Journal of Agricultural and Applied Economics (2023), **55**, 238–255
doi:10.1017/aae.2023.10

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Land Tenure Rights and Short- and Long-term Agricultural Practices: Empirical Evidence From Burkina Faso

Achille Augustin Diendéré and Jean-Paul Wadio

Thomas SANKARA University, Center for Economic and Social Studies, Documentation and Research (CEDRES), 12 BP 417 Ouagadougou, Burkina Faso
Corresponding author. Email: hchille@yahoo.fr

Abstract
This study examines the impact of land tenure rights on the adoption of short- and long-term agricultural practices and the impact of these practices on the income and food insecurity for rural households in Burkina Faso. The bivariate probit model and propensity score matching are used to analyze data collected from 4,398 rural households. The results show that ownership of permanent land rights only increases the likelihood of adopting long-term agricultural practices. In addition, adoption of short-term practices increases household income and reduces food insecurity, while adoption of long-term practices only increases household income.

Keywords: Burkina Faso; food insecurity; income; land tenure rights; long-term practices; short-term practices

JEL classifications: O13; Q15; Q16; Q18

1. Introduction

Agricultural practices for climate change adaptation are important means for addressing the vulnerability of rural households' livelihhoods in most developing countries (Tilman and Clark, 2014; Mwangi and Karriuki, 2015). In the face of an increasingly adverse climate, the adoption of water and soil conservation as well as agroforestry practices is expected to strengthen the resilience of local communities, thereby improving their incomes and food security (Van Ittersum et al., 2016).

Although these practices have the potential to strengthen the resilience of local communities while protecting the environment, their uptake remains low in many countries in sub-Saharan Africa (Kassie et al., 2020; Macours et al., 2010). Even though the economic literature reports on the importance of agricultural practices, factors influencing their adoption are less clear. In addition, little is known about the impact of these practices on the well-being of local communities. Following the economic theory of property rights (Commons, 1968; Ostrom, 1990; Schlager and Ostrom, 1992; Paavola and Adger, 2005), the property rights system plays a fundamental role in the behavior of common pool resource users. In particular, Schlager and Ostrom (1992) show the importance of distinguishing between property regimes, according to various bundles of rights that may be held, cumulatively, by natural resource users. The authors identify the following bundles of rights: access, extraction, management, exclusion, and alienation. Actors who have specific property rights to a resource are also confronted with more fundamental rules that affect the structure of the situations in which they are involved. Therefore, the challenge for farmers is to be granted certain types of rights in order to benefit from farm resources. Property rights systems vary considerably from one geographical area to another. In sub-Saharan Africa, two types of land rights often coexist in rural areas: permanent land rights and temporary land rights. The former are acquired by purchase, donation, or inheritance and are usually secured. In contrast, temporary land rights are acquired by lease or loan.

The empirical literature reaches conflicting conclusions about the relationship between land rights and the adoption of agricultural practices. On the one hand, insecure land tenure does not encourage farmers to invest because the risk of expropriation is high (Feder, 1987; Besley, 1995; Wang et al., 2018). Such risks discourage these farmers from intensifying their cropping systems to increase production. In the case of Zambia, Nkomoki et al. (2018) show that, given the risk of expropriation, households without permanent land use rights have a lower probability of adopting certain agricultural practices of crop rotation and agroforestry compared to households with such rights. Shittu et al. (2018) corroborates these results for developing countries overall. For Macours et al. (2010), insecure property rights over agricultural land reduces the performance of land markets, contributing to increased social inequality. The incentive to invest increases when the investor is convinced that a larger share of the final return on investment will be received (Besley, 1995). In contrast, Place and Hazell's (1993) research in Ghana, Kenya, and Rwanda concludes that land rights are not determinants of agricultural investment. Along the same lines, Festus et al. (2020) argue that land rights alone do not determine investment dynamics. They explain that a number of farmers, including those without land tenure rights, have made different types of investments in sustainable land management (soil fertility improvement, tree planting, and conservation of specific plant species). Brasselle et al (2002) in Burkina Faso and Deininger and Jin (2006) in Ethiopia also question the existence of a systematic influence of secure use rights on agricultural intensification and agroforestry and show that increased land rights do not appear to stimulate investment. This result is consistent with Smucker et al. (2000) in the case of agricultural producers in Haiti.

Burkina Faso is an interesting example to study this issue. Indeed, the country faces the negative effects of climate change, which translates into low agricultural incomes and pronounced food insecurity. According to FAO (2013), in addition to the precarious climatic conditions that the country faces, the low diffusion of sustainable agricultural practices is another factor that hinders the development of the agricultural sector. Furthermore, the land tenure system in Burkina Faso is highly unstable and faces enormous challenges. While customary and modern law coexist in rural areas, the prevailing of customs is unfavorable to some disadvantaged groups.

In an effort to improve the performance of the national agricultural system, Burkina Faso has undertaken an agrarian reform program since 2009 that allows producers to acquire secure land ownership rights. The 2009 land tenure reform aims to improve access to land for vulnerable groups and by guaranteeing the land ownership necessary to stimulate agricultural activity However, Séogo and Zahonogo (2019) and Zahonogo (2016) point out that insecure land tenure is still a growing problem and one of the causes of rural poverty in Burkina Faso.

To better understand the relationship between land security and agricultural investments, a closer analysis of the empirical studies presented above seems to indicate the need to consider not only the complexity of the context under study but also the specificities of agricultural practices. In the case of Burkina Faso, practices used by farmers can be specified according to their implementation period and/or their expected benefits. These practices can be short term or long term. The water and soil conservation practices (Zaï, half-moon farming, and stone cordons) can be considered short-term agricultural practices in the sense that the implementation period of realization and/or the expected benefits are immediate. In the Zaï technique, small holes with a diameter of 20–30 cm and a depth of 10 cm are dug, where organic material and seeds are put. In the half-moon technique, holes are also dug in the shape of a half-moon, following the slope and contours of the soil. Both Zaï- and half-moons increase water infiltration, enable rehabilitation of degraded land, and reduce erosion. Stone cords are a series of stones placed along the contour lines of a site to reduce the velocity of stormwater runoff. Long-term agricultural practices require a longer period of time to be implemented and benefits take more time to be ripped. Agroforestry is one of these long-term agricultural practices. Agroforestry refers to the association of trees and other woody perennial species with crops or pastures to benefit from ecological and economic interactions. It mitigates land degradation, maintains the productive capacity of the ecosystem, and combats deforestation and global warming while providing timber and nontimber forest services. In the rest of the document, practices with an immediate period of achievement and/or expected benefit are called short-term practices. Practices that require a longer period of time to achieve and benefit from are referred to as long-term practices. Farmers can adopt both short-term and long-term practices simultaneously. Therefore, research should not preclude the possibility that short-term and long-term technology choices may be interrelated. In addition, more thorough research on the impact of these practices on household income and food insecurity is essential. The objectives of this study are twofold. First, to analyze the impact of land tenure rights on the adoption of short- and long-term agricultural practices in Burkina Faso, taking into account their potential complementarity. Second, to assess the impact of these agricultural practices on the income and food insecurity of rural households.

To investigate the possibility of joint decisions in the choice of short- and long-term agricultural practices, a bivariate probit model is used. This model provides an appropriate analytical framework to avoid various biases in the estimation of analytical models. If such a possibility of joint choices is ignored, the influence of property rights on the choice decision could be underestimated or overestimated. Given the unique characteristics of agricultural practices, we assume that both short-term and long-term practices, as well as their potential complementarity, must be considered when analyzing the impact of land ownership rights on the adoption of these agricultural practices. The propensity score matching (PSM) method is then used to estimate the impact of short- and long-term agricultural practices on household income and food insecurity. The interest of this method lies in the intent to avoid identification problems that arise from a simple comparison of households that adopt these different practices and those that do not.

The remainder of the paper is organized as follows. Section 2 presents the methodological approach. Section 3 presents the results on the drivers of technology adoption and the impact of these practices on income and food insecurity. Section 4 provides policy implications.

2. Methodology Design

After specifying the data sources for this study, this section presents the two methods for data analysis: the bivariate probit model and PSM.

2.1. Data Source

The data used in this study are from the database of the Ministry of Agriculture and Hydro-Agricultural Development (MAAH) of Burkina Faso. They come from the results of the Permanent Agricultural Survey (EPA) conducted in 2019. The EPA is a production survey for agricultural data which main purpose is to estimate annual production volumes. It provides decision-makers with forecasts of grain harvests by state and postharvest estimates of agricultural production by commodity and state. All the information used in the analysis comes from a single database. The survey aims to collect detailed information on the socioeconomic characteristics of households, farm characteristics, farming techniques used, food, and nutritional security. It also provides estimates for key food and nutrition security indicators. The survey covers farm households in all 45 provinces of Burkina Faso. The sampling procedure is a two-stage, stratified procedure. In the first stage, primary units (villages) are drawn with probability proportional to the number of farm households and without replacement. In the second stage, secondary units (households) are selected by simple random drawing without replacement. Each household in the same primary unit has the same probability of appearing in the sample. The survey included a nationally representative sample of approximately 5,304 farm households, representing three households in each of the 1768 villages. Credibility is measured by the 95% confidence level.

The sample selected concerns heads of households engaged in agriculture. Similarly, the southwestern region was removed from the database due to numerous missing data. This restriction yields 4,398 agricultural households distributed in 1,466 villages, i.e., three agricultural households per village.

2.2. The Bivariate Probit Model as a Method for Analyzing the Determinants of Agricultural Technology Adoption

To consider the possible interdependence in the adoption of agricultural practices, two types are distinguished: short-term agricultural practices (Zaï, half-moons, and stone cords) and long-term practices (agroforestry). This interrelationship between technology adoption decisions accounts for multiple resource problems by adopting practices that provide the greatest economic benefits to farmers. The analysis is based on the fact that the decision to adopt short-term cropping practices may not be an independent decision, but rather an interdependent one; the two common decisions may be correlated.

Unlike the univariate probit model, the bivariate probit model allows the joint estimation of the probabilities of two events, taking into account the possible relationship between the error terms of the two estimated equations (Greene, 1996). The correlation between the adoption of agricultural practices indicates either complementarity (positive correlation) or substitutability (negative correlation). Treating separately the decision to adopt agricultural practices would lead to biased estimates because the univariate probit model ignores the correlation between disturbances in the underlying stochastic utility function associated with short- and long-term practices (Greene, 1996). The two dichotomous response variables, Y_1 and Y_2, are coded 1 if the farmer adopts at least a short- and/or long-term agricultural technology and 0 if he adopts none of the practices. The bivariate probit model is specified as follows:

$$\{Y_1^* = a_1\mathrm{DP}_1 + X_1\beta_1 + \varepsilon_1 \quad (1)$$

$$\{\ Y_2^* = a_2\mathrm{DP}_2 + X_2\beta_2 + \varepsilon_2 \quad (2)$$

The two errors are assumed to be independent of the explanatory variables X_1 and X_2. The observed dichotomous results are specified as follows:

$$Y_1 = \begin{cases} 1 & siY_1^* > 0 \\ 0, & otherwise \end{cases} \quad (3)$$

$$Y_2 = \begin{cases} 1 & siY_2^* > 0 \\ 0, & otherwise \end{cases} \quad (4)$$

Where y_1* and y_2* represent the unobserved utilities associated with the adoption of the short- and long-term agricultural practices, respectively; DP_1 and DP_2 represent the permanent property rights in each of the equations; X_1 and X_2 are vectors of potential explanatory variables that influence the decision to adopt a particular technology (control variables); a_1; a_2; β_1 and β_2 are vectors of the associated parameters to be estimated. In this model, the stochastic errors, ϵ_1 and ϵ_2 are assumed to be normally distributed with:

$$\begin{cases} \varepsilon_1 = \eta_t + \mu_1 \\ \varepsilon_2 = \eta_t + \mu_2 \end{cases} \quad \text{where} \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} = \mathrm{var}(0, \Sigma)\text{with } \Sigma = \begin{bmatrix} 1 & \rho_{1,2} \\ \rho_{2,1} & 1 \end{bmatrix} \quad (5)$$

The errors in these two equations consist of a part (ηi) that is common to both and a part that is unique to each equation (μ_{1i} and μ_{2i}) ; μ_{1i} and μ_{2i} are assumed to be zero mean, independent of the explanatory variables, and normally distributed. The related ϵ_{1i} and ϵ_{2i} have a bivariate normal distribution that hides several simultaneous choices and can be derived from the joint distribution of y_1 and y_2 on condition of X_1 and X_2. These joint probabilities can be identified as follows:

$$Pr(Y_1 = 1, Y_2 = 1|X_1, X_2) = \Pr(\varepsilon_1 > -X_1\beta_1, \varepsilon_2 > -X_2\beta_2) = \varphi_2(X_1\beta_1, X_2\beta_2, \rho) \quad (6)$$

$$Pr(Y_1 = 1, Y_2 = 0|X_1, X_2) = \Pr(\varepsilon_1 > -X_1\beta_1, \varepsilon_2 < -X_2\beta_2) = \varphi_2(X_1\beta_1, -X_2\beta_2, -\rho) \quad (7)$$

$$Pr(Y_1 = 0, Y_2 = 1|X_1, X_2) = \Pr(\varepsilon_1 < -X_1\beta_1, \varepsilon_2 > -X_2\beta_2) = \varphi_2(-X_1\beta_1, X_2\beta_2, -\rho) \quad (8)$$

$$Pr(Y_1 = 0, Y_2 = 0|X_1, X_2) = \Pr(\varepsilon_1 < -X_1\beta_1, \varepsilon_2 < -X_2\beta_2) = \varphi_2(-X_1\beta_1, -X_2\beta_2, \rho) \quad (9)$$

Where Pr denotes the probability and ϕ2 represents the bivariate standard normal cumulative distribution function. Using the maximum likelihood method, the log-likelihood function of the bivariate probit model is given by

$$lnL(\beta_1, \beta_2, \rho) = \sum Y_1 Y_2 ln\varphi_2(X_1\beta_1, X_2\beta_2, \rho) + \sum Y_1(1 - Y_2) ln\varphi_2(X_1\beta_1, -X_2\beta_2, -\rho)$$
$$+ \sum (1 - Y_1) Y_2 ln\varphi_2(-X_1\beta_1, X_2\beta_2, -\rho) + \sum (1 - Y_1)(1 - Y_2) ln\varphi_2(-X_1\beta_1, -X_2\beta_2, \rho) \quad (10)$$

The correlation coefficient Rho (ρ) is interpreted as the correlation between the adoption decisions of a short-term pratique and a long-term pratique. If $\rho = 0$, then the errors are independent and the two decisions are uncorrelated. If $\rho \neq 0$, then the errors and the decisions are correlated and the probability of adopting a short-term technology depends on the probability of adopting a long-term technology. The coefficient ρ allows analyzing the dependence or synergistic relationship between the adoption of agricultural practices as a function of the technical complexity of each process. When rho is positive and significantly different from zero, there is a complementary relationship between short-term and long-term agricultural practices. When rho is negative, there is a relationship of substitutability. The specified model is presented as a system of equations:

$$\begin{aligned} Adoption(Y_1) = {} & \beta_0 + \beta_1 Landright + \beta_2 Gender + \beta_3 Age + \beta_4 Age^2 + \beta_5 Literacy \\ & + \beta_6 Householdsize + \beta_7 Surface + \beta_8 MFO + \beta_9 IGA + \beta_{10} Training \\ & + \beta_{11} Relief + \beta_{12} Collman + \beta_{13}\, Paidlabor + \beta_{14} Credit + \beta_{15} Seed + \varepsilon_1 \end{aligned} \quad (11)$$

$$\begin{aligned} Adoption(Y_2) = {} & \mu_0 + \mu_1 Landright + \mu_2 Gender + \mu_3 Age + \mu_4 Age^2 + \mu_5 Literacy \\ & + \mu_6 Householdsize + \mu_7 Surface + \mu_8 MFO + \mu_9 IGA + \mu_{10} Training \\ & + \mu_{11} Relief + \mu_{12} collman + \mu_{13}\, Paidlabor + \mu_{14} Credit + \mu_{15} Seed + \varepsilon_2 \end{aligned} \quad (12)$$

Variables are described in Table 1.

In addition to the bivariate probit model, an impact analysis method is used.

2.3. PSM as a Method for Analyzing the Impact of Practices on Income and Food Insecurity

Several methods can be used to analyze the impact of agricultural technology adoption on household income and food security. The PSM method (Rubin, 1977; Rosenbaum and Rubin, 1983) is used in this study. Its basic principle is to create a comparison group by matching adopters of agricultural practices with similar nonadopters based on predicting their likelihood of participating to the intervention or program. This is called a propensity score, which is calculated using several observed characteristics. The PSM is used to estimate the average treatment effect (ATE) of short- and long-term adoption of agricultural practices on income and food insecurity. In this case, treatment households (farmers who have adopted the practices) are compared to control households (who have not adopted the practices). More specifically, the technique involves selecting for each farmer *i* in the user subpopulation a farmer *j* in the nonuser subpopulation with the same characteristics as farmer *i* based on pretreatment observable characteristics and then measuring the average difference in the outcome variable between users and nonusers.

Table 1. Description of model variables

Variables	Description
Dependent variables	
Zaï	1 if the household head adopts, 0 otherwise
Stone cords	1 if the household head adopts, 0 otherwise
Half-moon	1 if the household head adopts, 0 otherwise
Agroforestry	1 if the household head adopts, 0 otherwise
Independent variables	
Landright	1 if the household head has permanent property rights, 0 otherwise
Gender	1 if the household head is a man, 0 otherwise
Age	Age of household head (year)
Literacy	1 if the household head is literate, 0 otherwise
Householdsize	Number of people in the household
Surface	Cultivated area (hectares)
MFO	1 if the household head belongs to a farmers' organization, 0 otherwise
IGA	1 if the head of the household has an income generating activity, 0 otherwise
Training	1 if the household head has received agricultural training, 0 otherwise
Relief	1 if the relief of the parcel is plains/plateaus, 0 shallows
Collman	1 if the parcel is managed collectively, 0 individual
Paidlabor	1 if the household head employs paid labor, 0 otherwise
Credit	1 if the household head has access to agricultural credit, 0 otherwise
Seed	1 if the household head uses local seeds, 0 otherwise

The PSM method is a robust impact evaluation method that should be used when extensive data are available. The results of applying PSM are only valid if all important characteristics are observable and included. Otherwise the results may be biased. A bivariate probit model is used in which the adopters of short-term and long-term practices are explained by several preparatory characteristics. The preprocessing characteristics of the model are: the variables used must be observable; the sample size must be large; the existence of two groups of individuals and the individuals in the untreated group must be greater than those in the treated group. Then, the predictions from this estimation are used to create the propensity score, which varies from 0 to 1. Here, the Propensity Score is estimated as the probability of adopting a short-term and long-term technology using vector X as the conditional factor. The equation for the score is as follows:

$$PS = P(D = 1|X) \tag{13}$$

P (.): the probability; D: the participation indicator; X: the conditioning factor
1|X : denotes the farmer's decision to adopt a given agricultural technology, given observable characteristics.

The ATE measures the average impact of an innovation on a sample as a whole and represents the expected impact on a randomly selected individual in the sample. It is defined as follows:

$$ATE = E(Y_{1i} - Y_{0i}) = E(Y_{1i}) - E(Y_{0i}) \tag{14}$$

https://doi.org/10.1017/aae.2023.10 Published online by Cambridge University Press

$E(.)$ denotes the expectancy; Y_{1i} represents the observed outcome for the adopting farmer i and Y_{0i} the observed outcome for the non-adopting farmer.

The ATE on the Treated (ATT) determines the average impact of an innovation in the sub-population of treated individuals. Here, it represents the expected impact on a randomly selected user among farmers who adopted the agricultural practices.

$$ATT = E(Y_{1i} - Y_{0i}|T_i = 1) = E(Y_{1i}|T_i = 1) - E(Y_{0i}|T_i = 1) \quad (15)$$

Short-term and long-term agricultural practices are the treatment variables, while income and food insecurity are the outcome variables. The average total income of the household head is approximated by his or her total consumption expenditures on food (groceries, beverages, etc.) and nonfood items (health, education, inputs, etc.).

$$Y_i = \sum y_{i,k} \quad (16)$$

Where Y_i is the overall average income of the farm household head and $Y_{i,k}$ is the average income by type of good consumed. Incomes are valued in dollars for the purposes of this research.

Food consumption indicators are intended to provide quantitative or qualitative information on household diets. According to the World Food Program (WFP), the most commonly used indicator for assessing the accessibility dimension of food security is the food consumption score. This is a proxy indicator that reflects dietary diversity and the caloric value of the food consumed. The Food Consumption Score (FCS) is determined using a questionnaire consisting of eight food groups. Each food group has a specific weighting that determines the energy value of the food. This is done by multiplying the number of days a particular food group was consumed by the weight of the corresponding group. Foods are classified by food groups and the respective consumption frequencies for each of these groups are added. The FCS is calculated according to the following formula:

$$SCA = \sum x_i a_i \quad (17)$$

With $\boldsymbol{x_i}$ the number of days of consumption for each food group and $\boldsymbol{a_i}$ the weight assigned to food group i ($i = 1, \ldots, 8$). $\boldsymbol{a_1} = 3$ for pulses; $\boldsymbol{a_2} = 2$ for cereals and tubers; $\boldsymbol{a_3} = 1$ for vegetables; $\boldsymbol{a_4} = 1$ for fruits; $\boldsymbol{a_5} = 4$ for meat and fish; $\boldsymbol{a_6} = 4$ for milk; $\boldsymbol{a_7} = 0.5$ for sugar; $\boldsymbol{a_8} = 0.5$ for oil.

2.4. Descriptive Statistics for Variables Affecting the Adoption of Agricultural Practices

Table 2 presents the descriptive statistics for the variables in the model. The statistics for the demographic variables show that, on average, 52.28% of farmers are male. In addition, 26.17% of the sampled households are literate in at least one national or French-Arabic language. Farmers' age varies from 16 to 79 years with an average age of 49 years. The households' size varies from 1 to 63 with an average of 11 people. The phenomenon of population growth combined with soil degradation is forcing more and more households to farm on plots averaging 0.54 hectares with a maximum area of 22.32 hectares.

In terms of the agricultural practices studied, the adoption rate of short-term practices is 15.88%. Of the total sample, only 17.1% of households have adopted stone cords, 16.21% have adopted Zaï, and 14.34% have adopted half-moon far. Similarly, 10.7% of the sampled households have adopted the long-term agricultural technology of agroforestry.

Statistics also indicate that 61.3% of the surveyed households have permanent property rights. Of these households, 10.85% have adopted agroforestry, while 49.43% use short-term practices. In addition, more than half of the farms are collectively managed. In fact, 52.31% of farms are collective farms, and of these collective farms, 7.2% of households have adopted short-term practices and 11.2% have adopted long-term practices.

Table 2. Descriptive statistics for variables

Variables	Mean	Min.	Max.	Standard deviation	Short-run practices (%)	Long-run practices (%)
Dépendent variables						
Zaï	0,162	0	1	0,005		
Stone cords	0,170	0	1	0,005		
Half-moon	0,143	0	1	0,005		
Agroforestry	0,107	0	1	0,004		
Indépendant variables						
Landright	0,613	0	1	0,007	0,494	0,108
Gender	0,522	0	1	0,007	0,459	0,114
Age	49,61	16	79			
Literacy	0,261	0	1	0,006	0,512	0,141
Householdsize	11,32	1	63			
Surface	0,542	0,10	22,32			
MFO	0,288	0	1	0,006	0,523	0,143
IGA	0,374	0	1	0,007	0,519	0,110
Training	0,348	0	1	0,007	0,509	0,151
Relief	0,817	0	1	0,005	0,478	0,086
Collman	0,523	0	1	0,007	0,457	0,084
Paidlabor	0,107	0	1	0,004	0,458	0,080
Credit	0,155	0	1	0,005	0,520	0,161
Seed	0,877	0	1	0,004	0,471	0,107

In addition, more than a quarter of the households in the sample are members of a farmers' organization, while 35% report having received agricultural training. The statistics also show that 10.75% of the sample employ paid labor on their farms and 28.89% are members of a rural producer organization. Of the farmers who belong to producer organizations, 52.35% have adopted at least one short-term technology and 14.38% have adopted agroforestry. In addition, the statistics show that 15.54% of the sample received credit during the last agricultural year. 52.01% of the farmers who received credit adopted short-term practices and 16.13% of these beneficiaries' practiced agroforestry. The majority of farmers use local seeds on their farms (87.77%).

The following section presents and discusses findings of the econometric estimates.

3. Findings and Discussion

First, the interaction effects are examined and then the direct effects are discussed. The results of the impact assessment are then presented.

3.1. Interaction Effects Between Short-term and Long-term Technology Adoption

Before presenting the results, it is important to check the validity of the bivariate probit model. The Wald test uses the Chi^2 statistic with the null hypothesis H_0 that the coefficients associated with the explanatory variables are simultaneously equal to zero against the alternative hypothesis H_1 that at least one of the coefficients is nonzero. The results show that the probability associated

https://doi.org/10.1017/aae.2023.10 Published online by Cambridge University Press

with the nonsignificance of the Chi^2 statistic is zero, so the null hypothesis H_0 is rejected. Thus, the model is significant overall. In addition, we tested for possible multicollinearity problems by running linear auxiliary regressions with the independent variables in each of the equations for short-term and long-term adoption of agricultural technology. The variance inflation factors showed no problem with multicollinearity bias ($VIF < 5$).

An important result of this research is the significance of the correlation coefficient in two systems of equations (Table 3). In particular, the analysis of the correlation coefficient shows that there is a significant relationship between the adoption of some short-term practices, namely Zaï and half-moon, and the adoption of the long-term technology, namely agroforestry. In particular, the correlation coefficient between the adoption of Zaï and agroforestry is significant and positive ($Rho = 0.217$). This result indicates the existence of synergy and complementarity between the adoption of Zaï and agroforestry. The complementarity between these two practices could be explained by the fact that the presence of trees provides organic material necessary for the application of Zaï. This indicates that there are real biophysical and economic synergies between the adoption of these two practices. This complementarity would allow farming households to balance their consumption needs and avoid famine due to climatic uncertainties.

The correlation coefficient between the simultaneous introduction of half-moon farming and agroforestry is negative ($Rho = -0.117$), unlike the previous one. Such a result might suggest that farmers perceive tradeoffs or view these practices as substitutes. These tradeoffs could take the form of competing needs for short-term return on investment rather than long-term investment. In addition, in Burkina Faso, the practice of agroforestry is not yet well established in farmers' habits, so agroforestry should not be given priority over intensive agricultural practices, particularly that of half-moons. Indeed, farmers are likely to allocate more investment to short-term farming techniques than to waste their time on long-term techniques. Also, because half-moon techniques are generally larger and have a relatively greater water storage capacity than Zaï techniques, the presence of trees could reduce water storage, or could be an obstacle to their implementation.

In contrast, the results show a nonsignificant correlation between the use of stone cords and the use of agroforestry. This result could be explained by the fact that the use of these two practices is not only costly but also requires a lot of time, material, and physical effort.

3.2. Determinants of Short- and Long-term Agricultural Practices Adoption

The analysis in Table 3 shows the differential effects of property rights and other factors on the likelihood of adopting short- and long-term practices. After examining the effects of property rights, the other adoption factors are discussed.

3.2.1. Land Tenure

Importantly, in each of the three models, ownership of permanent land rights is significantly and positively correlated with adoption of long-term technology, but has no significant effect on adoption of short-term practices. Specifically, ownership of permanent land rights increases the likelihood that the household adopts agroforestry, but has no effect on the decision to adopt the short-term practices of Zaï, half-moon, and stone cords. These results may be explained by the fact that land rights in Burkina Faso are still dominated by the customary system, in which nonlandowners are not allowed to plant trees or make improvements that would allow them to gain a foothold on the land. This is because the customary system allows households that do not own land to intensively use the land, but provides little incentive to make certain investments aimed at improving the land in a sustainable way. An outsider often interprets the planting of trees as an assertion of permanent right and ownership of the land. Landowners therefore resist this situation.

https://doi.org/10.1017/aae.2023.10 Published online by Cambridge University Press

Table 3. Econometric estimates with the bivariate probit model

	Model 1		Model 2		Model 3	
Variables	Zaï	Agroforestry	half-moon	Agroforestry	Stone cords	Agroforestry
Landright	−0,058 (0,054)	0,121** (0,056)	0, 0530 (0,056)	0,127** (0,056)	0,216*** (0,050)	0,129** (0,057)
Gender	−0,024(0,050)	0,118** (0,052)	−0,006 (0,051)	0,115** (0,052)	−0,049 (0,045)	0,115** (0,052)
Literacy	0, 015 (0,056)	0, 232*** (0,058)	−0,093 (0,057)	−0,227*** (0,058)	0,022 (0,052)	0,227*** (0,058)
Householdsize	−0, 002 (0,003)	−0,010*** (0,003)	0,002 (0,003)	−0,010*** (0,003)	0,002 (0,003)	−0,009** (0,003)
Age	0, 400*** (0,026)	0,076*** (0,016)	0,204*** (0,022)	0,075*** (0,016)	−0,073*** (0,013)	0,075*** (0,016)
Age^2	−0,004***(0,000)	−0,000***(0,000)	−0,002***(0,000)	−0,000***(0,000)	−0,000***(0,000)	−0,000***(0,000)
Surface	0,013 (0,027)	−0,021 (0,031)	0,007 (0,026)	−0.021 (0.031)	−0,065** (0,029)	−0,020 (0,031)
Collman	0, 014 (0,053)	−0,266*** (0,055)	0,037 (0,054)	−0,276*** (0,055)	−0.164*** (0.048)	−0.277*** (0.055)
Relief	−0,180*** (0,063)	−0,043*** (0,061)	0,331*** (0,071)	−0,448*** (0,061)	0,102* (0,059)	−0,450*** (0,061)
MFO	−0, 336*** (0, 064)	0,139*** (0,061)	0,252*** (0,058)	−0,145** (0,061)	−0,166*** (0,056)	0,144** (0,061)
IGA	−0, 094* (0,052)	−0,063 (0,055)	0,088* (0,052)	−0,067 (0,055)	−0,023 (0,047)	−0,066 (0,055)
Training	0, 307*** (0,056)	0,287*** (0,058)	−0,178*** (0,058)	0,285*** (0,058)	−0,080 (0,053)	0,285*** (0,058)
Paidlabor	−0,025 (0,086)	−0,145 (0,094)	−0,051 (0,084)	−0,144 (0,094)	0,009 (0,077)	−0,143* (0,094)
Credit	0,177**(0,074)	0,1843**(0,074)	−0,219***(0,077)	0,180**(0,074)	0,118**(0,070)	0,181**(0,074)
Seed	0,032(0,078)	0,026(0,082)	−0,039(0,077)	0,023(0,082)	−0,029(0,068)	0,025(0,082)
Intercept	−8, 620***(0,598)	−2,872*** (0,410)	−4,847***(0,492)	−2,860*** (0,408)	−2,560*** (0,330)	−2,864*** (0,408)
Rho (ρ)	0, 217*** (0,042)		−0, 117** (0,045)		0,003(0,039)	
LR test rho = 0	27,026***		6,587**		0,010	
Wald chi2	552,60		463,33		283,27	
Prob >chi2	0,000		0,010		0,919	
Obs.	4,398		4,398		4,398	

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Values in parentheses denote standard deviations.

In addition, the existence of sunk costs for farmers without permanent rights and the complexity of the technology could also justify this fact. Indeed, in addition to its duration, agroforestry is a difficult and costly technique, unlike half-moon and Zaï. The existence of sunk costs, such as not being able to dig up trees in the event of eviction, may discourage farmers without rights from practicing agroforestry. A household that does not have permanent land rights is therefore less likely to make a long-term investment because the risk of expropriation is high long before it can truly benefit. Thus, for a household to have an incentive to engage in agroforestry, it must have permanent land rights. This conclusion is consistent with the findings of Lawry et al. (2014) and Delville (2006) supporting that secure land rights allow farmers to work and invest in their farms in the hope of reaping the benefits without fear of arbitrary expropriation of their land. Secure land rights likely reduce the risk of appropriation of the investment in the future before all benefits are harvested. In contrast, the acceptance of short-term investments does not appear to depend on the possession of permanent land rights. For this type of investment, even if the household were to be displaced, it would bear fewer implementation costs than for a long-term investment.

3.2.2. Age of the Household Head

The age of the household head is an important determinant of both short-term and long-term adoption of agricultural practices. The results show that older farmers have a higher probability of adopting agricultural practices compared to younger farmers. This result could be explained by the fact that older farmers have more experience with practices than younger farmers. However, the results show that this probability decreases after 54 years old.

3.2.3. Gender of the Household Head

Table 3 shows that the gender of the household head is a significant variable only for the adoption of agroforestry, but not for the adoption of short-term practices. This result holds for all three models. The results of the econometric estimates show that men are more likely to adopt a long-term technology compared to women. Such a result is consistent with the findings of Drucza and Peveri (2018) and Po and Kickey (2018). It is understandable that men are more likely to be the holders of land tenure rights that allow them to make long-term investments in land. Unlike men who own land rights and pass them from father to son, women are among the vulnerable groups who face more difficulties in accessing land. Rural women are discriminated against in terms of land, which prevents them from adopting agricultural practices, especially long-term ones. Such land discrimination can also be at the root of other forms of discrimination, notably discrimination in access to credit.

3.2.4. Agricultural Credit

The results of the econometric estimations reveal that access to agricultural credit is a determinant of the adoption of short-term and long-term agricultural practices. Indeed, farmers who have received credit in the last 12 months are more likely to adopt short-term and long-term agricultural practices than farmers who have not received any credit. This result is similar to that of Garzon-Delvaux et al. (2020). This result implies that access to credit is a very important factor in alleviating the liquidity constraints of smallholder farmers in financing agricultural operations. Indeed, the adoption of zaï, half-moon, stone cordon, and agroforestry practices requires substantial financial resources. Thus, access to credit increases opportunities and provides a channel of financing to farmers for the purchase of inputs and complementary materials essential to the adoption of these agricultural practices.

3.2.5. Household Size and Level of Literacy

The results of the econometric estimations show that for each of the three models, a high number of people in the household reduces the probability of adopting agroforestry. This result is inconsistent with the theoretical predictions, as the adoption of agroforestry practices requires both skilled and unskilled labor to restore and maintain soil fertility. However, this result could be explained by the significant migration of agricultural labor to nonagricultural activities observed in recent years. This result could also be due to the high number of people to feed, which may lead households to turn to intensive agriculture instead of taking time to produce and reap the long-term benefits of implementing agroforestry.

Compared to household size, literacy also only affects long-term technology adoption, but in the opposite way. Literacy appears to be important in accelerating the adoption of agricultural practices. It likely improves households' perceptions of practices, and agroforestry in particular, and enables them to understand the benefits of adoption. This result is consistent with the findings of Deressa et al. (2009) and Huffman (2020).

3.2.6. Membership in a Farmer Organization (MFO)

In all three models, membership in a farmers' organization significantly increases the probability of adopting the pratique in the long run. This result is consistent with that of Diendéré (2019). Indeed, membership in a farmers' association offers many benefits. These benefits include the provision of certain agricultural materials and seeds by the government or NGOs. In addition, the farmers' organization is an ideal channel for sharing experiences and information for households on best practices for adopting agricultural practices.

3.2.7. Income-generating Activities (IGAs)

The results in Table 3 show that engaging in income-generating activities only positively affects the adoption of half-moon. This result is consistent with previous research by Savadogo et al. (1998), which indicated that income-generating activities are an important source of financing for farmers as an additional source of income. This additional income helps farmers to cover the cost of applying short-term practices; especially half-moon cropping, through the purchase of equipment (carts, shovels, hoes, etc.) and inputs (chemical or organic fertilizer) needed to apply half-moon cropping and increase agricultural productivity. On the other hand, the results indicate that the practice of income-generating activities has a negative impact on the adoption of Zaï. In other words, farm households with off-farm income sources such as trade are less likely to adopt Zaï than those without off-farm income sources.

3.2.8. Agricultural Extension

Agricultural extension plays a key role in the adoption process for both short-term and long-term practices. These results confirm those of Rodriguez-Entrena and Arriaza (2013), which show, for instance, that training and extension are among factors that encourage or compel farmers to adopt agroforestry. Indeed, agroforestry practices are not yet firmly entrenched in farmers' habits in Burkina Faso. Agricultural extension allows farmers to become better informed and equipped on the techniques and knowledge of these practices. According to Teklewold et al. (2013), agricultural extension encourages farm households to promote sustainable production systems and promotes access to more relevant information and knowledge. Agricultural training generally focuses on strengthening farmers' knowledge and skills through dialog, experience sharing, advisory support, information/awareness raising and monitoring of producers. Future research would benefit from estimating the probability of adoption by taking into account the specificities and contents of agricultural training.

3.2.9. Collective Plot Management

A plot is said to be collective if all active members are required to work on it first. Any plot that is not collective is said to be an individual plot, i.e., operated by a single member or a subgroup of the household (a brother and his children, for example, in a household with several brothers). If all members except the women work the plot, it is considered a collective plot. This variable has a differential effect on pratique adoption. Collective management decreases the probability of adopting the long-term technology, while it does not contribute significantly to the adoption of the short-term practices of Zaï and half-moon farming. This result shows that the self-interested behavior of the economic agent seems to make him more efficient individually than collectively. It also shows that collective management of the plot reduces the probability of adopting stone barriers. This negative effect of collective management on stone cords adoption could be related to the study area. Indeed, stone cords are mainly adopted on sloping land or slopes. The study area covers the whole territory and the sample descriptive statistics show that more than 81% of the relief consists of plains/plateaus. Due to the dominance of plains/plateaus, the use of stone cords may not be appropriate in many areas.

3.2.10. Relief of the Parcel

It is also found that the relief of the plot is a key factor in the adoption of both short-term and long-term agricultural practices. However, this variable has differential effects on the likelihood of adopting different types of agricultural practices. Plains/plateaus significantly reduce the likelihood of household adoption of agroforestry compared to lowlands. Plains/plateaus are often communal lands with stony, shallow, low-fertility soils, which may make agroforestry difficult to practice, as opposed to lowlands, which are deep and more fertile. The lowlands are generally managed individually in the dry season for off-season crops. In addition, the plains/plateaus appear to be positively correlated with the adoption of half-moons and stone cordons. Such a result indicates that short-term agricultural practices (half-moons and stone barriers) are practices that are primarily carried out on dry, low-fertility land with low rainfall.

3.3. Estimating the Impact of Technology Adoption on Household Income and Food Insecurity

A diagnostic test of matching quality is carried out after matching to estimate standard errors and treatment effects. Similarly, balance tests are conducted to estimate matching quality, mean absolute bias, t-statistics, and reduction in bias before and after matching (Becker and Ichino, 2002; Caliendo and Kopeinig, 2008). The indicators of covariate balancing show that the results obtained for covariate balancing after matching and the application of the common support are satisfactory.

The PSM allows assessing the impact of short- and long-term adoption of agricultural practices on food security and household income. Figures 1 and 2 show the distributions of propensity scores of adopters and nonadopters of short-term and long-term practices. The distribution of propensity scores is over a large common support, so that each adopter finds at least one nonadopter with a similar propensity score.

The results of the PSM estimates (Table 4) show that the coefficients of the ATE are positive, significant for the propensity score and not significant for the nearest neighbor match. These results show that across the entire sample, households that adopt short-term practices are likely to increase their income by $26.26 compared to households that do not adopt any of these practices. Similarly, the coefficients on the ATE on Treated (ATT) are positive and significant for the Propensity Score, and not significant for the Nearest Neighbor Match. This result implies that the adoption of short-term practices increases household income by $29.98 above the sample average income.

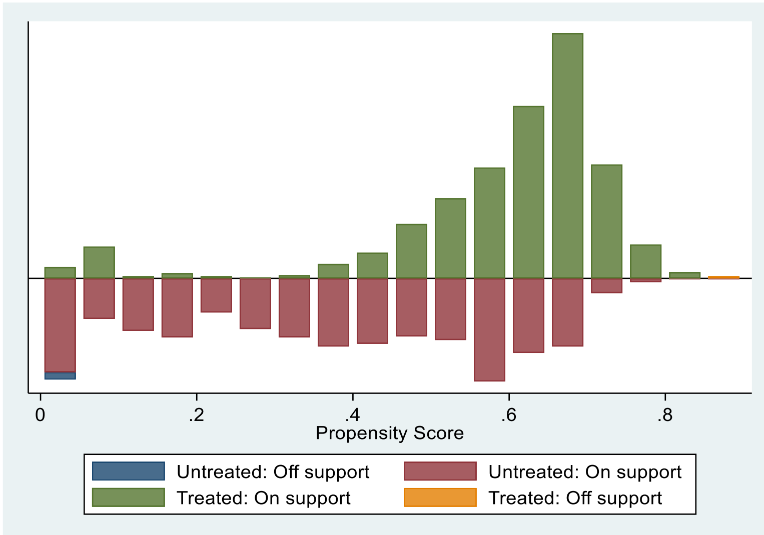

Figure 1. Propensity score distribution: short-term practices.

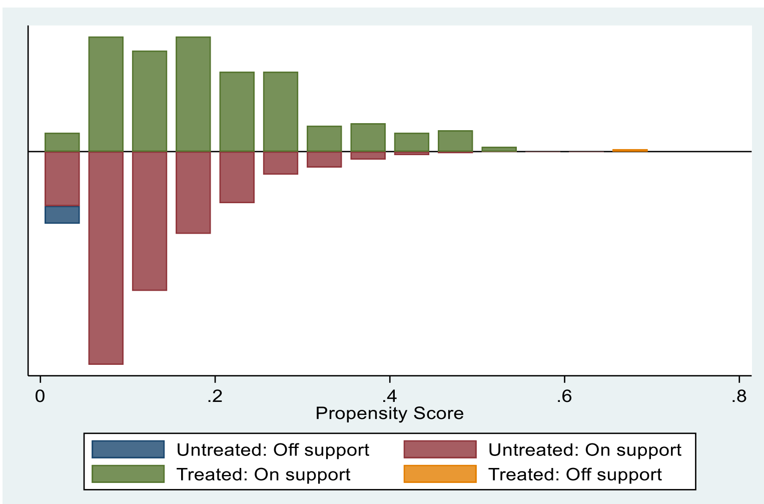

Figure 2. Propensity score distribution: long-term practice (agroforestry).

On the other hand, the results in Table 4 suggest a negative impact of the adoption of short-term practices on household food insecurity. These results reflect that households that adopt short-term practices are more likely to reduce their food insecurity than households that do not. Specifically, households that adopt short-term practices are more likely to reduce their food insecurity (ranging from 12.76% to 23.85%) than households that do not.

Moreover, Table 5 show that households that practice agroforestry can increase their income by \$43.71 compared to households that do not practice it. Indeed, both coefficients of the ATE are positive and significant for both the Propensity Score and the Nearest Neighbor Match. Similarly, the coefficients of the ATE for the treated are positive and significant for both the Propensity Score and the Nearest Neighbor Match. This result indicates that the introduction of agroforestry is

https://doi.org/10.1017/aae.2023.10 Published online by Cambridge University Press

Table 4. Impacts of adopting short-term agricultural practices on household income and food insecurity

Matching algorithm	Outcome variables	ATE (1 vs 0)	ATT (1 vs 0)
Propensity score	Household income	26.269**	29.986**
Nearest neighbor	Household income	23.509	24.458
Propensity score	Food insecurity	−0.233***	−0.238***
Inverse weighting of the probability	Food insecurity	−0.126	−0.127***

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

Table 5. Impacts of the adoption of long-term agricultural practices on household income and food insecurity

Matching algorithm	Outcome variables	ATE (1 vs 0)	ATT (1 vs 0)
Propensity score	Household income	43.712**	48.97134**
Nearest neighbor	Household income	43.525**	65.199***
Propensity score	Food insecurity	0.013	0.009
Inverse weighting of the probability	Food insecurity	−0.007	0.007

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

likely to increase household income by $65.19 above the sample average income. However, the adoption of agroforestry does not appear to have a significant impact on food insecurity.

4. Conclusion and Policy Implications

This study analyzes the impact of land tenure rights on the adoption of short- and long-term agricultural practices, as well as the impact of these practices on the income and food insecurity for rural households in Burkina Faso. Unlike previous research that has treated the decision to adopt short-term and long-term agricultural practices as separate decisions, this research considers the possibility of joint decisions in the choice of these practices and explores their possible complementary relationship. The reasons for adopting short-term and long-term agricultural practices may not be interdependent, but rather mutually dependent. Ignoring such a possibility could underestimate or overestimate the influence of factors on decision-making regarding the adoption of short- and long-term agricultural practices in Burkina Faso.

An important finding from the bivariate probit model is the significance of the correlation coefficient in the two systems of equations. In particular, there is a significant correlation between the adoption of some short-term practices, especially Zaï and half-moon farming, and the adoption of long-term practices, especially agroforestry. The results demonstrate the substitutability between half-moon farming and agroforestry practices and the complementarity between Zaï and agroforestry practices. However, the study shows that there is no significant correlation between the adoption of stone cordons and the adoption of agroforestry.

Findings from the econometric estimates also make it clear that the variables that influence the adoption of short-term practices are not all the same as those determining the adoption of long-term practices. In particular, ownership of permanent land rights increases the likelihood of adopting long-term agricultural practices, but does not contribute significantly to the adoption of short-term practices. On the other hand, type of land parcel, membership in farmers' organization, and agricultural extension were found to be catalysts for both short-term and long-term practices.

https://doi.org/10.1017/aae.2023.10 Published online by Cambridge University Press

An analysis of the impact of the introduction of these agricultural practices is then conducted using the PSM method. The results show that the adoption of short-term practices increases household income and reduces food insecurity compared to households that do not adopt these practices. In contrast, the adoption of long-term practices only increases household income but has no significant impact on food insecurity. Income differences are annual differences. These income differences are important for farmers. The average annual income of a household in rural areas is estimated at 115,000 FCFA or $189).

In terms of policy implications, this research suggests rethinking the prevailing customary system through open consultations with all stakeholders to facilitate access to land for vulnerable groups. It is therefore essential to create an effective land redistribution system that allows households without permanent rights and who want to make long-term innovations in the agricultural sector to do so without fear. It is therefore crucial to defend fair policies that oppose the monopoly or monopolization of land by some social classes.

In addition, this research suggests that given the low adoption rate of climate change adaptation's practices in Burkina Faso, extension programs should be included in national climate change adaptation and resilience strategies. This study suggests that agricultural policies consider the critical role of agricultural extension in the adoption of short- and long-term agricultural practices. Agroforestry is considered a relatively new practice, and the lack of information and training does not contribute to its adoption given the different perceptions of the technology. Some farmers believe that the presence of trees limits their acreage or that it is incompatible with some crops. Training on agroforestry technology is therefore essential because it allows farmers to be well informed and to understand the environmental implications. It is therefore necessary to promote human capital through adequate and regular training on agroforestry in order to encourage farmers to practice these practices in order to increase their well-being in a sustainable way. It is also important to integrate agronomic, environmental, and financial knowledge into extension programs. In addition, several works propose to differentiate the different types of extension. A research perspective could be to take into account such differentiation to refine our results.

The important role of collective management in the adoption of agricultural practices also suggests the need to support and encourage small family farms. Indeed, the adoption of Zaï, half-moon farming, stone cords, and agroforestry requires significant financial and material resources. Given the limited resources of rural households, they feel unable to obtain certain inputs (organic fertilizer and production materials) needed to implement these practices. It is therefore critical that the government improve agricultural financing to encourage the adoption of short-term agricultural practices by a large number of rural households in Burkina Faso.

Acknowledgements. None.

Data Availability. We ensure data availability. There are no data restrictions. The data sets used during the current article are available from the author on request.

Author Contributions. Conceptualization, AAD, JPW; Methodology, AAD, JPW; Formal analysis, AAD, JPW; Data curation, JPW; Writing—original draft, AAD, JPW; Writing—review and editing, AAD, JPW; Supervision, AAD; Funding acquisition, AAD, JPW.

Funding Statement. This research received no specific grant from any funding agency, commercial, or not-for-profit sectors.

Competing Interests. Author A and Author B declare none.

References

Becker, S.O., and A. Ichino. "Estimation of Average Treatment Effects Based on Propensity Scores." *The Stata Journal* **2**,4(2002):358–77.

Besley, T. "Property Rights and Investment Incentives: Theory and Evidence from Ghana." *Journal of Political Economy* **103**,5(1995):903–37.

https://doi.org/10.1017/aae.2023.10 Published online by Cambridge University Press

Brasselle, A.S., F. Gaspart, and J. Platteau. "Land Tenure Security and Investment Inventives: Puzzling Evidence from Burkina Faso." *Journal of Development Economics* **67**(2002):373–418.

Caliendo, M., and S. Kopeinig. "." *Journal of Economic Surveys* **22**,1(2008):31–72.

Commons, J.R. *Legal Foundations of Capitalism*. Madison: University of Wisconsin Press, vol. 394, 1968.

Deininger, K., and S. Jin. "Tenure Security and Land-Related Investment: Evidence from Ethiopia." *European Economic Review* **50**,2(2006):1245–77.

Delville, L.P. Politiques et interventions en matière de foncier et de gestion des ressources naturelles. Projet de recherche CLAIMS, London, IIED/CLAIMS, 2006.

Deressa, T.T., R.M. Hassan, C. Ringler, T. Alemu, and M. Yusuf. "Determinants of Farmers' Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia." *Global Environmental Change* **19**,2(2009):248–55.

Diendéré, A.A. "Famers' Perceptions of Climate Change and Farm-level Adaptation Strategies : Evidence from Bassila in Benin." *African Journal of Agricultural and Ressource Economics* **14**,311-2019-682(2019):42–55.

Drucza, K., and V. Peveri. "Literature on Gendered Agriculture in Pakistan: Neglect of Women's Contributions." *Women's Studies International Forum* **69**(2018):180–9.

EPA. *Methodologie du panel 2020-2024 de l'enquete permanente agricole*. Ouagadougou: EPA, 2019.

FAO. *Analyse des incitations et pénalisations pour le sorgho au Burkina Faso*. Rome: Série rapport pays SPAAA, FAO, 2013.

Feder, G. "Land Ownershisp Security and Farm Productivity: Evidence from Thailand." *The Journal of Develoment Studies* **24**,1(1987):16–30.

Festus, A.A., M.A. Hirons, and Y. Malhi. "Questioning the Link Between Tenure Security and Sustainable Land Management in Cocoa Landscapes in Ghana." *World Development* **130**,104913(2020):1–53.

Garzon-Delvaux, P.A., L. Riesgo, and S. Gomez y Paloma. Sustainable agricultural practices and their adoption in sub-Saharan Africa: A selected review. EUR 30283 EN, Publications Office of the European Union, Luxembourg, 2020.

Greene, W.H. *Marginal Effects in the Bivariate Probit Model*, 1996, NYU numéro EC-96-11.

Huffman, W.E. "Human Capital and Adoption of Innovations: Policy Implications." *Journal of Applied Economic Perspectives And Policy* **42**,1(2020):92–9.

Kassie, M., M. Fisher, G. Muricho, and G. Diiro. "Woumen's Empowerment Boosts the Gains in Dietary Diversity from Agricultural Technology Adoption in Kenya." *Food Policy* **95**(2020):101957.

Lawry, S., C. Samii, R. Hall, A. Leopold, D. Hornby, and F. Mtero. "The Impact of Land Property Rights Interventions on Investment and Agricultural Productivity in Developing Countries: A Systematic Review." *Campbell Systematic Reviews* **10**,1(2014):1–104.

Macours, K., D.A. Janvry, and E. Sadoulet. "Insecurity of Property Rights and Social Matching in the Tenancy Market." *European Economic Review* **54**,7(2010):880–99.

Mwangi, M., and S. Karriuki. "Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries." *Journal of Economics and Sustainable Development* **6**,5(2015):08–216.

Nkomoki, W., M. Bavorova, and J. Banout. "Adoption of Sustainable Agricultural Pratices and Food Security Threats: Effects of Land Tenure in Zambia." *Land Use Policy* **78**(2018):532–8.

Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*. New York, NY: Cambridge University Press, 1990.

Paavola, J., and W.N. Adger. "Institutional Ecological Economics." *Ecological Economics* **53**(2005):353–68.

Place, F., and P. Hazell. "Productivity Effects of Indigenous Land Tenure Systems in Sub-Saharan Africa." *American Journal of Agricultural Economics* **75**,1(1993):10–9.

Po., J.Y.T., and G.M. Kickey. "Local Institution and Smallhoder Women's Access to Land Resources in Semi-arid Kenya." *Land Use Policy* **76**(2018):252–63.

Rodriguez-Entrena, M., and M. Arriaza. "Adoption of Conservation Agriculture in Olive Groves: Evidences from Southern Spain." *Land Use Policy* **34**(2013):294–300.

Rosenbaum, P.R., and D.B. Rubin. "The Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometika* **70**,1(1983):41–55.

Rubin, D. "Assignment to Treatment Group on the Basis of a Covariate." *Journal of Educational Statistics* **2**,1(1977):1–26.

Savadogo, K., T. Reardon, and K. Pietola. "Adoption of Improved Land Use Technologies to Increase Food Security in Burkina Faso: Relating Animal Traction, Productivity, and Non-Farm Income." *Agricultural Systems* **58**,3(1998):441–64.

Schlager, E., and E. Ostrom. "Property-Rights Regimes and Natural Resource: A Conceptual Analysis." *Land Economics* **68**,3(1992):249–62.

Séogo, W., and P. Zahonogo. "Land Tenure System Innovation and Agricultural Technology Adoption in Burkina Faso: Comparing Empirical Evidence to the Worsening Situation of Both Rural People Vulnerability and Vulnerable Groups' Access to Land." *African Journal of Science* **11**,7(2019):833–42.

Shittu, A.M., O.M. Kehinde, and M.G. Ogunnaike. "Effects of Land Tenure and Property Rights on Farm Households' Willingness to Accept Incentives to Invest in Measures to Combat Land Degradation in Nigeria." *Agricultural and Ressource Economics Review* **47**,2(2018):357–87.

Smucker, G.R., T.A. White, and M. Bannister. *Land Tenure and the Adoption of Agricultural Technology in Haiti*, CAPRi Working Paper No. 6, IFPRI, 2000.

Teklewold, H., M. Kassie, and B. Shiferaw. "Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia." *Journal of Agricultural Economics* **64**,3(2013):597–623.

Tilman, D., and M. Clark. "Global Diets Link Environmental Sustainability and Human Health." *Nature* **515**,7528(2014):518–22.

Van Ittersum, M.K., B.V. Lenny, J.W. Grassini, and J.V. Wart. "Can Sub-Saharan Africa Feed Itself ?." *Procceedings of the National Academy of Sciences 113*. vol. **52**, 2016, pp. 14964–9.

Wang, J., Y. L.Yifan, G. Anthony, and X. Yuequing. "Land-use Changes and Land Policies Evolution in China's Urbanization Processes." *Land Use Policy* **75**(2018):375–87.

Zahonogo, P. "Property Rights and Farmers's Investment Decisions in Burina Faso." *Ghanaian Journal of Economics* **4**(2016):139–57.

Cite this article: Diendéré, A.A. and J.-P. Wadio (2023). "Land Tenure Rights and Short- and Long-term Agricultural Practices: Empirical Evidence From Burkina Faso." *Journal of Agricultural and Applied Economics* **55**, 238–255. https://doi.org/10.1017/aae.2023.10