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Adoption of Farm Mechanization, Cropland Expansion, and Intensification in Ghana

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Abstract

This research assesses whether the recent public and private efforts to improve farmer's access to mechanical power in Ghana, have had their intended effects on the country's agricultural sector. Using panel survey data, this paper analyzes the impacts of mechanization on cropland expansion and farming system intensification in Northern Ghana. Findings show a positive correlation between farm mechanization and cropland expansion during the survey period. However, there was no evidence of increasing farm input use with the use of tractors. Indeed, findings seem to suggest an inverse relationship between mechanization and farm intensification. We conclude that tractorization is unlikely to foster farm input intensification in regions such as Northern Ghana where farmlands are still abundant.

Keywords: mechanization policy, tractor, cropland expansion, agricultural intensification, Ghana

JEL code: Q13, Q15, Q18, O3

1. Introduction

Rapidly changing agricultural landscape along with other factors have led to increased demand for mechanization among Ghanaian farmers in recent years. Agricultural mechanization; that is the use of draft power, tractor, or any other form of farm power in agriculture can reduce farm labor drudgery, maintain or increase farm production and productivity (see, for example, Obi and Chisango, 2011; Verma, 2006; Binswanger and Ruttan, 1978). Mechanization has long been of interests for many African countries where Governments had massively invested in the sector following independence. These early initiatives were grounded in the prevailing paradigms and development strategies which essentially argue in favor of more state involvement in agriculture and rural development during the post-colonial period (confer Zeller, 2011). However, efforts to mechanize agriculture in Africa were discredited by state failures as well as lack of demand for mechanization (Pingali et al., 1987).

Recently, demand for agricultural mechanization has risen in Ghana (Diao et al., 2014). In response, support for mechanization has resurfaced in the country since 2003. This support has taken the form of importation and provision of subsidized tractors to individual farmers as well as specialized centers (see, for example, Agricultural Engineering Service Directorate -AESD-, 2012; Houssou et al., 2013). Furthermore, over the past decade, a growing private market of used agricultural machines has emerged in the country (Diao et al., 2012). Consistent with this emerging private market, a survey conducted by the International Food Policy Research Institute and Savanna Agricultural Research Institute (IFPRI/SARI, 2013) in selected districts of Ghana, suggests that tractor ownership has considerably increased among medium and large-scale farmers over the past five years. These developments have considerably improved accessibility to tractors across farming communities in the country. With the increase in access to tractor power, farming households are expected to increase their use of tractors and put more land into cultivation to meet the country's growing food needs.

Ghana is relatively a land-abundant country, especially in the Northern part where tenure can essentially be qualified as open access. In such situations, increased farm power can lead to direct increases in production through increasing the land area cultivated by farmers as they can handle more area than if they were to manually prepare the land (Clarke, 2000). Because mechanized farming reduces the drudgery of farm labor and can be instrumental in expanding cultivation into areas where there is significant amount of unutilized arable lands, such as Northern Ghana, it is regarded as a positive development (World Bank, 2012). Using panel data from three districts of Northern Ghana, this paper assesses the extent to which improved access to tractors has led to cropland expansion, fertilizer, and labor input intensification among farming households in the country. From the theoretical and policy perspective, this research fits into the current debate on the proper path to agricultural mechanization in Ghana and aims to provide useful lessons for countries in Africa South of the Sahara engaged in a peer learning process with Ghana as an example.

2. Research Questions and Hypotheses

The main goal of this paper is to evaluate the impact of the recent public and private efforts to mechanize agriculture in Ghana. Specifically, this paper assesses whether farm mechanization has led to cropland expansion and intensified use of inputs among farmers in the Northern region of the country. The research seeks to answer the following key questions:

a) *Has farm mechanization led to cropland expansion, intensified use of fertilizer and hired labor among tractor users?*
b) *What is the scale of farmers' response to mechanization in terms of cropland expansion, fertilizer, and labor use?*

Based on the above research questions, we test the following hypotheses:

1. *Farm mechanization, measured by the area plowed has had a positive impact on the area cultivated. Thus, farmers have responded to increased tractor availability by increasing their croplands.*
2. *Farm mechanization, measured by the area plowed has had a positive impact on fertilizer and hired labor use. Thus, farmers have responded to increased tractor availability by increasing their input use and use intensity.*

This remainder of the paper is organized as follows. Section 3 presents the conceptual framework. Section 4 discusses agricultural mechanization within the Ghanaian context, whereas, Section 5 describes some key features of the survey districts. Section 6 presents the data and methodology, whereas Section 7 discusses the results. Section 8 offers our concluding remarks.

3. Conceptual Framework

We used the analytical framework in Figure 1 to assess the impacts of agricultural mechanization on cropland expansion and farm input intensification in Northern Ghana. The framework essentially suggests that agricultural policies (and economic policies in general) aim at inducing changes in market, prices, infrastructures, or setting out an economic environment that in turn affects farmer's objectives and constraints. Furthermore, this framework assumes that a farmer's behavior can rationally be explained by the objectives he/she pursues and the constraints faced in pursuit of these objectives. For example, a farmer may pursue income maximization, food security, or seek to fulfil his social obligations, but he/she may be constrained by available farmlands, capital, labor, technologies, and markets.

Figure 1 here

Farmer behavior can be expressed by how he allocates productive resources (labor, land, capital) to various farm and non-farm activities, the land area he chooses to cultivate or plow/till (by a handhoe, a tractor, or draft animals), the quantity of inputs he purchases, the quantity of produces he sells on the market, among others. This behavior may in turn lead to changes in the mix of crops, types and quantity of labor, seed, fertilizer, chemicals used, and the type and scale of farm power used (hand hoe, draft animals, or tractor) which will determine his cropland expansion and intensification patterns. This behavior may also result in a given income level which will determine his welfare. With regard to the constraints a farmer may face, if for example, lack of capital to acquire a tractor is the major constraint to the adoption of mechanical technologies, the government may design a micro-credit program to improve farmer access to credit. Once this constraint is lifted, it is likely that farmers will acquire/adopt tractor use and increase their production or productivity. Agricultural mechanization is driven by various factors, understanding the ways through which these factors interact requires a comprehensive framework. Given the chain of impacts that may result from mechanization, this paper adopts a holistic approach to assess the impacts of mechanization on key farming systems components, such as croplands, fertilizer, and labor.

4. Agricultural Mechanization: The Ghanaian context

Recently, policymakers' interest in mechanization has reemerged in Ghana due to a combination of factors, including the desire to reduce labor drudgery and tedium associated with agriculture, growing urban population and food demand, improving smallholder farmers' access to mechanization services, attracting the youth into agriculture, and triggering private sector investment into mechanization, among others. Currently, Ghana hosts 13.6 million hectares of agricultural lands of which 59% (8 million hectares) are suitable for mechanization (AESD, 2012). As of 2007, only 20% (1.6 million hectares) of these lands have been mechanized in the country.

Under Ghana's agricultural modernization policy, decision makers aim to mechanize 4 million hectares of lands by 2015 (i.e. 50% of land suitable for mechanization). The Agricultural Engineering Service Directorate indicates that the country will need about 16,667 tractors by 2015 to meet its mechanization target (AESD, 2012). In line with this target, the Government of Ghana (GoG) has since 2007 been providing subsidized agricultural machineries to individual farmers and state-supported private enterprises established as Agricultural Mechanization Services Enterprise Centers - AMSECs[1]. Most of the tractors imported by GoG went to the Northern regions where there is a huge potential for converting more lands into cultivation.

While GoG has been importing and distributing agricultural machines to farmers, a private market has developed in parallel with considerable importation of used tractors (Diao et al., 2014). As of July 2012, Customs, Excise and Preventive Service (CEPS) data indicate that the total tractor population has increased to about 7,500 units in the country. Consistent with this pattern, a survey conducted by IFPRI/SARI in selected districts in 2013 shows that tractor ownership has increased substantially among farmers in the past five years. However, most farmers do not own tractors but depend on tractor hire services. IFPRI/SARI survey (2013) indicates that about 80% of the tractor owners provide mechanization services to other farmers. Nearly 80% of the total areas plowed by tractor owners comes from service provision (IFPRI/SARI survey, 2013).

[1] See AESD (2012) for further details on the mechanization policy.

5. Agriculture in the Study Area

The survey area lies in the Guinea Savannah agro-ecological zone in the Northern region of Ghana. This region is house to 20 of the 170 districts of the country. The survey districts include Savalegu-Nanton, West Mamprusi, and Tamale, the capital city of Northern Ghana. With the exception of drought years, the Northern region receives above normal and uni-modal rainfall averaging 1,100mm a year (Statistics, Research, and Information Directorate -SRID-, 2013a), which along with other factors determine the volume of agricultural production in the region.

Northern Ghana is mostly agrarian. The 2010 population and housing census data indicate that 70% of the population in the region are rural and 73% of the economically active population (over 15 year of age) are engaged in agriculture, forestry, and fishing. District level data on major cereal production shows an increasing pattern between 2005 and 2012 with a few exceptions (Figure 2). Both the area cultivated and cereal production in the districts have declined in 2007 and 2011, a pattern that is consistent with the regional production.

Figure 2 here

With regard to agricultural mechanization, a census of tractor owners by United States Agency for International Development (USAID)/Agricultural Development and Value Enhancement (ADVANCE) in 2013 shows that Savalegu-Nanton hosts 108 serviceable tractors, whereas Tamale is home to more than 191 serviceable tractors. A study by Nakamura (2013) indicates that West Mamprusi houses 58 tractors. However, these numbers may not reflect the district levels of mechanization. Tractor owners are very mobile across districts during the farming seasons. Indeed, during our field interviews in 2013, farmers indicated that tractor owners travel from Tamale to Savalegu-Nanton which is just 15-minute drive to render plowing services during the farming season. More to this, IFPRI/SARI survey (2013) suggests that owners migrate from districts in the South, such as Ejura to provide plowing services to farmers in the three Northern regions. Given the demarcation of farming seasons between the North and the South of the country, these owners stay in the North for 60 days before returning home (IFPRI/SARI survey, 2013).

Land tenure is essentially characterized by open access in Northern Ghana, a condition under which the majority of the population have sufficient access to lands (see, for example, Braimoh, 2009). Compared to the South where population growth and rapid urbanization exert a considerable pressure on available lands, the Northern region still hosts large tracts of farmlands with relatively easy access. Therefore, the conditions seem to be met to observe the full impact of mechanization on cropland expansion in the study area.

6. Data and Methodology

6.1. Data

This paper uses data from a three-year household-level panel survey of 936 farming households in Northern Ghana, Tamale municipality, West Mamprusi, and Savelugu-Nanton. The survey was implemented by Innovations for Poverty Action (IPA) in the three districts between 2010 and 2012 (Figure 3). The initial sample of surveyed households was drawn from the Ghana Living Standards Survey 5 Plus (GLSS5+) survey data, a survey conducted between April and September 2008 by the Institute of Statistical, Social and Economic Research (ISSER) at the University of Ghana – Legon in collaboration with the Ghana Statistical Service. The GLSS5+ is a clustered representative random sample with households randomly chosen based on a census of selected enumeration areas in the 23 Millennium Development Authority (MiDA) districts. From the GLSS5+ sample frame, IPA selected communities to undertake a survey “Examining Underinvestment in Agriculture (EUI)” in three districts, Tamale municipality, West Mamprusi, and Savelugu-Nanton.

Attrition is not very high in this survey with only 152 households (about 13%) of the initially sampled households not being re-interviewed in the subsequent survey years. 1,088 households were interviewed in the first wave in 2010 of which 1,041 were re-interviewed in 2011 and 936 were re-interviewed in 2012.

Figure 3 here

6.2. Methodology

6.2.1. Farm Mechanization and Cropland Expansion

To examine the impact of mechanization on cropland expansion, we estimated CRE models using the panel data. Alternative estimation methods which could be used include Pooled Ordinary Least

Square (POLS) with fixed or ordinary random effects. However, compared with CRE models, these methods may produce inefficient and biased results. With the fixed effect approach, the model can be specified as follows:

$$y_{it} = \alpha_i + X_{it}\beta + \mu_{it}\,, \tag{1}$$

where α_i captures all the household unobserved, time-constant factors that affect cropland expansion (y_{it}). The underlying assumption of the fixed effects specification is that the explanatory variables (X_{it}) and unobserved heterogeneity (α_i) are correlated. However, if the unobserved heterogeneity is uncorrelated with any of the explanatory variables in all time periods, then estimating equation (1) using fixed effect is inefficient. An alternative is to estimate a random effect model which allows the inclusion of time-constant variables as follows:

$$y_{it} = \beta_0 + X_{it}\beta + \varepsilon_{it}, \text{where } \ \varepsilon_{it} = \alpha_i + \mu_{it} \tag{2}$$

However, this specification still assumes that the fixed effect factor is uncorrelated with the explanatory variables, which may not be the case. To overcome the shortcomings of both fixed and random effects estimators, we used the correlated random effects (CRE) or the Mundlak-Chamberlain device proposed by Mundlak (1978) and Chamberlain (1984), where we included time average variables for all time variant explanatory variables in our estimation. With a CRE model, the household unobserved time constant factors, α_i are modelled as follows:

$$\alpha_i = \delta + \varphi\bar{X}_i + \varsigma_i, \quad \varsigma_i \mid X_i \sim N(0, \sigma_\varsigma^2)\,, \tag{3}$$

where $\bar{X}_i$ represents the time-averaged X_{it} over the various panel periods. This model allows controlling for unobserved time-constant heterogeneity as with fixed effects as well as measuring the effects of time-invariant independent variables as with random effects models specified in equations 1 and 2 respectively. In general, the CRE model unifies both the fixed and random effects estimation approaches. The drawbacks of the CRE estimator are that we have to impose somewhat strong assumptions, such as a strict exogeneity conditional on α_i and a standard normal distribution on the estimated model.

6.2.2. Farm Mechanization, Fertilizer and Labor Use and Use Intensity

The main dependent variables in the fertilizer use and use intensity models are whether the household uses fertilizer or not (one if the household uses fertilizer, and zero otherwise) and the quantity of fertilizer use measured in kilogram per hectare, with the number of hectares plowed as an independent variable. However, major econometric issues arise when modelling the impact of mechanization on fertilizer use intensity. The quantity of fertilizer used by farmers in our survey has a highly positive skewed distribution. Only 23 percent of the households did not use fertilizer, the distribution of the quantity of fertilizer exhibits a large number of cases lumped as zero with the remaining observations being greater than zero. Since the decision to use fertilizer produces a zero value for the quantity of fertilizer, we modelled this as a corner solution and not a censored observation. The rationale for a corner solution model is that a value of zero fertilizer used is a valid economic choice to be explained, not an indication of missing data.

Therefore, in estimating the impact of mechanization on fertilizer use and use intensity, we followed Burke (2012) recommendation to fit the Cragg's double-hurdle model to gain efficiency due to the corner solution associated with fertilizer use intensity. The Cragg's double-hurdle model (Cragg, 1971) is a bivariate generalization of the Tobit model, but unlike Tobit, allows both the decisions about whether to use fertilizer or not and the quantity of fertilizer to use to be determined by different processes. The double-hurdle model is designed to analyze instances of an event that may or may not occur, and if it occurs, takes on continuous positive values. In the case of fertilizer use, we assume that a decision to use fertilizer or not comes first, followed by the decision on what quantity of fertilizer to use. The structure of our double-hurdle model is as follows:

$$FertU_{it}^* = \gamma X_{1t} + e_i \qquad e_i \sim N(0, \sigma^2), \qquad (4)$$

where $FertU_i = 1$ if $FertU_i^* > 0$, otherwise $FertU_i = 0$.

$$FertQ_{it}^* = \beta X_{2t} + u_i \qquad u_i \sim N(0, \sigma^2), \qquad (5)$$

where $FertQ_i = FertQ_i^*$ if $FertQ_i^* > 0$ and $FertU_i = 1$, otherwise $FertQ_i = 0$.

The subscript *it* refers to the *i*th farmer during period t, $FertU_{it}$ is the observable discrete decision to use fertilizer or not, while $FertU_{it}^{*}$ is the latent (unobservable) variable of $FertU_{it}$. $FertQ_{i}^{*}$ is an unobserved, latent variable of the quantity of fertilizer used, while $FertQ_i$ is the observed quantity of fertilizer used. X_1 and X_2 are vectors of explanatory variables assumed to be exogenous in the fertilizer use and use intensity equations and γ and β are parameters to be estimated under the conditional independence of the latent variable distribution. Thus, conditional on X, there is no correlation between the disturbances from the fertilizer use (e_i) and use intensity (u_i) equations.

We also estimated the impacts of mechanization on labor use (which takes the value one if the household uses hired labor, and zero otherwise) and use intensity (measured by the number of hours hired labor is used per hectare) using a logistic regression and a CRE model as described earlier. Following the conceptual framework presented in Section 3, the set of covariates used in the models seek to capture farming households' characteristics and their input use, while controlling for district and time effects in the panel. These covariates broadly consider exogenous variables that have been shown to influence or impact on mechanization, cropland expansion, and intensification (see, for example, Braimoh, 2009; Cunguara and Darhofer, 2011; Chapoto and Ragasa, 2013).

6.2.3. Endogeneity Issues

Endogeneity with the choice variables such as area plowed by a tractor remains an issue in our paper. Given the mix of input use and allocation decision, it is reasonable to believe that some of the variables in the models might potentially be endogenous. In the absence of valid instruments, it was not possible to estimate models with instrumental variables or check the robustness of the model results. Therefore, our results should be interpreted with this caveat in mind as presence of endogeneity would weaken the conclusions of the paper.

7. Results and Discussion

7.1. Selected Patterns of Mechanization among Farmers in the Survey Districts

Table 1 shows how the characteristics of tractor users compare with draft animal users and nonusers in the pooled sample[2]. The broad term mechanization refers to both animal and tractor-based farm power, whilst tractorization refers to tractor plowing.

Table 1 here

Farm power use rate is high in the sample with about 95% of the farming households using either tractor or draft animals for plowing. With respect to the source of power used, a breakdown by type shows that 79% of the households used tractor only for plowing, 10% used both tractor and draft power, and 7% used draft animals only. Overall, tractor is by far the main farm power use in the sample (88%). Draft animal use amounts to 16% overall.

Tractor use in the survey districts is mainly through tractor hiring as tractor ownership is very low in the sample, only 1.5% of the farmers own tractors. 86 percent of the tractor users in the sample hired plowing services, indicating that there is a vibrant tractor hiring market in the districts. Cunguara and Darhofer (2011) found a similar pattern in Mozambique. These results are also consistent with findings from the 2013 IFPRI/SARI survey which indicate that in addition to plowing on own farms, every tractor owner served 100 other farmers on average during the plowing season.

Similarly, draft animal hiring rate is higher than ownership rate in the sample (11% versus 4.4%). As shown in Table 1, few farming households combine both tractor and draft power to meet their farm power needs probably because one type of power may not be suitable for their farm plots (e.g. some plots may be stony, shallow, or hilly) or just to supplement tractor power which may not be available on time.

With regard to the demographic characteristics, household heads in the sample are 45 years old and have 3 years of education on average (Table 1). Across farm power groups, there is no statistically significant difference between tractor users, draft animal users, users of both

[2] For brevity reasons, we only compare the groups using the pooled sample.

technologies, and nonusers in terms of age and education of household head. However, the survey results show that households using both farm power have one more member (8 members) compared to the other three groups, tractor users, draft users, and nonusers having 7 members. In general, female headship in the three districts is very low with only 33 households female-headed (FHH), thus 99 cases (4%) in the pooled sample. Interestingly, 94% of the FHH used either tractor, draft animals, or both farm power for plowing, suggesting an equally high access to tractor-based mechanization among FHH compared to male-headed households (MHH).

7.2. Estimation Results

Results from the econometric models are presented in the following subsections starting with the estimation of the impacts of mechanization on cropland expansion. Appendix A provides the definitions of the variables used in the models.

7.2.1. Does Mechanization Lead to Cropland Expansion?

Table 2 presents the net impacts of the independent variables on cropland expansion. Cropland expansion is strongly correlated with both area plowed with a tractor and area plowed with draft animals. A hectare increase in the area plowed by a tractor increases cropland area by 14%. Likewise, a hectare increase in the area plowed by draft animals increases cropland area by 13% on average among draft animal users. These results suggest that farm mechanization may have had has a positive impact on cropland expansion during the survey period. Thus, cropland expansion may have been driven in part by farm mechanization (i.e. plowing with tractor or draft animals) in the districts during the survey period. This result is consistent with Verma (2006), Pingali (2007), and Van der Berg et al. (2007). The fact that Northern Ghana is essentially characterized by open land access (Braimoh, 2009) and pronounced farm power bottleneck during land preparation (Diao et al., 2012) may indicate that farm mechanization has had positive benefits and no adverse equity effects (e.g. little or no tenant/labor displacements) on the farming population.

Table 2 here

Tractor ownership is weakly correlated with cropland expansion. This result may be driven by the very low tractor ownership rate in the sample (1.5%). Most tractor users rely on the tractor hiring market for plowing their farmlands. Likewise, ownership of draft animals is not correlated with cropland expansion. With regard to the demographic variables, gender and education of the household head have an influence on cropland expansion, whereas the age of household head does not have any effect in the model. Compared to their male counterparts, the area cropped by FHH declined by 24% during the survey period. Surprisingly, education (formal) in terms of years of schooling of household head exhibits a negative relationship with cropland expansion. Higher levels of household head's education seem to have resulted in less cropland expansion, but this effect is very small (minus 0.2%). Likewise, the average education level of the household heads in the sample is three years (Table 1), indicating that majority of the farmers in the three districts are not highly educated.

Landholding size had a positive and significant impact on cropland expansion. Thus, one hectare increase in landholding size increased cropland by 0.8% on average during the survey period. The cultivation of grains i.e. cereal and legume crops had a net positive and highly significant impact on cropland expansion. Cultivating cereals and legumes as main crops increased cropland by 18% and 9%, respectively compared to other crops during the survey period. The results show that cropland expansion has been in part driven by cereal and legume production, with the impact of cereal crops being twice that of legume crops.

The average distance from homestead to farm plots shows a significant and positive relationship with cropland expansion, indicating that farmers that are farm farther from the homestead have expanded their croplands more than farmers that farm closer to the homestead. Under increasing demographic pressure, land expansion is only possible farther away from communities' homesteads where unused farmlands may be available. As expected, having more fallow lands has had a negative impact on cropland expansion. One percent increase in the area fallowed reduces croplands by 25% on average. Allowing for fallow periods means reducing the land available for cultivation. The ratio of hired labor to total labor, farmland fragmentation, tenure security, and access to credit did not have any significant impact on cropland expansion during the survey period.

With regard to district-level effects, cropland expansion is significantly lower in Tamale compared to Savalegu-Nanton. These results may be explained by district-level factors that could not be individually included in the models, such as district tractor population, proximity to Tamale (regional capital), and population density. While Tamale hosts by far the highest number of tractors, rural population density is quite high in the district, implying a higher labor to land ratio (that is, less land available for farming or expansion) compared with Savalegu-Nanton. Due to its proximity to Tamale, Savalegu-Nanton benefits greatly from tractor owners who travel to provide plowing services to farmers in the district which is underprivileged in terms of tractor numbers, but has more farmlands and lower population density. There were no significant differences between Savalegu-Nanton and West-Mamprusi in terms of cropland expansion during the survey period. With regard to time effect, cropland expansion was significantly higher in 2010 and 2011 compared with 2009.

Two interaction terms were introduced in the model to assess whether there are differential impacts of mechanization on cropland expansion across the three districts. The results show that the impact of mechanization on farmland expansion is significantly higher among farmers in Tamale and significantly lower in West Mamprusi compared to Savalegu-Nanton. This result may be driven by differences in access to tractors in the districts with Tamale having the highest access, followed by Savalegu-Nanton, and West Mamprusi.

7.2.2. Does Mechanization Lead to Farm Input Intensification?

We present in this section results from the models analyzing the net effects of mechanization on intensification measured by fertilizer and hired labor use and use intensity (Tables 3 and 4). With regard to labor use, the estimates in Table 3 suggest that the higher the area plowed by a tractor, the higher the likelihood of using hired labor. However, in terms of intensity of labor use, the higher the area plowed by a tractor, the lower the quantity of hired labor per ha among hired labor users. Tractorization seems to be associated with lower intensity of hired labor use. Agricultural mechanization, especially the use of tractor for plowing is inversely correlated with labor input intensification. This finding is consistent with the inverse relationship between farm size and labor intensification.

Table 3 here

Conversely, there is no correlation between the area plowed by draft animals and hired labor use and use intensity. Similarly, ownership of tractor or draft animals did not have an effect on hired labor use in both labor models, contrasting with the expectation that farmers who own tractors are generally expected to be better endowed with productive capital which is likely to lead to high use of inputs (Binswanger, 1978). With regard to the demographic variables, the coefficients on gender of household head display a statistically significant sign in both models, while the coefficients on squared age and education of head are significant in the labor use model only. Age of household head has a non-linear relationship with hired labor use, the likelihood of using hired labor decreases beyond a certain age, but there is no relationship between age of household head and labor use intensity. Being a FHH significantly increases the likelihood of using hired labor compared with being a MHH. Likewise, being a FHH significantly increases hired labor use by about 8 hours per ha, suggesting that FHH may have less family labor available compared to MHH and, hence, resort to using more hired labor. FHH have 4 members compared to 7 members among MHH.

With regard to education, the results show that household heads who spent more time attending school are more likely to use hired labor, implying production beyond the abilities of the family labor and/ or participation to off-farm activities. This in turn may demand increased managerial skills (thus more education) on the part of the household head (Enete et al., 2005). Landholding size has no relationship with hired labor use per hectare. Farming households who produced cereals and legumes as main crops were more likely to use hired labor. Furthermore, the production of legumes increases the intensity of hired labor use. Legume crops, such as soybean, cowpea, and groundnuts are mostly produced as cash crops, hence the positive correlation between the production of these crops and hired labor use per hectare. Distance to plot, tenure security, and access to credit did not exibit any significant correlation with hired labor use and use intensity.

With regard to district-level effects, farmers in West Mamprusi were less likely to hire labor for farming operations compared to those in Savelugu-Nanton. Also, farmers in West Mamprusi hired significantly less labor per hectare compared with their counterparts in Savalegu-Nanton. As concerns the time effect, farming households were more likley to use hired labor in 2011 farming season compared with 2009. Likewise, they used three more labor-hours per hectare in 2011 compared with 2009 season. There was no significant time effect between 2010 and 2009.

With regard to the fertilizer use and use intensity models, the results in Table 4 show that the area plowed by a tractor and the area plowed by draft animals have had a significant positive impact on fertilizer use. One hectare increase in the area plowed by a tractor and draft animals increased the chance of using fertilizer by 8-6%, respectively. However, the areas mechanized by both tractor and draft animals had a negative impact on fertilizer use intensity. Mechanized land preparation (by a tractor or draft animals) seems to have led to lower fertilizer use per hectare. One hectare increase in the area plowed by a tractor and draft animals reduces the quantity of fertilizer used by 7-11 kilograms per hectare, respectively. On the other hand, tractor ownership is not correlated with fertilizer use, whereas draft animal ownership had a significant positive correlation with fertilizer use intensity.

Table 4 here

With respect to the demographic variables, age and gender of the household head have a negative relationship with fertilizer use intensity in the panel, while education has positive and statistically significant coefficients in both models. One year increase in the age of the household head reduced the quantity of fertilizer use per hectare by 1 kilogram. Likewise, being a FHH reduced fertilizer use by 15 kg per hectare on average compared with being a MHH. Younger farmers are expected to be more progressive in the use of farm inputs compared with older ones. The differential effects of gender on fertiizer use intensity may reveal differences in both financial and physical access to fertilizer inputs. The higher the educational level of the household head, the higher the likelihood of using fertilizer and the higher the quantity of fertilizer use per hectare. Educated household heads may be more capable of accessing and assimilating information regarding the use of fertilizer and other inputs. This result is consistent with Freeman and Omiti (2003) and Waithaka et al. (2007) who reported that there was a significant evidence that education positively influences the use of fertilizer among farming households. Also, according to Panin and Brummer (2000), education increases both the allocative and technical efficiency of an individual and facilitates a better information processing from different sources about the use of farm technologies.

With regard to land owned, landholding size displays a significant and negative relationship with intensity of fertilizer use. As expected, the cultivation of cereal crops has a significant positive impact on both fertilizer use and use intensity in the panel. This result may be due to the fertilizer subsidy program which is mainly earmarked for cereal production.

Surprisingly, the average distance from homestead to plots had a positive and statistically significant relationship with fertilizer use intensity. Thus, the farther away the farm plots, the higher the quantity of fertilizer use per hectare. At first one might think that this may not be plausible but this result suggests that in order to offset the costs of farming farther away from their homestead, farmers may be investing in fertilizer to ensure that they get higher outputs. The ratio of hired labor to total labor, tenure security, and access to credit are not significant in the fertilizer use and use intensity models.

With regard to district-level effects, farmers in Tamale are more likely to use fertilizer compared to those in Savalegu-Nanton. Conversely, farmers in West Mamprusi are less likely to use fertilizer, and when they do use it, they apply significantly less quantities per hectare compared with their counterparts in Savelugu-Nanton. Tamale is the administrative capital of the Northern region and, thus, farm households have better access to the fertilizer market in the district. As a result, they used significantly higher quantities of fertilizer per hectare, a conclusion that is consistent with Chapoto and Tetteh (2014). In addition, factors such as better yield response may explain the difference in fertilizer application rates between districts[3]. The coefficients on the time effect suggest that farming households were more likley to use fertlizer in 2011 and 2010 compared to 2009. This result may be explained by changes made to the Government fertilizer subsidy programs. Indeed, in 2010, the fertilizer distribution scheme was modified from a targeted (or voucher) system to a universal or waybill system which targeted all farmers in the country (Benin et al., 2012).

8. Concluding Remarks

This paper assesses the impacts of tractor plowing on cropland expansion and input use among farming households in Northern Ghana where farm mechanization is expected to produce the highest impact on agricultural production and intensification. Farm mechanization seems to have positively impacted on cropland expansion during the survey period. It is likely that mechanization

[3] Chapoto and Tetteh (2014) observed higher maize yields (1,031 kg/ha) on the mostly silty loam soils of Tamale compared to the predominantly sandy loam soils of Savalegu-Nanton and West Mamprusi (839 kg/ha and 545 kg/ha, respectively).

has contributed to increased agricultural production in Northern Ghana. Plowing with a tractor was essential for expanding croplands.

However, there was no evidence of increasing farm input use with the use of tractors. Indeed, our findings seem to suggest that there is an inverse relationship between farm mechanization and fertilizer and labor intensification. Tractor plowing is not essential for farming systems intensification in terms of fertilizer and hired labor use. It seems fair to say that tractor-based mechanization may have led to cropland expansion, but farmers did not intensify use of labor and fertilizer in the presence of large tracts of agricultural lands and subsidized fertilizer.

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Table 1. Household demographic characteristics and farm power use for plowing - Pooled panel sample

	Overall	Farm power use for plowing			
		Tractor only	Tractor & draft	Draft only	Nonusers (did not plow)
Number of observations	*2,808*	*2,205*	*273*	*187*	*143*
Farm power use rate (%)	94.9	78.5	9.7	6.7	5.1
Tractor ownership (%)	1.5	1.8	.7	.0	.0
Draft animal ownership (%)	4.4	2.8	14.3	11.8	1.4
Hiring of tractor for plowing (%)	86.8	98.2	99.3	.0	.0
Hiring of draft animals for plowing (%)	11.2	.0	68.5	67.9	.0
Age of household head (years)	44.7	44.7_a	44.0_a	46.4_a	44.0_a
Years of education, head	3.2	3.2_a	3.7_a	2.5_a	3.1_a
Female-headed households (%)	3.5	3.6	1.1	5.9	4.2
Household size	7.2	7.2_a	8.1_b	6.9_a	6.5_a

Source: Authors'estimations based on EUI Survey, Northern Ghana 2009, 2010, and 2011.
Note: MFI stands for Microfinance Institution.
Values in the same row and subtable not sharing the same subscript are significantly different at p< .05 in the two-sided test of equality for column means. Cells with no subscript are not included in the test. Tests assume equal variances.
Tests are adjusted for all pairwise comparisons within a row of each innermost subtable using the Bonferroni correction.

Table 2. Impacts of agricultural mechanization on cropland expansion

	Correlated Random Effects (CRE) Dependent variable: Log cultivated area (ha)			
	Coefficients (A)	Standard errors (B)	Coefficients (C)	Standard errors (D)
Area plowed by tractor	0.140***	0.0070	0.140***	0.0083
Area plowed by draft power (ha)	0.130***	0.0087	0.127***	0.0087
Own draft animals (=1, 0 otherwise)	0.031	0.0235	0.039*	0.0230
Own tractor (=1, 0 otherwise)	-0.045	0.0995	-0.029	0.1062
Age of household head (years)	0.003	0.0090	0.003	0.0089
Age of household head squared	-0.000	0.0001	-0.000	0.0001
Female headed households (=1, 0 otherwise)	-0.243***	0.0582	-0.238***	0.0567
Years of education of household head	-0.002**	0.0011	-0.002*	0.0011
Landholding size (ha)	0.008**	0.0030	0.008**	0.0029
Cereals reported as main crops (=1, 0 otherwise)	0.178***	0.0340	0.174***	0.0338
Legumes reported as main crops (=1, 0 otherwise)	0.094***	0.0180	0.093***	0.0173
Ratio of hired labor to total labor per ha (%)	0.065	0.0401	0.059	0.0388
Average distance from homestead to plots (km)	0.004**	0.0018	0.004**	0.0019
Land fragmentation (proportion of plots measuring less than 2 acres (%)	0.001	0.0006	0.001	0.0006
Land fallowed (% of total farmlands)	-0.248***	0.0368	-0.237***	0.0352
Tenure security (=1, 0 otherwise)	-0.008	0.0134	-0.006	0.0134
Credit from banks/MFI (=1, 0 otherwise)	0.002	0.0387	0.019	0.0358
District dummies (ref. Savelugu-Nanton)				
Tamale (=1)	-0.108***	0.0266	-0.279***	0.0481
West Mamprusi (=1)	0.017	0.0257	0.080*	0.0428
Time (ref. year=2009)				
Survey year 2010 (=1)	0.043***	0.0126	0.048***	0.0125
Survey year 2011 (=1)	0.046**	0.0152	0.047**	0.0149
Interaction terms				
Area mechanized by tractor*Tamale			0.070***	0.0139
Area mechanized by tractor* West Mamprusi			-0.020**	0.0086
Constant	-0.022	0.0930	0.006	0.0939
Observations	2804		2804	
Chi-squared	3207.629		3732.516	

Source: Authors'estimations based on EUI Survey, Northern Ghana 2009, 2010, and 2011.

Note: ref. stands for reference. MFI denotes Microfinance Institution. *** denotes significant at the 99% level. ** denotes significant at the 95% level. * denotes significant at the 90% level.

Table 3. Impact of mechanization on hired labor and use intensity

	Binary Logit		Correlated Random Effects (CRE)	
	Hired labor use		Hired labor use hours/ha	
	Coefficients (A)	Standard errors (B)	Coefficients (C)	Standard errors (D)
Area plowed by tractor (ha)	0.138***	0.025	-0.465**	0.198
Area plowed by draft animals (ha)	0.037	0.050	-0.285	0.308
Own draft animals (=1, 0 otherwise)	0.133	0.166	0.891	1.044
Own tractor (=1, 0 otherwise)	0.264	0.534	3.101	7.805
Age of household head (years)	0.028	0.019	-0.444	0.317
Age of household head squared	-0.000**	0.000	0.004	0.003
Female headed households (=1, 0 otherwise)	1.337***	0.338	7.913**	2.960
Years of education of household head	0.024**	0.009	0.110	0.072
Landholding size (ha)	0.013	0.010	-0.104	0.083
Cereals reported as main crops (=1, 0 otherwise)	0.428**	0.210	0.384	2.565
Legumes reported as main crops (=1, 0 otherwise)	0.431***	0.118	2.597**	0.897
Average distance from homestead to plots (km)	0.010	0.008	0.079	0.170
Tenure security (=1, 0 otherwise)	-0.042	0.109	0.329	1.063
Credit from banks/MFI (=1, 0 otherwise)	0.211	0.318	1.180	5.302
District dummies (ref. Savelugu-Nanton)				
Tamale (=1)	-0.266	0.172	-1.744	1.574
West Mamprusi (=1)	-0.853***	0.154	-4.855***	0.904
Time (ref. year=2009)				
Survey year 2010 (=1)	0.055	0.111	-0.831	0.836
Survey year 2011 (=1)	0.631***	0.115	2.965**	1.221
Constant	-1.245**	0.497	3.577	4.716
Observations	2808		2808	
Log likelihood.	-1749.190			
Chi-squared	167.558		153.479	

Source: Authors'estimations based on EUI Survey, Northern Ghana 2009, 2010, and 2011.

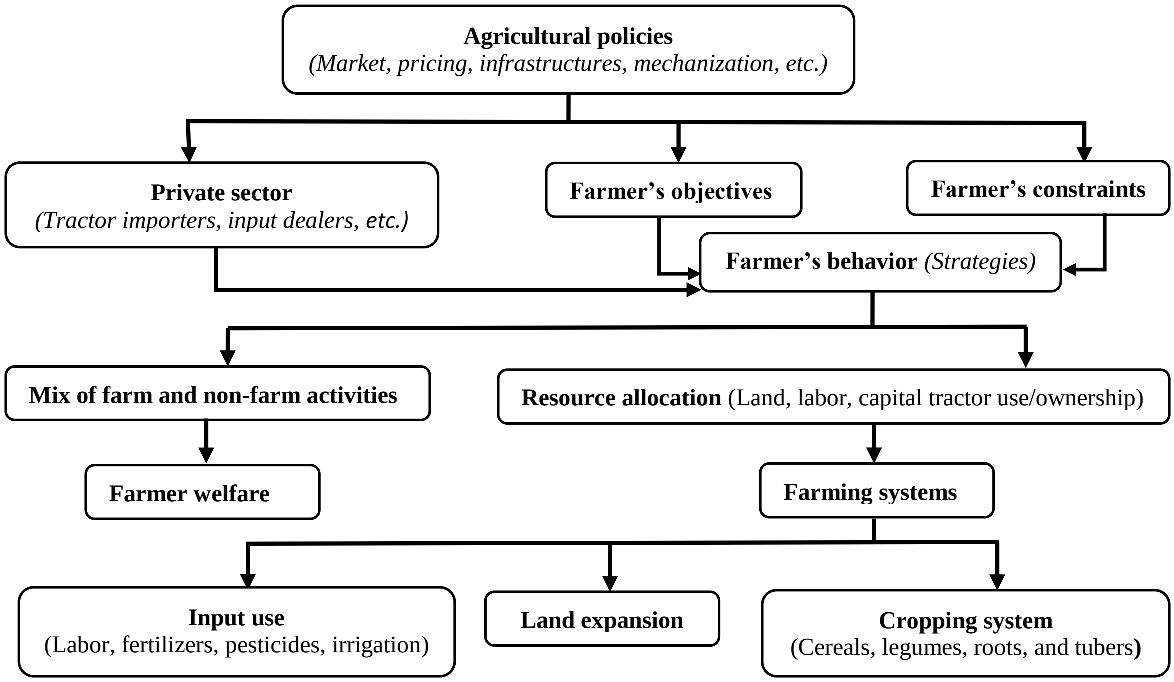
Note: ref. stands for reference. MFI denotes Microfinance Institution. *** denotes significant at the 99% level. ** denotes significant at the 95% level. * denotes significant at the 90% level.

Table 4. Impact of mechanization on fertilizer use and use intensity

	Cragg's Double Hurdle Model					
	Fertilizer use		**Fertilizer use intensity**			
	Dy/Dx	Standard errors	Log normal	Standard errors	Partial effects	Standard errors
Area plowed by tractor (ha)	0.081***	0.0244	-36.076***	7.3962	-6.573***	1.780
Area plowed by draft power (ha)	0.060*	0.0333	-52.007***	11.8816	-10.962***	2.789
Own draft animals (=1, 0 otherwise)	0.132	0.1373	41.496	28.7352	14.463**	6.999
Own tractor (=1, 0 otherwise)	0.383	0.5399	-28.389	56.4630	1.477	17.937
Age of household head (years)	-0.012	0.0206	-4.389*	2.3068	-1.373*	0.703
Age of household head squared	0.000	0.0002	0.046	0.0316	0.014	0.009
Female-headed households (=1, 0 otherwise)	-0.187	0.1655	-46.526*	24.3902	-14.549*	7.421
Years of education of household head	0.020***	0.0057	0.119	0.8710	0.537**	0.256
Landholding size (ha)	0.002	0.0070	-5.254**	1.8878	-1.216**	0.483
Cereals reported as main crops (=1, 0 otherwise)	0.696***	0.1374	79.075**	36.1763	33.081***	10.328
Ratio of hired labor to total labor per ha (%)	-0.178	0.2215	28.240	34.1114	2.188	9.393
Average distance from homestead to plots (km)	-0.004	0.0062	3.126*	1.7455	0.648	0.437
Tenure security (=1, 0 otherwise)	0.075	0.0705	-4.988	12.0504	0.753	3.234
Credit from banks/MFI (=1, 0 otherwise)	-0.054	0.2605	-21.730	27.3312	-6.292	9.469
District dummies (ref. Savelugu-Nanton)						
Tamale (=1)	0.461***	0.1074	5.089	15.6334	12.285**	4.548
West Mamprusi (=1)	-0.268**	0.0923	-39.993**	17.1995	-16.001***	5.075
Time (ref. year=2009)						
Survey year 2010 (=1)	0.273***	0.0595	15.381	11.9633	10.698***	3.304
Survey year 2011 (=1)	0.420***	0.0660	-19.207	11.8902	5.537*	2.916
Constant	-0.490	0.3307	34.097	62.1825		
Observations	2805					
Log likelihood.	-12953.325					
Chi-squared	251.368					

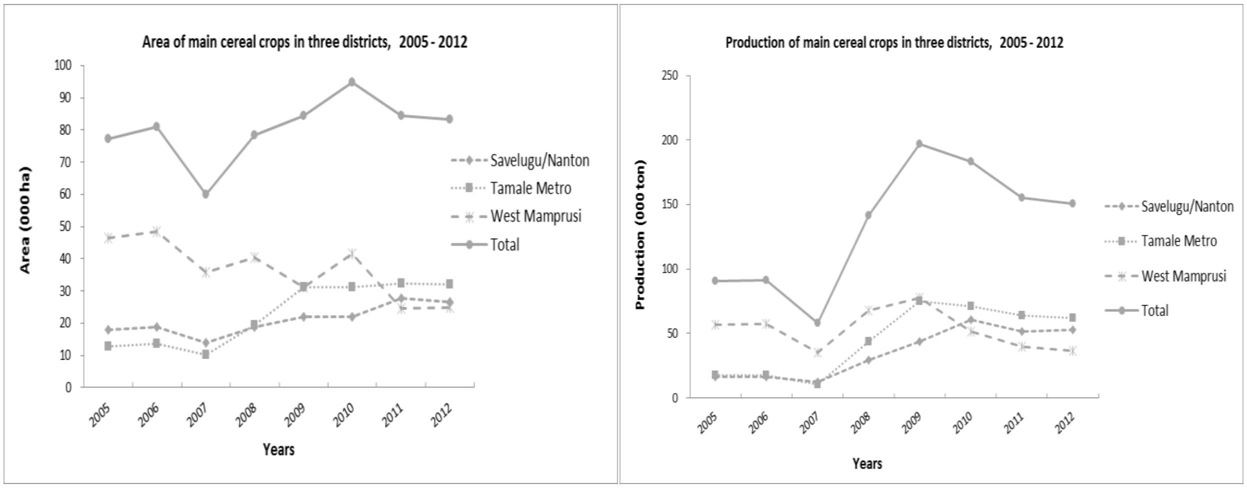
Source: Authors'estimations based on EUI Survey, Northern Ghana 2009, 2010, and 2011.
Note: ref. stands for reference. MFI denotes Microfinance Institution. *** denotes significant at the 99% level. ** denotes significant at the 95% level. * denotes significant at the 90% level.

Figure 1: Conceptual framework showing the links between tractorization, cropland expansion, and intensification.



Source: Adapted from Lariviere et al. (1998) and Reardon et al. (1999).

Figure 2. Survey districts' agricultural statistics, 2005-2012



Source: Compiled from SRID data (2013b).
Note: Achievable yields are 6 Mt/ha (maize), 6.5 Mt/ha (rice) and, 2 Mt/ha (millet and sorghum).

Figure 3. Map of Ghana showing the survey districts

Source: HarvestChoice and GADM data (2014)

Appendix A. Definitions of variables used in the models and tables

Variables	Definitions
Log of cultivated area	Logarithm of total land area cultivated to all crops (in hectares): cereals, legumes, tree crops, roots and tubers
Area plowed by tractor (ha)	Number of hectares plowed by a tractor
Area plowed by draft animals (ha)	Number of hectares plowed by a draft animals
Own draft animals (=1, 0 otherwise)	Whether the farmer owns draft animal or not
Own tractor (=1, 0 otherwise)	Whether the farmer owns a tractor or not
Age of household head (years)	How old is the household head?
Age of household head squared	Squared age of household head
Years of education of household head	Number of years household head has attended school
Female-headed households (=1, 0 otherwise)	Whether household head is female or not
Landholding size (ha)	Number of hectares of land hold by the household
Cereals reported as main crops (=1, 0 otherwise)	Whether household cultivates cereals as their main crops or not
Legumes reported as main crops (=1, 0 otherwise)	Whether household cultivates legumes as their main crops or not
Total labor used per ha (hours)	Number of hours of labor used per hectare of land cultivated
Ratio of hired labor to total labor per ha (%)	Number of hired labor hours used divided by total labor hours in percent
Inorganic fertilizer use (=1, 0 otherwise)	Whether household uses inorganic fertilizer or not
Total inorganic fertilizer used (kg/ha)	Quantity of inorganic fertilizer used in kilograms per hectare
Average distance from homestead to plots (km)	Distance from household compound to household plots in kilometer
Number of hectares fallowed	Number of hectares fallowed
Land fallowed (%)	Number of hectares fallowed divided by total land holding in percent
Land fragmentation (%)	Number of plots measuring less than 2 acres divided by the total number of household plots in percent
Tenure security (=1, 0 otherwise))	Whether household can leave its lands uncultivated indefinitely without losing its ownership right
Credit from banks/MFI (=1, 0 otherwise)	Whether household receives any credit/loans from private banks or microfinance institution

Source: Authors'estimations based on EUI Survey, Northern Ghana 2009, 2010, and 2011. Note: MFI stands for Microfinance Institution.