of the businesses they finance in order to assess whether they will be able to pay back the credit, it is unsurprising that farmers who keep records of their farming activities are less likely to be credit constrained.

Complicated / costly / long credit process

Finally, if the credit application process is cumbersome, farmers are less likely to apply for and receive credit. Same is true for processes that are costly, for example in the form of transportation cost and application fees (Ankrah Twumasi et al., 2020b). Overall, the more information people in need of credit have on credit process and its terms, the less likely they are to experience credit constraints.

2.2 Soybean farming and adoption of inoculation technology

The soybean is a relative newcomer among the cultivated crops in Ghana and its cultivation is gaining popularity (Asodina et al., 2021; Khojely et al., 2018). In a country with a rising population and high rates of soil nutrient depletion, the soybean has the potential to improve households' nutritional status while improving the fertility of the soil for intercropping with other crops such as maize. Additional benefits include providing feed for livestock (Asodina et al., 2020).

Soybean yields can be increased by use of fertilizers. An environmentally friendly and low-cost alternative for traditional inorganic fertilizers is the introduction of rhizobial inoculants to legume rhizospheres and soils. Rhizobia is a family of root nodule bacteria that is able to form symbiotic association with legumes such as the soybean plant (Kebede, 2021). The rhizospheres of legumes can be artificially inoculated with these bacteria by applying them to the seeds of the legume – hence the name rhizobial inoculation technology. Rhizobial inoculation technology improves plant growth, nutrient availability and uptake, and thereby yields. It can be applied even in infertile soils (Oburger et al., 2022). The symbiosis with the legume allows the legume to fix atmospheric nitrogen to the soil thus increasing productivity of the farmland. Additionally, the rhizobial inoculants improve plant resistance against pathogenic diseases and thereby function as biocontrol agents (Kebede, 2021).

The double function of the rhizobium inoculation is important in both Ghana and other Sub-Saharan African regions where most soils are nitrogen deficient and most of the smallholder farmers cannot afford to buy traditional nitrogen fertilizers (Asodina et al., 2020; Khojely et al., 2018). Inoculation technology is both an environmentally and economically sustainable approach to addressing the problems in the agricultural production of soybeans and a solution for the intertwined problems of global food insecurity and environmental degradation (Kebede, 2021).

While rhizobium bacteria do occur naturally in the soils, many agricultural soils do not have the adequate amounts of rhizobia (Kebede, 2021). The amount of rhizobium bacteria in the soils can be increased artificially by applying purchased rhizobium inoculants to the seeds of a legume, such as soybean, prior to planting. Rhizobial inoculants can be purchased commercially, yet the markets in Ghana are still nascent. They are a cost-effective alternative or substitute to chemical fertilizers as the price of inoculants is affordable compared to chemical fertilizers (Kebede, 2021). The Northern region of Ghana suffers from soil erosion (Tesfahunegn et al., 2021), which is why the soil fertility improving capacities of rhizobium inoculation are very beneficial in the particular region.

Credit for adopting rhizobium inoculation technology is a textbook example of Carter's (1989) theory on how access to credit affects agricultural production and improves farmers' lives. It is a new technology that allows farmers to increase their legume production. It affects the amount and combination of inputs needed, replacing chemical fertilizers and improving soil quality. Used in the soybean production, it affects the nutrition-productivity of the farmer, making use of the scarce resources.

2.3 Financing of rhizobial inoculation

Financing agricultural production contains risks for the lender due to the possibility of natural disasters and crop diseases, and the fact that the seasonality of production leads to cash flows to farmers being irregular (Nordjo & Adjasi, 2020; Ankrah Twumasi et al., 2020a). For these reasons, some lenders prefer to avoid the sector. However, as rhizobium inoculation, among other things, prevents crop diseases, lending money for the cause in fact mitigates some of the risks associated with the agricultural sector.

Land degradation is both exacerbated by climate change and a driver of climate change (IPCC, 2022a). Hence, improving soil quality is both a climate change adaptation and mitigation effort. Climate-smart agriculture helps to exploit the synergies between productivity, adaptation and

mitigation (IPCC, 2022b). From a lender’s perspective, even if financing agricultural sector contains risks and even more so in an area vulnerable to climate change, there are incentives to do so. Financing soil improving activities can be considered climate finance (Streck & Gay, 2017), a field that has been growing in the past decade and the importance of which is recognised by the global financial community (Naran et al., 2022). In the global context, contributing to climate change mitigation and adaptation finance can be done, for example, through providing finance for the local institutions lending to smallholder farmers, who in turn take on the concrete activities mitigating soil carbon loss and strengthening the adaptive capacity of their farms and communities.

3 Context of the study

3.1 PASUSI Project

The data used in the master’s thesis is part of a larger research project funded by a joint Europe Africa Research and Innovation (R&I) initiative related to Food and Nutrition Security and Sustainable Agriculture (LEAP-Agri). The PASUSI³ Project took place between September 2018 and September 2022 with aim of “[i]mprov[ing] productivity, livelihoods, nutrition and household wellbeing in Ghana and Uganda, while counteracting environmental degradation and mineral depletion caused by monocultures” (Anonymous, 2017). Some of its objectives included:

- Improving cropping systems of leguminous crops such as soybean (*Glycine max*);
- Enabling the use of nitrogen-fixing rhizobia for legumes such as soybean;
- Analysing the opportunities and obstacles in the rural community for a shift towards better agricultural practices and introduction of legumes. (Anonymous, 2017; for publicly available information, see University of Helsinki Research Portal, n.d.)

The scope of my thesis falls well within this framework.

³ Participatory Pathways to Sustainable Intensification. Innovation platforms to integrate leguminous crops and inoculants into small-scale agriculture and local value chains (LEAP-Agri project financed by the European Union). More information at: https://knowledge4policy.ec.europa.eu/projects-activities/pasusi-participatory-pathways-sustainable-intensification-innovation-platforms_en

As part of the project, a baseline study was conducted on scaling-up of the benefits of rhizobium inoculants technology among smallholder farmers in northern Ghana. The data used in this thesis come from this baseline study. I was not involved in the data collection nor in the research project itself.

3.2 Plans for scaling up the marketplace for biofertilizers

Farmers usually receive inoculants through purchase. During the PASUSI project, farmers first received inoculants for free and the subsequent batches were purchased.⁴

Currently, there are FNSSA⁵ initiatives in place for scaling up and reaching the marketplace for the biofertilizers (Rhizobium Inoculants). The initiatives include upgrading an existing inoculant production laboratory, training actors in the grain legume value chains on the use of legume-rhizobium inoculation technology, and developing effective marketing channels for inoculant distribution and adoption among the actors in the value chain (e.g., geo-referencing of agro-inputs dealers).⁶ However, it will not be possible to create a functioning market for inoculation technology unless there are consumers of rhizobium inoculants who are able to pay for the product, either directly or with credit. To ascertain broad adoption of the technology, it is imperative to study the existing credit constraints of the farmers and the subgroups most affected by these constraints.

3.3 Origin of the data and studied area

The data used for in this thesis was collected by Benjamin Tetteh Anang (University of Development Studies, Tamale, Ghana) and Mawuli Yevu (CSIR-Savanna Agricultural Research Institute, Tamale, Ghana) in 2019. It contains a sample of 251 smallholder soybean farmers who were surveyed regarding their soybean production. The data was collected through interviews in local dialect and a questionnaire. The questionnaire included questions concerning farmers' socioeconomic characteristics, farmland, farm operations and management, inputs and soybean yield, farm and other

⁴ Personal communication Edwin K. Akley to John Sumelius, April 12, 2021.

⁵ Partnership on Food and Nutrition Security and Sustainable Agriculture (FNSSA) as part of the AU-EU High Level Policy Dialogue on Science Technology and Innovation. More information at: https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/europe-world/international-cooperation/eu-africa-cooperation/partnership-food-and-nutrition-security-and-sustainable-agriculture-fnssa_en

⁶ Personal communication Edwin K. Akley to John Sumelius, April 12, 2021.

assets, knowledge on inoculant use and benefits, membership in organisations or associations, as well as questions on division of tasks and decision-making by gender. Also, the questionnaire included questions on credit taken to farm in the past year and on the constraints encountered in soybean production during that year.

The sampled farmers were based in five regions of northern Ghana (Northern, North East, Savannah,⁷ Upper East and Upper West regions). A map of the area is presented in figure 1. This area is covered by Sudan Savannah agroecological zone in the north and Guinea Savannah elsewhere (Martey & Kuwornu, 2021). These are the areas of Ghana that are the most severely affected by erosion (Tesfahunegn et al., 2021) and the most exposed to climate risks (Adzawla & Baumüller, 2021). They are also the regions with the highest prevalence of poverty and food insecurity (Adu et al., 2018; Cooke et al., 2016). A majority of the people in the area get their livelihood from agriculture (Adzawla & Baumüller, 2021; Martey & Kuwornu, 2021). The combination of these factors makes the people in the region both physically and economically vulnerable to the effects of climate change.

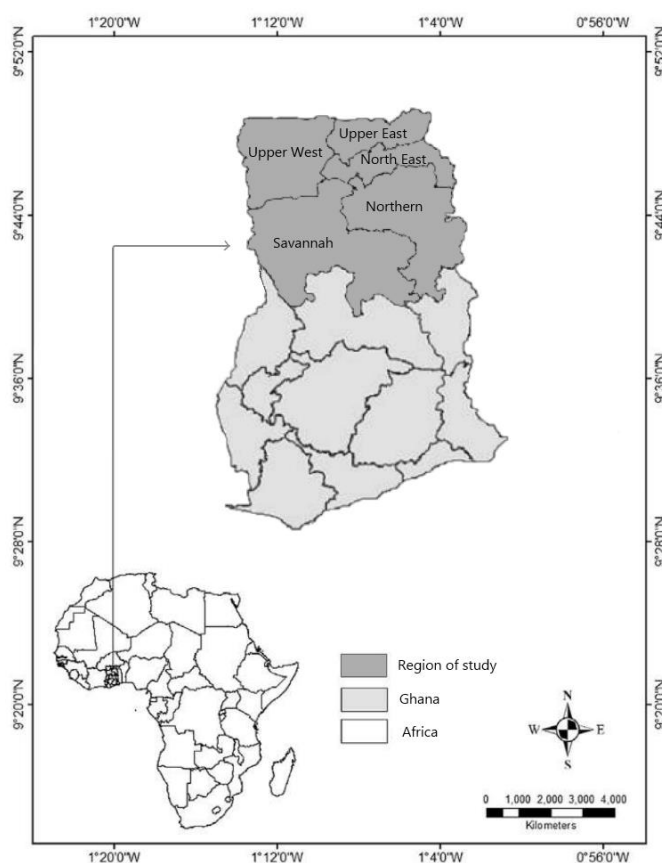


Figure 1. Map of the study area. Adapted from Anang and Zakariah (2022).

⁷ Sometimes, Northern, North East and Savannah regions are collectively referred to as Northern region.

The poor soil quality, poverty, and dependence on agriculture are intertwined problems, whereby also the solutions are interlinked. Farmers' access to rhizobium inoculation technology, the affordable biofertilizer that improves soil quality and boosts production, would be one important factor for the development of the region.

4 Data and methodology

4.1 Data

4.1.1 Definition of credit constrained farmers

The data used for this study does not directly reveal whether a smallholder soybean farmer is financially constrained or not. Therefore, information on credit constraints were elicited based on the information given.

The dataset contains information on whether a farmer took credit for the farm in the past year; most of the credit was used for purchasing farm inputs, including inoculants. However, as there is no information on whether a farmer applied for credit, it is possible that the group of non-credit takers contains both credit unconstrained farmers (non-borrowers) and credit constrained farmers (denied borrowers or discouraged borrowers). The non-borrowers did not apply for credit as they did not need it. The denied borrowers are those who applied for credit but whose credit applications were denied. The discouraged borrowers are those who did not apply for credit even when they would have needed it as they were discouraged from applying due to factors such as high transaction costs or perceived high probability of refusal (Cole, 2008).

To correct for the selection bias caused by not knowing the application status of the farmers, the information on receiving credit is combined with information on the main constraints of soybean production as stated by the farmers themselves. The farmers were asked to rank a list of problems that impacted their soybean production in the past year from least to most serious. Table A1 in Annex I presents the list of problems and their frequency of being considered the main problem. Almost 40% of the farmers ranked their main problem as financial constraints.

I use a similar definition of credit constraints to that of Ankrah Twumasi et al. (2020a). I make two assumptions:

- **Assumption 1:** All the farmers in the sample who had not received any cash or in-kind credit and who had ranked financial constraints as their main constraint are considered credit constrained.
- **Assumption 2:** All the farmers in the sample who had received some amount of cash or in-kind credit and who had not ranked financial constraints as their main constraint are considered as credit unconstrained.

Figure 1 gives a visual representation of these definitions, as presented by Ankrah Twumasi et al. (2020a).

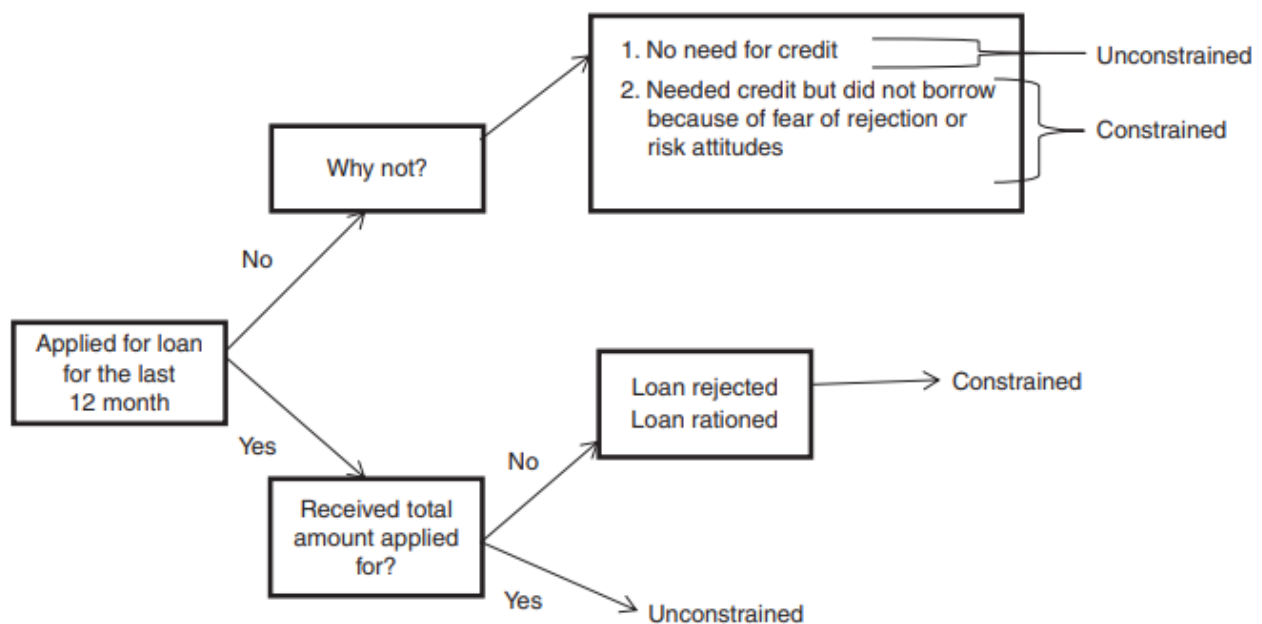


Figure 2. Definitions of being credit constrained and credit unconstrained as in Ankrah Twumasi et al. (2020a). In the absence of data on credit applications, assumptions on credit needs are made based on whether credit was received or not, and the self-rated severeness of financial constraints for farmers' soybean production.

This definition of being credit constrained or credit unconstrained leaves out individuals who considered financial constraints their main challenge in soybean production but who did receive some amount of credit (cash or in-kind).⁸ This definition also excludes those individuals who perhaps had

⁸ Based on the rated severeness of financial constraints, it could be assumed that the credit received was insufficient (that is, less than what had been applied for).

applied for credit and whose applications were refused but who did not see financial constraints as their main problem. These farmers might in reality experience credit constraints but those were exceeded by more acute problems, such as pests. These categories of farmers were left out of the final sample in order to avoid ambiguity. Leaving out individuals who belong to these categories, the sample size is narrowed from 251 to 133 farmers, 57 of whom are considered credit unconstrained and 76 credit constrained. Thereby, the prevalence of credit constraints in the sample is 57.1%.

4.1.2 Explanatory variables

The likelihood of a person being credit constrained is not randomly assigned but depends on several characteristics of both the borrower and the lender. Some of these characteristics are revealed, but many of them not. The credit constrained and unconstrained farmers are not homogenous with respect to these characteristics. However, as discussed in section 2.2., some groups of people have been found to be more likely to be credit constrained than others. In the absence of information on the lender and on the institutional aspects of credit, such as interest rate available, the chosen model only includes socioeconomic and technical variables of the borrower.

Table 2. Description of variables.

Variables	Description	Categories
Dependent variable:		
credit constrained	Dummy variable. Indicates whether the respondent is categorized as credit constrained or not.	1 = Yes, 0 = No
Explanatory variables:		
age	Age of the respondent.	
female	Dummy variable capturing the sex of the respondent.	1 = female, 0 = male
married	Dummy variable capturing whether the person is married.	1 = Yes, 0 = No
hh size	Total household size.	
educ yrs	Years of formal education.	
f association	Dummy variable. Indicates whether the respondent is member in a farmers' association.	1 = Yes, 0 = No
soya exper	Number of years in soybean production.	
cows	Dummy variable. Indicates whether the respondent owns at least one cow, calf or heifer.	1 = Yes, 0 = No
Upper East	Dummy variable. Indicates, whether the respondent is based in the region Upper East.	1 = Yes, 0 = No. Base category: North East, Savanna or Upper West
Northern	Dummy variable. Indicates, whether the respondent is based in the region Northern.	1 = Yes, 0 = No. Base category: North East, Savanna or Upper West

Taking into consideration the findings of the studies discussed in chapter 2.1, data availability, and correlations in the dataset at hand, the variables presented in table 2 are included in the regression model. Table 3 provides summary statistics of the sample.

Table 3. Summary statistics of the sample (n = 133).

Variable	Mean	Std. Dev.	Min	Max
credit constrained	0.571	0.497	0	1
age	41.541	11.95	20	75
female	0.466	0.501	0	1
married	0.857	0.351	0	1
hh size	9.647	3.895	3	24
educ yrs	3.489	5.371	0	17
f association	0.609	0.490	0	1
soya exper	6.293	4.610	1	26
cows	0.218	0.414	0	1
Upper East	0.293	0.457	0	1
Northern	0.429	0.497	0	1

4.2 Method and model

4.2.1 Regression theory

Being credit constrained is a discrete variable: a farmer either is credit constrained or is not. As the variable can only take values 0 and 1, using an OLS estimator would not give fitting estimators. This is why a binary response model needs to be used; the model will predict the probability of a farmer being credit constrained (Wooldridge, 2013). The probability function

$$P(y = 1 | \mathbf{x}) = G(\beta_0 + \beta_1 x_1 + \dots + \beta_k x_k) = G(\beta_0 + \mathbf{x}\boldsymbol{\beta}) = G(z) \quad (1)$$

will be defined in such a way that it takes values strictly between zero and one: $0 < G(z) < 1$. The two most applied binary models and nonlinear functions $G(z)$ are (as defined by Wooldridge (2013)):

- The **probit model**, where the probability function $G(z)$ is a standard normal cumulative distribution function

$$G(z) = \Phi(z) \equiv \int_{-\infty}^z \varphi(v) dv, \quad (2)$$

and where $\varphi(z)$ is the standard normal density

$$\varphi(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}. \quad (3)$$

- The **logit model**, where the probability function $G(z)$ is a logistic function

$$G(z) = \frac{e^z}{1+e^z} = \frac{1}{1+e^{-z}}, \quad (4)$$

that is,

$$P(y = 1 | \mathbf{x}) = \frac{1}{1+e^{-(\beta_0 + \mathbf{x}\boldsymbol{\beta})}}. \quad (5)$$

For the purpose of interpreting the results, the logits can be converted into probabilities by defining

$$\text{logit}(P) = \log\left(\frac{P}{1-P}\right), \quad (6)$$

where $\left(\frac{P}{1-P}\right)$ is the "odds ratio", that is, the probability of an event (here being credit constrained) occurring divided by the probability of the event not occurring. By substituting (5) into (6), we get

$$\text{logit}(P) = \beta_0 + \beta_1 X_1 + \dots + \beta_k x_k. \quad (7)$$

Here, the β_n can be interpreted as the effect of the variable x_n on the log odds of $P(Y)$ (Trueck & Rachev, 2009).

A comparison of the predictions by a probit and a logit model reveals that the logit model is more accurate in predicting negative outcomes correctly for the given data (the specificity⁹ of logit model being 77.19% compared to 75.44% of the probit model, while the sensitivity¹⁰ of both models is 88.16%). Hence, a logistic model is chosen over the probit model.

⁹ Percentage of correctly predicted negative outcomes

¹⁰ Percentage of correctly predicted positive outcomes

4.2.2 Model

Based on what has been discussed in chapters 4.1 and 4.2.1, the following logistic regression model is adopted:

$$\begin{aligned} \text{logit}(P(\text{credit_constrained} = 1)) = & \beta_0 + \beta_1 \text{age} + \beta_2 \text{female} + \beta_3 \text{married} + \\ & \beta_4 \text{hh_size} + \beta_5 \text{educ_yrs} + \beta_6 \text{f_association} + \beta_7 \text{soya_exper} + \\ & \beta_8 \text{cows} + \beta_9 \text{Upper_East} + \beta_{10} \text{Northern} + \varepsilon . \end{aligned} \quad (8)$$

The variables *age*, *female*, *married*, *hh_size* and *educ_yrs* capture socioeconomic characteristics of a farmer. *F_association* and *soya_exper* represent whether a farmer is member in a farmers' group and the experience they have in soybean production. The variable *cows* is a proxy for assets, and the variables *Upper_East* and *Northern* are dummy-variables capturing a farmer's region of residence.¹¹

5 Results and discussion

As shown in Table 4, the factors affecting a farmer's status as credit constrained on a statistically significant level are a farmer's gender, membership in a farmers' association, experience in soybean production, cattle ownership, and region of residence. Besides the regional dummy variable *Northern*, all these variables decrease the likelihood of credit constraints, which is aligned with the *a priori* expectations as discussed in chapter 2.1.3. Table 4 includes both the coefficients and the odds ratios; the coefficients describe the marginal effect of a given variable on the probability of credit constraints, and the odds ratios (defined by equation (8)) describe the effect of a variable on the ratio between the probabilities of the outcome occurring and not occurring (that is, the ratio between the probability of a farmer being credit constrained and the probability of a farmer not being credit constrained). Hence, an odds ratio less than one means decreasing effect and odds ratio greater than one increasing effect on the likelihood of credit constraints.

¹¹ The three other regional dummies, Upper West, North East, and Savannah, had samples too small to draw significant results. They together form the reference group.

Table 4. Logistic regression estimates for credit constraints.

Dependent variable: credit constrained	Coefficient	Odds ratio	z	p-value
age	-0.013 (0.029)	0.987 (0.029)	-0.45	0.650
female	-1.789*** (0.689)	0.167*** (0.115)	-2.60	0.009
married	-1.187 (0.931)	0.305 (0.284)	-1.27	0.203
hh size	0.005 (0.075)	1.005 (0.075)	0.07	0.947
educ yrs	-0.067 (0.065)	0.935 (0.061)	-1.03	0.302
f association	-1.534** (0.634)	0.216** (0.137)	-2.42	0.016
soya exper	-0.150** (0.070)	0.861** (0.060)	-2.15	0.032
cows	-2.782*** (0.870)	0.062*** (0.054)	-3.20	0.001
Upper East	-1.969** (0.790)	0.140** (0.110)	-2.49	0.013
Northern	2.510*** (0.845)	12.31*** (10.39)	2.97	0.003
constant	4.961** (2.217)	142.7** (316.4)	2.24	0.025

Number of obs = 133
 LR chi2(10) = 91.84
 Prob > chi2 = 0.0000
 Pseudo R2 = 0.5056

Log likelihood = -44.908412

Note: **, *** represent statistical significance at 5 and 1 percent levels, respectively.
 Standard deviations in parentheses.

According to the results, being woman reduces the odds of being credit constrained by a factor of 0.167. In percentage, this equals $(0.167 - 1) \times 100\% = 83.3\%$ reduction in the odds of being credit constrained compared to male farmers. This may partly depend on the way that being credit constrained was defined in the sample. An inspection of the original sample of 251 farmers reveals that of those farmers, who had not taken credit to the farm in the past year, fewer women than men had ranked financial constraints as their main problem (39% compared to 48%); see Table A1 in Annex I. According to Assumption 1 made in Chapter 4.1.1, only those farmers were included in the final sample. This means that the farmers who possibly experienced credit constraints as they had not received any credit but who were struggling with a more acute problem, for example pests (16.7% of women compared to 8% of men), were excluded from the sample.

The difference between the credit constrained status of men and women might be explained by the type of credit available. For example, it is possible that some loan instruments are specifically targeted for women. Unfortunately, there is no data available on whether this was the case. It is also possible that women have some other unobserved characteristics that explain the difference in the credit constraints between the genders.

Being member in a farmers' association is linked to a reduction by a factor of 0.216 (78% reduction) in the odds of being credit constrained. This is in accordance with the findings of Ankrah et al.

(2020b), Ansah et al. (2016), Denkyirah et al. (2016), and Sekyi et al. (2017). It can be explained by farmer groups' role in providing information, linking farmers to credit sources, and the possibility of joint guarantees, as discussed in Chapter 2.1.3.

The more experienced the farmers are in soybean production, the less likely they are to be credit constrained. Each additional year of experience is associated with a 14% decrease in the odds of a farmer being credit constrained. As the context of the study is credit taken in order to adopt a new technology in soybean production, here rhizobial inoculation, this is an unsurprising result. From a lenders point of view, farmers with more experience are more likely to make wise investment decisions and thus to be able to pay back the credit.

As expected, farmers with assets, here cattle, are much less likely to be credit constrained. A farmer that owns at least one calf, heifer, or cow experiences a reduction of 93% in the odds of being credit constrained compared to a farmer that does not own any cattle.

The regional differences are estimated as significant. The odds of credit constraints for farmers in the Upper East are reduced by 86% , while farmers living in the region Northern have 12.3 times the odds of being credit constrained. The North of Ghana leads the national statistics both in poverty rates and poverty depth. However, while the Upper East has made some progress in terms of poverty reduction, the progress has been marginal in the Northern region (Cooke et al., 2016; Ewusie, 2020: World Bank, 2020). These regional trends may affect the credit supply in the region, increasing the likelihood of credit constraints beyond a farmer's individual socioeconomic characteristics. This is a possible explanation for why farmers in the Northern region are more likely to be credit constrained than farmers in the Upper East or in the reference regions (Upper West, North East, and Savannah).

In conclusion, besides the farmer-specific factors that understandably decrease the likelihood of credit constraints, that is, farmers' association membership, experience in soybean production, and ownership of cattle, the remaining differences in credit constraints are likely explained by supply side factors. Thus, more emphasis should be placed on the type of credit instruments available and to the regional disparities in supply.

6 Conclusions

As Kebede (2021) mentioned, “researchers should work on eradicating farmers’ constraints in using rhizobia”. Eradicating financial constraints on purchasing rhizobium inoculants and thus enabling creation of a market for the inoculants is a key element in working towards sustainable and viable smallholder production.

In this study, I first defined credit constrained status of a sample of smallholder farmers and concluded that the prevalence of observable credit constraints in the sample is 57.1%. I identified two broad determinants of credit constraints. First, who will or will not get credit is influenced by the degree of assurance of repayment ability that a farmer can offer to the lender. This can mean providing physical guarantees, such as cattle or joint guarantees of farmer groups, or confidence that the farmer will make good investment decision with the credit (here approximated by experience in soybean farming). Secondly, access to credit is affected by the availability of credit supplied. The credit supply contains both the dimension of credit available to certain groups of people, such as women or men, and credit available in different regions, some of which may be less promising business environments for the lenders. By influencing the supply and terms and conditions of credit, the financial constraints of smallholder farmers can be alleviated, contributing to adoption of sustainable farming practices.

Because of the many benefits of rhizobial inoculation in soybean production, it would be reasonable to suggest providing credit instruments specifically for the adoption of this technology. This can be, for example, selling rhizobial inoculants on credit that is to be paid back only after harvest. As the small creditors in the region might be unable or unwilling to bear the risk associated with lending to the agricultural sector, there is a role for the broader financier community in supporting the small local financial intermediaries and inoculant providers through instruments such as financial guarantees. This is a reasonable appeal, considering the manifold climate pledges made by international financiers.

Access to finance is a leverage point for strengthening the climate change adaptation capacity of small-scale farmers in the Northern Region of Ghana, as identified by Rosengren et al. (2020). However, as Rosengren et al. (2020) point out, it is not access to finance alone that will substantially improve the adaptive capacity of a farmer or a society, but it needs to be combined with other leverage points, that is, gender equality, social learning, and access to and use of information and knowledge. Hence, although this study stresses the importance of alleviating the credit constraints of farmers, the

smallholder soybean farmers in northern Ghana will benefit from a holistic approach to the economic and environmental challenges.

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Appendices

Annex I

Table A1. *The most serious problem or constraint in soybean production faced by smallholder soybean farmers in the past year as perceived by the farmers themselves. The farmers were asked to rank a list of constraints according to their severeness to their soybean production, 1 = most serious constraint, 11 = least serious constraint. The table summarizes how often a given constraint was ranked as number one in the list of constraints.*

Number one constraint

Constraint	Total (n = 251) Frequency (%)	Women (n = 144) Frequency (%)	Men (n = 137) Frequency (%)
Financial constraints	100 (39.8%)	37 (32.4%)	63 (46.0%)
High cost of ploughing	45 (17.9%)	28 (24.6%)	17 (12.4%)
High cost/Difficulties in accessing thresher	32 (12.7%)	10 (8.8%)	22 (16.1%)
Pest and diseases	30 (12.0%)	19 (16.7%)	11 (8.0%)
Difficulty in accessing inoculant	14 (5.6%)	2 (1.8%)	12 (8.8%)
Poor soils	7 (2.8%)	4 (3.5%)	3 (2.2%)
Unavailability of improved varieties	7 (2.8%)	4 (3.5%)	3 (2.2%)
Low yields	5 (2.0%)	2 (1.8%)	3 (2.2%)
High cost of seeds	5 (2.0%)	3 (2.6%)	2 (1.5%)
Low soybean price	4 (1.6%)	2 (1.8%)	2 (1.5%)
Lack of ready market	3 (1.2%)	3 (2.6%)	0 (0%)