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Land tenure security and agricultural production in the rural areas of Burkina Faso

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The security of land tenure is a critical aspect of enhancing agricultural production in rural areas of Burkina Faso. The aim of this analysis is to examine the impact of land tenure security on agricultural production and utilize the Mixed Conditional Process method to derive estimators in a recursive equation model. Panel data from the Programme National de Gestion des Terroirs was employed spanning the cropping seasons of 2010 and 2011. The findings indicate that enhanced land tenure security leads to a higher adoption of stone cordons and improved agricultural labor efficiency, ultimately resulting in enhanced agricultural production. Additionally, promoting agricultural mechanization that reduces physical labor could be valuable. Therefore, it is recommended to extend the use of stone barriers to all plots by providing necessary financial and technical support to farmers.

Key words: Land tenure, land security, rural areas, Burkina Faso.

INTRODUCTION

Population pressure, poverty, agricultural expansion, and intensification, along with the development of infrastructure, have changed land use patterns at the global scale (Davidar et al., 2010; Bargali et al., 2019; Padalia et al., 2022).

Agricultural production is directly related to sustainable agricultural practices by rural farming communities, where farmers grow various types of crops and raise livestock in the same area with the aim of using land optimally, but this is mostly carried out conventionally (Padalia et al., 2022). The agricultural intensification system has not been implemented properly (Karki et al., 2021), for example, the use of integrated nutrient management to increase crop yields, which may be due to unawareness and financial limitations (Pandey et al., 2011). Furthermore, the level of agricultural intensification depends on the land tenure held by the farmer. However, land tenure can result in unfair land access and suboptimal land usage due to market imperfections (Pavel and Johan, 2006; Dillon and Barrett, 2017). These imperfections have an impact on agrarian reforms, which mainly favor agri-businessmen over small producers who make up most of the production (Deininger et al., 2018).

This contradicts Chayanov's theory that labor intensity is proportional to farm size. Small producers only have land use rights and not ownership of the land (Berry and Cline, 1979). It is evident that land insecurity affects approximately 70% of farmers in Sub-Saharan Africa (Delville, 2006). This is a pressing issue exacerbated by the coexistence of customary and legal regimes in the

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region (Linkow, 2013). Land tenure uncertainty poses a challenge to investing in agricultural innovations in response to climate change. As a result, land tenure affects production directly through land insecurity (Pare et al., 2008; Sanou and Tallet, 2009; Jones-Casey et al., 2015) and indirectly by limiting innovation adoption (Brasselle et al., 2002; Gebremedhin et al., 2002; Smith, 2004). Consequently, the agrarian reforms implemented in many developing countries do not enable a reduction in land insecurity (Merlet, 2002). However, most agricultural production stems from smallholders who possess only small plots (Berry and Cline, 1979). Furthermore, large land areas are possessed by others for speculative purposes, resulting in underutilization by large farms and overutilization by small ones (Berry and Cline, 1979). These forms of exploitation constrain the advancement of production. The utilization of limited plots compels farmers to resort to fundamental technologies (Hagos and Holden, 2013). Innovations necessitate substantial investment only if the return on investment exceeds the cost (Simtowe et al., 2009). Insufficient savings are feasible on smaller plots (Patel, 2009). Enhancing tenure security will enrich living standards in the agricultural sector, leading to the augmentation of other domains (Dunstan and Ousmane, 1994; De Janvry et al., 2015; Zhang et al., 2023).

In the case of difficulties in acquiring land tenure, it would be beneficial to aid small-scale producers in gaining access to resources and both formal and informal credit facilities (Ricker-Gilbert et al., 2014). Enhancing productivity requires a strategic selection of inputs, techniques, and outputs. Small family farms reap greater advantages from an augmented workforce relative to larger farms that employ labor (Graham and Darroch, 2001). As the authors argue, the ease of obtaining secure land tenure hinges on the regulatory framework in place. In Sub-Saharan African countries, access to land is primarily determined by lineage (Bernheim et al., 1985; Rochegude, 2011). Land transfers can occur through donations, loans, or sale; however, legal access remains limited and reliant on local traditions. Customary rights, exclusive use rights, and legal rights are distinguished (Bernheim et al., 1985; Rochegude, 2011), with the former two offering less security than legal rights. Sharecropping remains scarce in these countries. Additionally, a large proportion of farmers in sub-Saharan Africa only possess user rights over the land (Feder and Freeny, 1991; Rochegude, 2011).

When the environment poses risks, resources are only used at a subsistence level to fulfill familial requirements (Chandra, 2000). This author also argues that subsistence production relies heavily on family labor, which explains the limited investment in these farms. For him, the fact that farmers do not use the full productive capacity of their land leads to sub-optimal use and hinders the transformation of the sector. Technological innovations could integrate these producers with international technological advancement.

Land tenure presents a hindrance to the acceptance of agricultural innovations (Smith, 2004). The absence of official land documents for customary landowners and those with usage rights proves to be a downfall in securing credit, which is necessary for deprived farmers (Rochegude, 2011; Twerefou et al., 2011; Ma et al., 2013). Only those possessing legal rights can do so (Feder and Freeny, 1991; Besley, 1995; Brasselle et al., 2002; Linkow, 2013). Once these young people are educated, they abandon agriculture, resulting in this activity primarily being practiced by the elderly, women, and children (Xia and Simmons, 2004). Consequently, cash transfers serve the purpose of consumption rather than agriculture. The adoption of innovations necessitates knowledge (Aghion and Cohen, 2004). If knowledge is combined with innovation, labor can be optimized (Jolliffe, 1998; Yang, 1997; Jones-Casey et al., 2015). Thus, it is prudent to differentiate between general and professional education (Lucas, 1988). Since knowledge can be transferred, it may impact the farmer. To disseminate agricultural knowledge in Sub-Saharan Africa, oral communication is widely utilized (Rogers, 1962). The acquisition of knowledge through practical application enables the preservation of efficient methodologies (Romer, 1987; Jones-Casey et al., 2015). When paired with secure land tenure, these techniques are employed productively, resulting in internal technical advancements (Schumpeter, 1926).

Such progress allows for incremental innovations amidst escalating populations and subsequent land scarcity, leading to a decrease in arable land (Castella et al., 2003; Reij and Thiombiano, 2003) and yield per capita. Thus, the implementation of new methodologies (Rochegude, 2011) becomes imperative to meet growing food demands. These innovations alleviate demographic shocks, with productivity gains being utilized elsewhere (Weeks, 1983). Therefore, they resolve the concerns that had previously been expressed. Some studies suggest that there is a positive correlation between land tenure security and investment in agricultural innovations. Secure land rights affect the decision to adopt innovations (Gavian and Fafchamps, 1996; Singirankabo and Ertsen, 2020), and investment is encouraged, leading to improved productivity (Gebremedhin et al., 2003; Ostrom, 2011). The lack of agricultural investment in Burkina Faso may be attributed to land tenure insecurity (Hochet, 2014; Zahonogo, 2016; Bambio and Agha, 2018; Nchanji et al., 2023). Farmers are more likely to invest in innovations to secure their rights (Brasselle et al., 2002; Gebremedhin and Swinton, 2003).

Techniques such as Soil and Water Conservation (SWC) or plantations are suggested (Smith, 2004; Clément et al.; 2008; Larson, 2013). Nonetheless, it is imperative to note that they only guarantee uncertain rights (Radint, 1982). On land that is given on loan or as a gift, such investments are regarded as appropriation and result in the loss of usage rights (Dialla, 2003). The insecurity of land tenure is harmful to the economy of Burkina Faso, where agriculture is vital (Banque Mondiale, 2019). Agricultural operations employ almost 80% of the working population and contribute 18.48% to GDP (INSD, 2022). Improved security of land tenure has the potential to support this growth. However, demographic pressure is destabilizing land tenure (FAO, 2018). A surplus of demand for land for non-agricultural purposes is leading to a scarcity of arable land (Dialla, 2003; Benjaminsen et al., 2009). The outcome is suboptimal crop production. The authorities suggest this issue is due to inadequate legislation on rural land tenure. The 2009 law and the 2012 decree clarify the provisions and enhance security to land not covered by the Agrarian and Land Tenure Reform (RAF) (Banque Mondiale, 2015). The RAF's aim is to secure property rights to promote agribusiness, in line with the national strategy for agricultural entrepreneurship (MAAH, 2013). According to the author, however, this would result in unfair competition that would threaten family farming. Furthermore, the RAF only secures developed land, which accounts for only 10% of agricultural land. An existing legal gap regarding undeveloped land has been filled by forestry, environmental, water, and pastoral laws. The Programme National de Gestion des Terroirs (PNGT) aimed to minimize land tenure insecurity through OPSF, which implemented communal consultations. However, the usage rights granted cannot be converted to cash, thus decreasing the farmers' capability to handle unexpected situations. Based on the 2009 report from the Millennium Challenge Account (MCC), ownership certificates of land have increased tenure security up to a maximum of 48%. The legislation, as per the author, does not account for discrimination. Nevertheless, securing land tenure remains a challenge for agricultural policies (Otsuka and Place, 2014). Like Burkina Faso, customary systems in sub-Saharan Africa are the norm where the author argues that farmers are discriminated against in terms of land tenure security.

Land tenure insecurity undermines innovation adoption and agricultural production, hindering progress. This study thus aims to analyze the impact of land tenure security on agricultural productivity, highlighting the interference of land tenure security dynamics in the process of increasing agricultural production in Burkina Faso. To achieve this, we explore the influence of land tenure security on agricultural productivity. It expects a positive effect of land tenure security on investment in innovation and input optimization. To robustly test these hypotheses, a recursive equation model is applied along with the mixed conditional process method on panel data from the 2010-2011 PNGT.

The paper is organized into four parts. The second section provides a literature review, the third describes the methodology, the fourth analyzes the results, and the final section concludes with policy implications and future prospects of the study.

METHODOLOGY

Analysis of the impact of land tenure on agricultural production requires defining the chosen variables, developing the model, determining identification strategies for parameters, and deciding on the method of data collection.

Specification of variables

The producer behavior economic theory and empirical studies on the factors affecting agricultural production enable the recognition of social, economic, demographic, and institutional variables. The presentation of endogenous and exogenous variables, to be utilized in formulating the econometric model, is presented herein.

Dependent variables

The effect of land tenure security on crop output is evaluated by means of a model that is founded on three dependent variables.

Investment decision (I): The investment decision model's dependent variable is (I). This variable (I) is determined by the decision to invest in one of the SWC techniques (bunds/cordons) along with animal traction, which enables identification of an opportunity for a household to invest in its plot. The observed variable (I) takes the value 1 when $I^* > 0$. Only if the producer foresees significant future gains from investment, such an investment become feasible. In any other scenario, the value of I would be 0 if $I^* \leq 0$.

Optimum choice of workforce (Ac): The optimal labor choice model's (Ac) dependent variable is an unobserved latent variable. The household's decision to allocate a labour force just necessary for production per hectare captures the Ac variable. It is determined by comparing the overall labor used per area sown to family labor. Optimization takes place when family labor is lower than the labor-to-area ratio. Thus, the observed variable (Ac) equals 1 if $Ac^* > 0$ (optimization). On the other hand, if the household makes a random allocation, then (Ac) is assigned the value 0 with $Ac^* < 0$.

Quantity of cereal production ($qcer$): The cereal production function for households is determined by the level of production of the main cereals - millet, maize, sorghum, and rice- due to their significance in dietary habits. The monocrop productions are established by the total quantities in kilograms acquired on all plots during the crop year.

Independent variables

The neoclassical theory of producer behaviour outlines several inputs involved in the production of an output.

Work (trav): Labour is the total amount of family and hired workers engaged in the production process during an agricultural season. Labor is measured here in man-days. This amount of labor, which can vary from one stage to another (planting, weeding, harvesting), is therefore a variable factor. The theory anticipates its positive effect on production.

Organic fertilizers (fumo): Organic fertilizer is composed of manure and compost that is collected and applied to the plot during the production process. It is measured in cartloads, which may slightly differ in volume on plots of equal size due to individual subjectivity in dosage. However, this factor is essentially unchangeable. Due to its ability to regenerate soil fertility, it is believed to have a positive impact on production.

Chemical fertilizer (engc): Two types of chemical fertilizer have been used in this study. NPK (engc1) and urea (engc2) are the primary fertilizers, and their application is measured in total kilograms applied to individual plots during the crop year. As there is uncertainty over their availability for cereals, growers utilize quantities that can vary for constant areas. Consequently, they are quasi-fixed factors. Although their effects are theoretically mixed, they are expected to be positive for cereal production.

Phytosanitary products (phyto): Plant protection products are utilized in safeguarding cereal crops against "crop pests" throughout the duration of the production process. This security is achieved by administering pesticides (phyto1) and herbicides (phyto2) on the crops. The amount used on the plot is measured in liters, but due to the subjective nature of their use concerning dosage, plant protection products are perceived as quasi-fixed factors. The ambiguity highlighted in the literature concerning their impact on production leads us to anticipate a positive influence on cereal production in this instance.

Techniques CES (wsc): The SWC variable denotes the utilization of water and soil conservation methods. SWC, due to their exceptional water retention abilities, facilitate farmers' adaptation to climate change in estimating their agricultural production. Four prominent techniques have been chosen: zaï (CES1), dikes/stony bunds (CES2), half-moons (CES3), and hedgerows (CES4). These CES techniques have retained an unchanged form since their initial development owing to their predictive nature over time. This emphasizes the fixed character of this factor and excludes subjective judgments. Ultimately, their ability to mitigate the risks of land degradation suggests that cereal production may be positively affected.

Animal traction: Animal traction has the potential to decrease physical exertion and the required number of laborers on a plot. It also has the potential to increase household income through non-agricultural activities that can be undertaken by drafting (Savadogo et al., 1994). A favorable outcome is therefore anticipated.

Number of employees (actif): The labor input in cereal production is the total number of members of the household involved in the work. It also reduces the physical effort required to use certain agricultural innovations (such as traction engines). As a result, this figure can have a constructive influence on the choice of investments and hence on the level of production. Although there is some empirical debate regarding its impact, it is anticipated to have a favorable influence on investment and production.

Age of head of farm (age_c): The age of the head farmer is determined by the number of years completed by the main farmer of the plot. Advanced age provides older farmers with a comparative advantage in human capital as they have gained traditional knowledge through the years (Waithaka et al., 2007). Meanwhile, younger farmers have a higher likelihood of introducing new practices than older ones as they are more aware and updated about investment options and advanced technologies (Adesina and Zinnah, 1993). This variable has ambiguous effects on investment decisions, labor efficiency, and, consequently, agricultural production.

Education level of farm manager (educ_c): The educational attainment of the farm manager can facilitate investment, labor optimization, and production decision-making. The **educ_c** variable is polytomous, corresponding to values of 1 if the manager is literate in any language, 2 if they have completed primary education, 3 if they have completed secondary education, and 4 if they hold a higher education degree. The extent of education allows for the producer's actions to be rationalized (Abdulai et al., 2008). Moreover, the development of human resources inevitably results in a migration of labor from rural regions to urban hubs (Akouwerabou, 2014; Schultz, 1992). To align with the study model's demands, this variable will be recoded as a dummy variable, assigned a 0 value for those lacking literacy skills and 1 value for the rest.

Gender of head of farm (sexe): Gender is a binary variable that measures whether the head of the holding is a man or a woman. Most privileges granted to men to the disadvantage of women result in a negative impact of this variable on investment and production decisions (Dialla, 2003). However, this variable may have a positive impact on labor optimization as women tend to be more active in field work. Therefore, it is difficult to predict the effect of the gender variable on the production process.

Farm credit (credit): Agricultural credit is a numerical measure of the funds extended to crop producers during a given year. Such credit serves to enhance the quantity of investments, stimulate optimal utilization of labor, and thereby augment agricultural output. Credit accessibility displays a positive link with technological adoption as it grants farmers access to vital market inputs that elevate productivity (Feder et al., 1985). Hence, a desirable result is anticipated.

Off-farm income (rev_na): Off-farm income is quantified as the total income derived from non-agricultural activities. Additionally, income from off-farm activities can provide insurance to households, allowing them to implement and embrace agricultural innovations (Evan and Ngau, 1991). This assists in mitigating investment limitations. This hypothesis is supported by evidence from rural areas of Burkina Faso (Zahonogo, 2016). A beneficial impact on investment is therefore expected.

Input costs (cout): The cost of factors is calculated by adding the amounts spent on purchasing/renting production factors and hiring labor for the production process. The considerable expense of investing in innovations (such as improved seeds, inputs, SWH, tractors, etc.) does not always result in their appropriation, even in the presence of a market (Simtowe and Zeller, 2009; Chibwana et al., 2012; Carter et al., 2014). Therefore, a negative effect is expected.

Security of land tenure (sfonc): Security of tenure is achieved through the rights that the farmer holds over the plot, specifically the right of sale, right of deposit, or a combination of both. This provides the farmer with security of tenure and is denoted by the variable taking the value 1 if either of these conditions is met, and 0 otherwise. Land tenure security allows farmers to overcome financing constraints by using land as collateral to access agricultural credit (Adesina and Zinnah, 1993). The development of third-generation agriculture could be propelled by the security of land tenure (Platteau, 1996; Dushimyimana et al., 2014). Such security is expected to have a positive impact on investment, labor optimization, and subsequently on the level of cereal production.

Plot the topographical sequence (topo_seq): The topo-sequence of the plot is evaluated using a dichotomous variable. A value of 0 is assigned if the plot is situated at the bottom of the slope, and 1 for any other position. The impact of soil fertility on the production process may vary due to geographical differences in investment and labor. Therefore, subjective evaluations are difficult to make.

Land type (typ_ter): Land type determines the soil composition of the plot. In some cases, this information can provide insight into the plot's fertility and influence a farmer's decision to invest. Soil type is measured by a dichotomous variable. The variable assumes the value of 0 if the land comprises clay and 1 if it does not. The anticipated effect of investment is ambiguous, as it depends on the type and level of investment required for each soil type.

Distance from the village to the market (dist): The distance between the market and the village is determined by a continuous variable that provides the distance in kilometers from the household's residence to the market. The absence of a market or greater distance to the market can also affect the production process (Waithaka et al., 2007). As the position of the place of residence in relation to the market can vary, this distance is variable, making this factor variable and its impact uncertain. The various aforementioned variables contribute to a clearer understanding of the study's model.

Formulation of the study model

The model presented in this study is founded upon the design framework established by an author (Feder and Noronha, 1987). After modifying the model and checking that the necessary conditions are met, we arrive at the following model, which represents the impact of land tenure security in the agricultural sector.

$$I^{*}_{mpt} = SF_{mpt}\vartheta + P_{mpt}\eta + Dem_{mt}\phi + Z\psi + \omega_m + \xi_{mpt} \quad (1)$$

$$Ac^{*}_{mpt} = I_{mpt}\vartheta' + P_{mpt}\eta' + Dem_{mt}\phi' + Z\psi' + \chi_m + \varsigma_{mpt} \quad (2)$$

$$lny_{mpt} = (a + \alpha_m) + \sum_{i=1}^{k} \delta_i lnP_{mit} + \sum_{j=1}^{v} \gamma_j lnDem_{mjt} + \eta Ac_{mpt} + \varphi + \lambda' IRM^{i}_{mpt} + \frac{1}{2}\sum_{i=1}^{k}\sum_{i'=1}^{k} \theta_{ii'}(lnP_{mit} * lnP_{mi't}) + \frac{1}{2}\sum_{j=1}^{v}\sum_{j'=1}^{v} \theta_{jj'}(lnDem_{mjt} * lnDem_{mj't}) + \sum_{i=1}^{k}\sum_{j=1}^{v} \theta_{ij}(lnP_{mit} * lnDem_{mjt}) + \sum_{l=k+1}^{r} \delta_l P_{mlt} + \sum_{b=v+1}^{n} \gamma_b Dem_{mbt} + v_{mpt} \quad (3)$$

Equation 1 represents the investment decision. This concerns stone barriers and/or animal traction. In this equation, the explanatory variables for investment behaviour are contained in matrices defined by : SF_{mpt} in the case of the matrix of proxies for land tenure security as perceived by the household m in relation to the plot p over time t ; P_{mpt} the characteristics of the plot of land for the household m of the plot p at the time t ; Dem_{mt} representing the socio-economic and demographic characteristics of the household m over the period t; ω_m and I^{*}_{mpt} reflect the unobserved characteristics of households and investments, and ξ_{mpt} the error term. The other (structural) variables are grouped together in the matrix Z. The remaining elements concern the parameters to be estimated: $\vartheta; \eta; \phi et \psi$.

Equation 2 materialises the effect of land security through investment on labour optimisation. It has an identical specification to Equation 1 except that χ_m and Ac^{*}_{mpt} represents the unobserved characteristics of households and labour optimisation decisions, and ς_{mpt} the error term. The other elements are the parameters to be estimated. Equation 3 relates to the effect of land security on agricultural production through the optimisation of agricultural labour. It results from a translogarithmic function because of its great flexibility. In this equation $\ln(.)$ represents the natural logarithm associated with each variable, y_{mpt} measures the household's cereal production m on the plot p on date t; IRM^{i}_{mpt} .represents the inverses of the Mills ratio linked to the decision i. P_{mit}, Dem_{mjt} are the characteristics of plots and households respectively. These characteristics are represented by quantitative variables that can be either totally or partially substituted for each other. P_{mlt} and Dem_{mbt} represent the characteristics of plots and households respectively. The latter are dichotomous variables or those that cannot be substituted in any way. $\eta, \tau, \delta_i, \gamma_j, \theta_{ii'}, \theta_{jj'}, \theta_{ij}, \delta_l, \gamma_b, \lambda$ and φ are the coefficients to be estimated. a, α_m, and v_{mpt}, represent the constant, the household-specific individual effects and the error term respectively. I_{mpt} and Ac_{mpt} represent the adjusted value of agricultural and labour investments, respectively.

Parameter identification strategy

Separate estimates of the different equations in the study model can lead to an underestimation of the effect of land tenure security on agricultural production. This method leads to less robust results (Roodman, 2007; Roodman, 2011).

The standard errors are very large, which explains the failure to correct the random term in the previous equation integrated into the previous equation, and so on for the n equations (Gavian and Fafchamps; 1996; Place and Otsuka, 2002). Ensemble estimation would make it possible to resolve these shortcomings. Given the endogeneity inherent in this type of model, insofar as land tenure security is endogenous in the investment decision model, as is the optimal labour force in a production function, to which must be added the dichotomous nature of the land tenure security and labour force variables, and the continuous nature of the production variable, the use of the standard instrumental variables framework with a two- or three-stage least squares approach (2SLS, 3SLS) to control such an econometric challenge seems inappropriate (Abadie et al., 2003; Chesher et al., 2013; Clougherty et al., 2016; Wooldridge, 2019).

The various methods for controlling the endogeneity of a binary variable in models with binary and continuous dependent variables are identified in the seminal work of (Amemiya, 1978). In this work, he uses limited information maximum likelihood (LIML) or full information maximum likelihood (FIML) as estimation methods. These methods control the endogeneity problems associated with sample selection and self-selection (endogenous processing and endogenous switching) (Clougherty et al., 2016). They are therefore a potentially more appropriate way of dealing with endogenous treatment problems associated with binary and censored dependent variables. To this end, an estimator (Mixed Conditional Process [CMP]) has been developed which allows LIML and FIML to be implemented for different models (binary, continuous and bounded dependent variable models) dealing with endogeneity problems (Roodman, 2011). In addition, it solves the identification problems by order and rank conditions frequently raised in recursive models. This estimator largely allows joint estimation of complex models such as a multi-equation system comprising a mixture of multivariate models, as in the present case. The mixed conditional process estimator can also be used to initiate an estimation sequence in a complex model by its ability to integrate the corrected residuals from equation to equation. It is also recognised that CMP is a technique that is particularly well suited to recursive models, while taking into account the cross-relationships that may exist between the different equations to obtain robust results. This makes it possible to consider one of the hypotheses of the study, according to which security of tenure positively affects the level of agricultural production through long-term investment. The CMP estimator is therefore used. Nevertheless, it should be remembered that the analogy between the generalised probit technique (Amemiya, 1978) and that of the CMP (Roodman, 2011) is very similar, but the CMP is more general, hence the additional motivation for its use.

Data collection methods

The data come from surveys conducted in 2010 and 2011 by the Laboratoire d'Analyse Quantitative Appliquée au Développement-Sahel among rural households in all 13 regions of the country as part of the evaluation of phases 1 and 2 of the PNGT. A stratified sample of 270 villages was selected, with a quota of 6 villages per province. In each village, 8 households were drawn at random from 3 strata according to the type of traction used (animal, motorised or manual). A total of 2,160 households and 2,981 plots were surveyed each year. The data collected concerned the plots cultivated, their surface area measured by GPS, the quantities produced, and family labour in man-day units.

In this paper, the cereal production criterion is included to obtain the sample needed to identify the phenomenon under study. This sample, which is a cylindrical panel over two years, is the result of a series of iterations on the raw data from this programme. Firstly, only farmers on plots that were surveyed in both 2010 and 2011 and that produced only the same cereal (sorghum, millet, maize and rice) on the plot during the different survey visits were included. Secondly, plots for which the area and quantities harvested were non-existent were also excluded. Thirdly, all values deemed to be outliers in terms of the volume of cereal production (exorbitant value per hectare) on the plot were also removed. Finally, plots with the status "old plot" in 2010 and "new plot" in 2011 were also removed. The sample used for the study is therefore made up of 2404 observations at the plot level out of a total of 5962 plots.

RESULTS

This part is designed to provide a coherent explanation of how land tenure security influences agricultural production levels. To achieve this, we begin by scrutinizing the composition of the sample, aiming to uncover any relationships between the variables using descriptive statistics. Subsequently, we delve into the econometric findings, and finally, we discuss the key insights, comparing them to those uncovered by other researchers.

Statistical analysis of land tenure security in cereal production

Our goal in this context is to pinpoint the characteristics of the farmers and plots in the sample. We also aim to analyze how cereal production changes in relation to land tenure security and the average cereal production in tons concerning both land tenure security and investment.

Characteristics of farmers and plots in the sample

An analysis of these characteristics reveals that most of the production (80%) is attributed to men, as they are the primary managers of cereal plots. Additionally, it's noteworthy that nearly all farmers (81%) possess basic literacy skills.

The highest educational attainment among farmers is at the secondary school level, with very few (4%) having completed this level of education. However, a relatively small portion (27%) of these farmers is members of a producer organization. This limited involvement could hinder the dissemination of information on innovative farming methods and techniques.

Regarding the plots and considering water runoff, it is likely that plots situated at the top and middle of slopes (70%) will experience significant degradation and a rapid loss of productive capacity. This justifies the use of agricultural inputs, even in the presence of land security constraints. Consequently, in terms of comparative growth, the use of inputs is more prevalent among farmers with secure land tenure. Urea, NPK, and seeds exhibited substantial negative growth rates of 95.67, 90.14, and 52.77%, respectively. In contrast, during the same period, these growth rates were much lower at 25.69, 22.95 and 7.32% for the same factors.

Land tenure security leads to stricter quality standards for improved land utilization. Furthermore, while on plots where the farmer holds secure rights; there is a decline in herbicide usage (25.93%), the rate of herbicide application increases significantly (50.30%) on plots with insecure land tenure. One counterintuitive finding is the lower utilization of organic manure (58.28%) by producers with secure land tenure compared to those with insecure land tenure. One possible explanation for this situation is the extended period required to produce high-quality organic manure. When the necessary time for the mineralization of organic compounds is not met, the use of such organic manure can result in crop damage due to the elevated temperature within the manure. Land tenure security, therefore, influences decisions to invest in inputs, as demonstrated in Table 1.

Comparative trends in cereal production as a function of land tenure security

The level of production is subject to variation based on the security of land tenure. Unsecured plots experience a 3% decrease in production. Conversely, the assurance of land tenure would result in an almost 77% increase in production. To address the decline in agricultural yields, it is crucial to offer farmers more secure land rights. The relationship is illustrated in Table 2.

Table 1. Growth rates in input use.

Variable	Secure land tenure 2010-2011	No security of land tenure 2010-2011
Seeds (%)	-52.77	-7.32
NPK (%)	-90.14	-22.95
Urea (%)	-95.67	-25.69
Pesticides (%)	2.52	-12.18
Herbicides (%)	-25.93	50.30
Organic manure (%)	-58.28	8.11

Source: Author based on PNGT 2010 and 2011 data.

Table 2. Growth rate of average cereal production as a function of land tenure security.

Variable	Secure land tenure		No security of tenure	
	2010	2011	2010	2011
Average production (in tonnes)	0.84	1.48	0.84	0.52
Production growth rate	0.77		-0.38	

Source: Author based on PNGT 2010 and 2011 data.

Table 3. Land security and labour optimisation.

Variable	Secure land tenure		No security of tenure	
	2010	2011	2010	2011
Overall work (man-days)	207.25	129.44	193.06	154.65
Family workforce (man-days)	144.35	121.80	133.85	126.27

Source: Authors based on PNGT 2010 and 2011 data.

The security of land tenure can also play a role in regulating labor allocation decisions on the land. As shown in Table 3, the impact of land tenure security on labor optimization can vary from year to year. Labor is expected to be optimized on plots with secure tenure consistently. This is because farmers who do not fear expropriation will aim to maximize their land rent. However, the ambivalent nature of the effect of land tenure security observed in Table 3, where farmers in both categories of plots tend to optimize labor overall, might be related to the high level of tension between herders and farmers. In situations of conflict, the principle of respecting property rights may no longer be upheld. Nonetheless, optimization is achieved by farmers with secure rights to their family labor allocated to the plot.

A longitudinal analysis of this situation, in terms of man-day growth rates, exposes a negative correlation between labor allocation and the type of land rights held by farmers. It becomes evident that farmers with secure land tenure allocate fewer man-days (62.46%) to the agricultural production process over time compared to those with insecure land tenure (81.11%). This observation is supported by the presence of negative and significant growth rates for farmers lacking land tenure security (-18.89%) in contrast to those with secure land rights (-37.54%). Therefore, land tenure security appears to encourage the decision to optimize farm labor, as demonstrated in Table 4.

On the other hand, investments in the plots can also have a positive impact on production levels. It is observed that the use of “zaï” results in a 1.37% increase in production compared to when it is not employed. This growth rate is substantially higher than that of plots that have not received such investment. Additionally, the absence of investment in stone cordons leads to a reduction in the productive capacity of the plots, with a significant 40% drop in the growth rate of production when this investment is not made. The utilization of half-moons and hedgerows similarly enhances production by 1.53 and 1.18, respectively, in contrast to 0.71 and 0.80 when these types of investment are not made. Furthermore, the use of animal traction leads to a significant improvement in the production growth rate, nearly reaching 0.72, as opposed to 0.12 when these investments are not made. Long-term investments thus have the potential to enhance the level of cereal

Table 4. Growth rate of the workforce according to the nature of land security.

Variable	Secure land tenure	No security of tenure
	2010-2011	2010-2011
Overall work (%)	-37.54	-18.89
Family workforce (%)	-15.62	-5.66

Source: Authors based on data from the PNGT 2010 and 2011.

Table 5. Average production growth rate in tonnes for cereals as a function of investment.

Investment	Year 2010		Year 2011		Growth rate	
	Directed	Not carried out	Directed	Not carried out	Directed	Not carried out
zaï	0.99	0.82	2.35	1.44	1.37	0.80
Stone cordon	0.83	0.85	1.40	0.82	0.69	-0.40
Half-moon	0.93	0.84	2.35	1.44	1.53	0.71
Hedges	1.10	0.82	2.4	1.44	1.18	0.80
Animal traction	0.83	0.73	0.89	0.82	0.72	0.12

Source: Authors based on PNGT 2010 and 2011 data.

Table 6. Relationship between security of tenure, investment and cereal production in tonnes.

Years	investment	Land security		Production growth rate	
		Present	Absent	Secure rights	Unsecured rights
2010	Animal traction	0.87	0.94	0.84	-0.55
2011		1.60	0.42		
2010	Stone cordon	0.46	0.83	0.96	-0.65
2011		0.90	0.29		
2010	zaï	0.24	0.9	0.45	-0.21
2011		0.35	0.78		
2010	Half moons	0.24	0.93	0.66	-0.45
2011		0.40	0.54		
2010	Hedges	0.94	1.10	0.70	-0.45
2011		1.60	0.61		

Source: Constructed by the authors based on the PNGT 2010 and 2011 data.

production on the plots, as outlined in Table 5.

Average cereal production in tonnes as a function of land security and investment

The security of land tenure may prompt the farmer to engage in long-term investments, and the benefits of such a decision would be an enhancement in the level of cereal production. Table 6 illustrates that the production growth rate (measured in tonnes) of farmers with secure land tenure who utilize animal traction is significantly better at 0.84, compared to those in a different scenario. Furthermore, long-term investments in water and soil conservation measures such as stone cordons, “zaï,” half-moons, and hedgerows are effective in elevating production levels by approximately 1.93, 0.45, 0.66, and 1.55, respectively. Hence, long-term investments have the potential to elevate production levels, particularly when the farmer holds secure tenure over the plots.

These findings are subject to confirmation or challenge by econometric analysis.

Econometric analysis of the effect of land tenure security on cereal production

By estimating the model using the CMP method, we can simultaneously assess the effects of land tenure security on the level of agricultural investment, on the optimization of agricultural labor, and consequently, on agricultural production. This estimate was made using Stata 16 software.

The effect of security of tenure on long-term investment decisions

The impact of land tenure security on long-term investments reveals a counterintuitive effect on the likelihood of investing in the construction of stone barriers on the plot. This result can be explained by the belief of farmers with secure rights over their plots that making such an investment represents an additional cost they must bear to safeguard themselves against potential expropriation. As a result, land tenure security serves to deter decisions involving additional expenses to mitigate land tenure insecurity.

Moreover, organic fertilizer exerts a positive influence on the decision to invest in stone barriers. In terms of soil fertility regeneration, the combined use of organic fertilizer and stone strips not only enhances the fertility of the plot but also preserves it. This preservation is achieved through the reduction of soil leaching due to erosion, a consequence of the presence of stone strips.

Additionally, the positive effect of population size on the decision to invest in stone barriers encourages farmers to make such investments, which provide an additional asset alongside secure land rights. Stone strips serve as a tangible representation of the rights the farmer holds over the plot. Conversely, a higher usage of NPK on the plot tends to discourage the farmer from investing in stone strips.

This result can be attributed to the level of land security the farmer enjoys on the plot. In the short term, NPK leads to increased production compared to stone cordons, even when land tenure is secure. However, in cases where land access is limited, there exists a substitution relationship between NPK and stone cordons. This relationship is more favorable to the use of NPK, which offers an immediate return to the farmer and reduces costs in the event of potential expropriation.

Conversely, land tenure security encourages rational decision-making when it comes to investing in stone cordons, thereby favoring decisions to invest in animal traction. This is supported by the positive effect of the use of stone cordons on the likelihood of investing in this agricultural equipment.

Additionally, the considerable distances between the village and a paved road should be considered. Given the state of the roads, farmers can rely on this equipment as a means of transportation when sowing extensive areas. An investment in animal traction, therefore, appears logical to achieve multiple objectives, including sowing large areas in a short time and cost-effective transportation.

Despite the evident significance of animal traction in agricultural production, farmers who have secured land rights exhibit a strong inclination to divert the credit allocated for increasing investments in this equipment. This diversion can be attributed to the adverse impact of the credit amount received on the decision to invest in animal traction. A plausible explanation may be rooted in socio-economic and cultural factors that influence the behavior of certain farmers. As agriculture represents their primary source of income, it appears that a portion of the credit they receive during the agricultural season is used for family necessities while awaiting the next harvest. Table 7 provides a summary of these results and underscores the varying levels of significance of these variables. These influences have an impact on workforce optimisation.

Effect of land tenure security on labour optimisation decisions

The utilization of animal traction necessitates an efficient allocation of labor to maximize the return on investment. The positive impact of this investment on labor optimization indicates that land tenure security not only positively affects the investment itself but also influences the effective management of labor. This enables the plot holder to allocate surplus labor to other plots and/or explore additional income-generating opportunities to fulfill family needs. Table 8 provides a visual representation of these diverse scenarios.

Table 8 also reveals that on small plots, farmers are less likely to optimize their labor. Conversely, on large plots, farmers tend to allocate just the right amount of manpower to farming activities. The size of the areas where farmers can derive significant labor-related benefits is at least 2.84 ha. This pattern can be explained by the interplay of the area variable and its square, with farmers making decisions based on anticipated gains over time. Farmers believe that it is more efficient to deploy a greater number of workers on small plots of land, rather than concentrating most of their resources on larger areas. The inclination to optimize labor is even more pronounced when the farmer is a recipient of agricultural credit. In this scenario, surplus labor serves as an additional source of income for the farmer, ensuring efficient management of the credit acquired. This accounts for the positive effect of this variable. The

Table 7. Effect of land tenure security on investment decisions.

Variable	Investment decisions			
	Stone strings		Animal traction	
	Coefficients	Standard deviation	Coefficients	Standard deviation
Organisation of producers.			-0.029	0.055
Distance from the village to a road			-0.004**	0.002
Distance to square			0.002**	0.001
Credit obtained	-0.000	0.000	-0.000***	0.000
Ownership of a television set	0.152*	0.091	0.033	0.096
Owning a radio			0.015	0.029
Type of equipment			-0.007*	0.004
Surface area of the plot	0.008	0.015	-0.002	0.014
Type of crops grown	-0.015	0.034	0.039	0.029
Topo-sequence of the plot	0.059	0.043	-0.047	0.039
Type of soil			-0.023	0.019
Operator's level of education	-0.004	0.057	-0.064	0.071
Age of operator			-0.002	0.002
Gender of operator			-0.050	0.142
Marital status			-0.041	0.041
Stock of livestock	-0.009	0.007	0.005	0.007
Type of plot			0.011	0.083
Use of stone strips			1.173***	0.200
Land security	-0.536***	0.201		
Increased use of manure (manure2)	0.009***	0.003		
Water level in the locality	-0.000	0.000		
Increased use of NPK (npk2)	-0.000**	0.000		
Local population	0.003*	0.002		
Constant	-0.596***	0.199	0.764**	0.320
Observations	2.404		2.404	

***p<0.01, **p<0.05, *p<0.1.
Source: Constructed by the authors based on study data.

topographical location and the nature of the land guide the farmer in making an optimal choice regarding labor allocation. The plot's position and its organic composition necessitate the farmer to make a judicious decision in terms of resources to enhance profitability. The type of equipment used and the specific cereal crop to be produced also play a role in optimizing labor. The positive effects of the variables equipment type, crop type, topographical location, and land type that exemplify this situation are highlighted in Table 8.

The effect of land tenure security on cereal production

In terms of cereal production, the combined effects of these two factors - investment and workforce optimization - have the potential to stimulate growth. Table 9 illustrates the impact of each of these factors. Interestingly, land security, when combined with labor optimization, leads to a reduction in cereal production volume. This unexpected outcome can be attributed to the relatively insufficient number of man-days available to achieve the required production levels, especially when measured against the most productive assets. Furthermore, the choice of seeds has a negative influence on cereal yields, which may be attributed to the quality and selection of the seeds used. Poor utilization of traditional and/or improved seeds could contribute to this situation, even when considering the rational use of the farmer's production capacity and the fertility of the plot. Additionally, it becomes evident that, for a constant surface area, phytosanitary treatments could negatively impact cereal production. This is evident from the negative effect of the interaction between the cultivated area and the quantities of herbicides used. When herbicide doses per hectare are not adhered to, phytosanitary treatments become counterproductive and may have adverse effects on production. Table 9 provides a summary of these various interactions.

To quantify the impact of each of these variables, it is appropriate to conduct an analysis in terms of production

Table 8. Effect of land security on labour optimisation.

Variable	Workforce optimisation	
	Coefficients	**Standard deviation**
Organisation of producers	-0.065	0.088
Distance from the village to a road	-0.005*	0.003
Distance to square	0.002	0.002
Credit obtained	0.000**	0.0004
Ownership of a television set	0.128	0.142
Owning a radio	0.059	0.051
Type of equipment	0.010*	0.006
Surface area of the plot	-2.355***	0.135
Type of crops grown	0.089**	0.043
Topo-sequence of the plot	0.097*	0.057
Type of soil	0.055*	0.032
Age of operator	0.002	0.003
Water level in the locality	-0.0003	0.0003
Local population	-0.005	0.006
Increased population in the locality (pop2)	0.000	0.000
Possession of a mobile phone	0.126	0.087
Increased surface area of the plot (surface area2)	0.102***	0.007
Operator's level of education	-0.001	0.021
Use of animal traction	0.662***	0.215
Constant	1.415**	0.643
Observations	2.404	

***p<0.01, **p<0.05, *p<0.1.
Source: Constructed by the author based on study data.

Table 9. Estimation of the production function.

Variable	Log production	
	Coefficients	**Standard deviation**
Log quantity of seed	-0.079**	0.036
Log quantity of urea	-0.041	0.045
Log pluviometry	-0.045	0.143
Optimising the workforce	-0.066*	0.036
Log surface area and log NPK	0.029	0.057
Surface area and accommodation	0.083	0.108
Log area and log manure	0.004	0.097
Log area and log pesticide	0.062	0.119
Log surface and log herbicide	-0.484**	0.241
Log number of equipment per square	-0.222	0.308
Log manure and log age	-0.005	0.029
Log herbicide and log age	0.101	0.074
Log stock of cattle	-0.008	0.055
Mill ratio	-0.015	0.506
Constant	2.502***	0.425
Observations	2.404	

***p<0.01, **p<0.05, *p<0.1.
Source: Constructed by the author based on study data.

factor elasticities. It's important to note that elasticities in discrete choice models may not be readily interpretable since variations in a binary variable lack economic significance. Additionally, the mean of these variables represents only the mean of the non-zero modality in the case of a dummy variable coded as 0 and 1. Therefore, only the elasticities associated with the variables in the production function can be calculated and understood. The production function reveals that an increase in seed quantities of 1 kg would result in a reduction in production volume of approximately 0.08 kg per hectare. However, it's worth emphasizing that seed usage and selection methods have the potential to reverse this outcome and significantly enhance yields. Therefore, it would be advisable for the farmer to focus on seed quality and employ proper technical practices during the cropping season. Similarly, land tenure security, when coupled with labor optimization, results in a decrease in agricultural production. Reducing the number of workers per labor unit by one man-day leads to a decrease of 0.07 kg in production. While labor optimization can help diversify sources of income, cereal farmers with secure land tenure should consider adjusting the allocation of man-days in the production process to take advantage of potential economies of scale. It's important to note that the combination of the area cultivated and herbicide usage also contributes to a reduction in production volume. An increase of 1 L of herbicide in the cereal production system leads to a 0.48 kg decrease in production for a constant surface area. Non-compliance with the herbicide's usage guidelines may be one explanation for this effect. In this regard, the involvement of technical agricultural experts could significantly improve the proper use of this plant protection product, thus enhancing cereal production.

DISCUSSION

The results suggest that land tenure security has a dual impact: it constrains investment decisions related to stone cordons while favoring those tied to animal traction. This conflicting effect of land tenure security contradicts classical theories, which typically anticipate a positive influence on investment decisions. An evolutionary interpretation of the literature on land tenure security can shed light on this outcome. This concept has also been observed considering the absence of land restrictions for farmers under communal management (Demsetz, 1967). In this context, where tenure security is defined and assured by the community, the risks of expropriation are minimized, reducing the incentive for land security investments. Furthermore, the marginal impact of land tenure security is negated in the presence of an efficient communal land tenure system. Investing in stone cordons as a means of securing land tenure may be limited to plots under communal management. The intricacies of land as an asset are also cited as a factor explaining this outcome (Radint, 1982). This implies that land investment may only be financially viable within a community context, excluding the concept of private ownership. This outcome can be attributed to the individualistic nature associated with private property (Besley, 1995). In rural areas, communitarianism tends to dominate, especially in long-term investments like stone cordons. Another perspective on this situation could be the legal and political regulations prevailing in the rural land sector. The misalignment between societal norms and state requirements in terms of land security may result in a scenario where agricultural investments operate below optimal conditions. The erosion of customary values and the questioning of ancestral agreements regarding agricultural land, currently observed, leave producers who have acquired land through this investment pathway uncertain. This uncertainty prompts them to lean towards short-term investments, primarily to mitigate potential losses in the event of sudden expropriation—a trend observed in the increasing number of land disputes in rural areas of Burkina Faso. Limited financial resources among farmers also contribute to this situation. Notably, investments with a cost-land ratio greater than one fail to motivate farmers. In fact, in such situations, these investments tend to have the opposite effect, especially when there is positive cross-price elasticity between the investment and land security. Additionally, when investment and security of land tenure are seen as substitutes, an improvement in one aspect tends to offset the impact of the other (Otsuka and Place, 2014). However, a substantial body of research contradicts this perspective. Studies conducted in Rwanda and Ghana; for instance, suggest that land tenure security actually encourages investment, in line with neoclassical economic theory (Shem and Haezll, 1991).

Similar findings emphasize the importance of credible land rights as a catalyst for increasing agricultural investment (Place and Hazell, 1993). Moreover, when land tenure is secure, the most favored investment is organic fertilizer (Bambio and Agha, 2018). The positive effect of land tenure security on investment is primarily attributed to the reduced risk of expropriation that secures land tenure offers (Otsuka and Place, 2014). This, in turn, guarantees a return on investment.

These findings align with prior research in this field (Ghebru and Holden, 2013; Akinola et al., 2013; Foning et al., 2014). In the absence of land tenure security, investments in chemical inputs are predominantly limited to subsistence production.

Moreover, it becomes evident that land tenure security has a positive impact on investments in animal traction over longer distances. The farther the distance between the village and a paved road, the more likely farmers are to invest in animal traction. The animals used for field work also serve as a means of transportation for the evacuation of produce.

This practice is particularly pronounced when the farmer owns larger plots of land, as indicated by the positive effect of the square of the plot's area. Simultaneously, this approach aids in optimizing labor utilization.

Regarding the influence of land surface area on investment, the results obtained here correspond with the findings of certain other researchers (Tura et al., 2010; Roudart and Dave, 2017). In the case of the former study (Tura et al., 2010); the size of the land area plays a pivotal role in shaping investment decisions. It enables the farmer to determine the most suitable type(s) of investment to enhance the value of the plot significantly and positively. Furthermore, it becomes evident that investment in erosion control measures is contingent on the size of the area to be cultivated, as highlighted in the study by Roudart and Dave (2013). They draw the conclusion that there exists a positive correlation between land area and investments in agricultural technology. This concept challenges the previously held notion that it is the small size of the area that motivates farmers to opt for an intensive production system involving substantial investments in agricultural technological innovations (Weeks, 1983). The objective here is to make small plots profitable on a larger scale, considering their limited temporal availability.

Despite the scarcity of agricultural plots, everyday practice tends to favor the adoption of extensible agriculture. Intensification appears to be an alternative, but given the availability and high cost associated with this approach, very few rural farmers can afford to invest in it due to their limited income (Mensah et al., 2016).

Furthermore, concerning the optimization of labor, the theory finds support in the positive effect of population size on investment (Weeks, 1983). Regions with a larger rural population tend to encourage farmers to engage in long-term investments. This not only enhances production but also contributes to increased land security. In line with Boserupian theory, it becomes evident that investment decisions in the adoption of agricultural innovations serve as a crucial response to the food challenges in densely populated areas. The results obtained here, therefore, align well with the situation in rural Burkina Faso, where the population density per square kilometer is relatively high.

Beyond the implications for investment and land security, this population also represents a workforce capable of boosting production (Tura et al., 2010; Oladele, 2005). However, it’s worth noting that this last result isn’t universally accepted, and similar to the present case, a negative effect on workforce optimization emerges (Mathieu et al., 2003).

This can be explained by taking several factors into account, such as the topographical arrangement of the plot, the use of animal traction, and the type of crop grown. While these variables may positively impact labor optimization, they may not necessarily lead to increased production levels when lower-quality seeds are used. The negative effect of seed quality on production, as reflected in the results, illustrates this point. This finding contradicts those of other authors (Chibwana et al., 2012), who offer an explanation for this phenomenon based on the genetic potential of the seeds provided to farmers. Several complaints have been lodged regarding seed quality, including issues like low germination rates, unidentified varieties, varietal impurities, and varieties ill-suited to the agro-climatic conditions of the local farming areas.

The presence of various constraints, including the choice of seeds, is likely to hamper cereal yields. As a result, the negative effect on labor optimization may be misleading and influenced by the seed type used in a given crop year. Similar findings have been observed in numerous studies (Foning et al., 2014; Yong et al., 2014). Moreover, the judicious use of chemical inputs, with careful attention to dosage, can mitigate the risk of soil degradation and empower the soil to enhance agricultural production. Secure land tenure has the potential to bolster production levels, provided that the necessary conditions are in place. Animal traction, seed quality, labor optimization, and the application of organic inputs stand as the primary pathways through which secure land tenure can contribute to improving cereal yields and, in turn, the well-being of rural farmers.

These findings enable us to draw conclusions and identify implications for economic policies geared toward augmenting agricultural production levels.

Conclusion

This analysis reveals that farmers with secure land tenure experience a substantial 77% increase in cereal production, in contrast to a 38% decline in the absence of such security. Land security significantly impacts farmers' choices, leading them to reduce the use of traditional seeds (-52.77%) and herbicides (-25.93%), both of which have a negative effect on production levels. This underscores the imperative need for investments in agricultural innovation, given the ever-growing demand for food.

Furthermore, the growth rate of cereal yields on secure plots where farmers have invested in animal traction is an impressive 84%. Conversely, yields on unsecured plots have fallen by 55%. A similar pattern emerges for investments in stone cordons, where plots with secure land tenure contribute to a remarkable 96% increase in cereal yields, while those with insecure tenure experience a 65% drop. These results underscore the vital role of land tenure security in the cereal production process, an essential component for effectively addressing the challenges of enhancing agricultural yields and, consequently, the well-being of rural farmers.

Hence, it can be theorized that the principal mechanisms through which land tenure security influences the cereal production process are long-term investments, such as stone cordons and animal traction. This notion aligns with the concept that enhancing the output of a production system necessitates the adoption of innovative technologies that have been developed within the sector. Conversely, optimizing the workforce provides farmers with substantial flexibility to engage in additional activities to meet social needs. These diverse findings imply the need for specific actions to be undertaken to boost cereal yields and, consequently, enhance the overall well-being of rural farming communities.

Economic policy implications

To transform the rural environment into an engine for growth and improved well-being, it is imperative to restructure the agricultural sector, with a specific focus on the cereals sector. Achieving this transformation necessitates a thorough understanding of the production behavior of all involved stakeholders to identify and address the barriers to sector development. The activities identified in this study must receive attention at every stage. Given that land serves as the primary basis for all production decisions, it is crucial to establish clear regulations for its management. This is essential for minimizing the risk of expropriation and encouraging increased investment.

To this end, a transparent collaboration between customary and state authorities should be instituted to oversee transactions and secure agricultural land, defining the respective roles and competencies of each party. Furthermore, the National Program for Land Security and the initiatives undertaken by the Millennium Challenge Corporation (MCC) should be sustained across the country. This would ensure that the positive externalities resulting from land tenure security reach as many farmers as possible.

The establishment of clear property rights through land tenure security would render long-term investments significantly more appealing. The decisions to adopt agricultural innovations like stone barriers and animal traction are contingent on the presence of land tenure security and the topographical arrangement of the plot. Consequently, once land tenure security is ensured, investment in stone cordons and animal traction should naturally experience resurgence, leading to a substantial increase in production levels.

It is imperative to strengthen the supply of technological innovations, such as animal traction and improved seeds, and make them available during agricultural seasons. The objective is to employ these innovations effectively in the production process, ultimately achieving the goal of enhancing agricultural yields.

Moreover, the findings highlight that farmers should not solely focus on increasing agricultural production but also consider the quality of that production. This dual requirement can be effectively addressed within the framework of secure property rights. The negative impact of NPK and the positive influence of organic fertilizer on the production process underscore the importance of this approach. Organic manure can serve as a substitute for NPK and should be promoted through extension campaigns, particularly because the use of organic manure witnessed a significant 59% decline between the 2010 and 2011 cropping seasons.

The government should encourage the use of organic manure by implementing a subsidy policy geared toward promoting this product, with a strong emphasis on local production like "Burkina phosphate." In the long run, this measure would not only foster the development of organic farming but also facilitate achieving production levels that align with international standards.

To meet this challenge, rural areas with high agricultural potential must be better connected, and marketing channels need to be developed. The State should increase the budget allocated to decentralized local authorities to enable them to effectively execute the objectives of the National Rural Sector Program, particularly in terms of rural road rehabilitation. Furthermore, enhancing the funds allocated to SONAGESS would allow the organization to procure sufficient quantities of agricultural produce, the surplus of which could be reused as seed in case of a shortage of high-yield seed. This would help reduce farmers' production costs.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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