Climatic Change (2023) 176:143
https://doi.org/10.1007/s10584-023-03616-y

Does land security matter in adapting to climate change? an empirical evidence from Benin

Gbêtondji Melaine Armel Nonvide[1]

Received: 6 October 2022 / Accepted: 19 September 2023 / Published online: 6 October 2023

Abstract
Does land security matter in climate change adaptation strategies choice? To provide answers to this, the paper used a survey data collected from a random sample of 341 agricultural households in 2020 in Benin. Descriptive statistics and multivariate probit model were used to analyze the data. The main adaptations strategies identified are adjustment in sowing time, tree planting, crop and livestock integration, use of irrigation, use of improved variety, and endogenous beliefs, while family land, own land and rented land are the types of land tenure arrangements. Results from a multivariate probit model show that the use of family land increases the likelihood of planting tree, crop and livestock integration, use of improved variety, and endogenous beliefs. Farmers using own land are more likely to adopt tree planting and endogenous beliefs as adaptation strategies, while they are less likely to adopt irrigation. The use of rented land increases the likelihood of adjusting the sowing time, crop and livestock integration, use of irrigation, use of improved variety, and use of endogenous beliefs. These findings suggest that the choice of adaptation strategies to cope with climate change depends on the type of land tenure arrangements.

Keywords Adaptation strategies · Climate change · Land tenure · Multivariate probit model · Benin

JEL Classification Q15 · Q24 · Q54

1 Introduction

The planetary climate system is undergoing large-scale changes that are amplified by both regional and local natural and anthropogenic factors (IPCC 2022). Climate change affects all sectors of activity on a daily basis and depends on the specificities of the local environment (Ali and Erenstein 2017). It constitutes a potentially major threat to the environment and sustainable development. In this sense, they affect the living conditions of local communities in different ways, including loss of agricultural production, food insecurity, water stress, rising

✉ Gbêtondji Melaine Armel Nonvide
melainearmel@gmail.com

[1] Faculté Des Sciences Economiques Et de Gestion, Université d'Abomey-Calavi, Abomey-Calavi, Benin

water levels and exposure to climatic disasters, changes affecting the ecosystem, biodiversity and human health (IPCC 2014, 2022; Soglo and Nonvide 2019). The opportunity to deal with them is becoming an increasingly urgent priority and should consist in the integration of these risks, firstly in development policies and strategies and then in the second phase in the implementation of measures to adaptation in all sectors of activity.

Various climate change adaptation strategies have been used by farmers. For example, the main strategies used by farmers in Benin include adjustment in sowing time, use of improved seeds, crop and livestock integration, tree planting, off-season cultivation, crop diversification, irrigation and drainage of excess water (Yegbemey et al. 2017; Soglo and Nonvide 2019). In Pakistan, adaptation strategies include adjustment in sowing time, use of drought-tolerant varieties and shifting to new crops (Ali and Erenstein (2017). Mwinkom et al. (2021), in North-Western Ghana, identified four major adaptation practices including changing planting time, planting early maturing crops, planting drought-resistant crops, and changing farm methods. Studies by Deressa et al. (2009), Belay et al. (2017) and Marie et al. (2020) found crop diversification, planting date adjustment, soil and water conservation and management, increasing the intensity of input use, integrating crop with livestock and tree planting as the major strategies used by farmers in Ethiopia. However, these various adaptation strategies are constrained by several factors including inadequate finance, scarcity of labor, poor agricultural extension services, inadequate access to climate information, unavailability of resistant varieties, poor agricultural program, inaccurate agro-meteorological information, high cost of labor, low wages and poor condition of work, complication of crop management and harvesting, inadequate farm input supplies, high cost of irrigation facilities, lack of technical know-how, crops competing for nutrient and land tenure issues (Satishkumar et al. 2013; Fagariba et al. 2018; Ige et al. 2021).

Lack of tenure security is a crucial limiting factor for adaptation to climate change. This particularly diminishes the efforts of farmers, who are highly dependent on land and the right of use. Land is valuable to farmers not only from an economic point of view but also owning land gives them a high level of social capital. Studies by Lambrecht and Asare (2016) and Murken and Gornott (2022) argue that tenure insecurity could demotivate long term investment into adoption of improved farming practices. It might also limit farmers' access to credit as they often use their land as collateral. According to a survey by Prindex (2020) an estimated one billion people live in precarious tenure conditions with considerable consequences for their livelihoods. Insecurity varies widely from region to region with the highest average rates of insecurity found in the Middle East and North Africa (28%), and in sub-Saharan Africa (26%), while the lowest is observed in Europe and Central Asia (12%), North America (14%), and East Asia and the Pacific (15%). Within most regions, tenure insecurity also varies widely from country to country. For example, among the West African countries, land insecurity is estimated at 35% in Benin, 44% in Burkina Faso, 27% in Ghana, 28% in Cote d'Ivoire.

This study aim to assess the effect of land tenure on the choice of climate change adaptation strategies in Benin. It adds knowledge to the literature in several ways. First, few studies have been focused on the role of land tenure in the process of adaptation to climate change. Thus, little is known on this nexus. In particular, no existing empirical studies have focused on the impact of land tenure on the choice of climate change adaptation strategies in Benin. Second, a recent study by Murken and Gornott (2022) revealed that majority of articles on land tenure and agricultural development face great challenges of selection bias and reverse causation, so more attention should be paid to these issues. To control for the selection bias associated to adoption, we employed a more rigorous methods, the multivariate probit model, which simultaneously estimates the adaptation decisions and allows the unobserved and unmeasured factors (error term) of each equation to be correlated (Bahinipati

and Venkatachalam 2015; Mittal and Mehar 2016; Soglo and Nonvide 2019). Third, the study has the merit to include the use of endogenous beliefs (prayers, consultation of diviners, libations, among others) among the adaptation strategies used by farmers. Indeed, in the time of long drought, farmers resort to traditional practices, in particular prayers, consultation of diviners, libations, among others. Fourth, in term of policy this study provides a specific answer to support climate change adaptation and land policy reforms in Benin.

The rest of the paper is organized as follows. Section "Land system and reforms in Benin" presents an overview of the land system in Benin, followed by the empirical approach in Sect. "Empirical approach" while data and descriptive statistics are presented in Sect. "Data and descriptive statistics". Results and discussion are reported in Sect. "Results and discussion", and finally Sect. "Conclusion" concludes with the policy implication.

2 Land system and reforms in Benin

In Benin, as in other former colonized countries, land rights are inherited from colonial laws, slightly updated at the country's independence in 1960; however, it turns out to be largely ineffective (Gbaguidi 1997; Simonneau 2015, 2017). The only legal procedure for access to land ownership is entirely controlled by the State through the registration of land and the granting of a land title (TF), which is beyond the reach of most Beninese, due to its complexity and cost. The majority of transactions are therefore carried out outside the law, on land held by virtue of custom on the outskirts of cities, or on land subject to a residence permit, whereas the latter confers a right of use, but does not authorize the sale. The land practices of Beninese city dwellers follow certain rules which do not come under the law but seem socially accepted and, for some, administratively recognized. These rules represent a flexible concept, which does not come under positive law, but rather a "law of practice" (Gbaguidi 1997; Le Roy and Hesseling 1990) being forged locally according to the systems of available and legitimate norms. These de facto land regulations emerge from the practices and interactions between the different actors of the urban land market: the State, the municipalities, the customary chiefs who traditionally hold the land, the private sector and the city dwellers.

According to Simonneau (2017), four types of land access strategies are practiced in Benin: the first type corresponds to the customary regulations exercised on the few plots held collectively according to custom in the center of royal cities such as Porto-Novo and Abomey. In this sense, the proof of ownership is essentially linked to the oral history of places and families, but can be concretized by an administrative document. The second type refers to the micro-local regulations at work in the "neo-customary" sectors of access to land in peri-urban areas (Durand-Lasserve et al. 2004), i.e., when dealing with farmland that has never been commodified before. In this context, transactions are evidenced by written sales agreements signed by the seller and the buyer and sometimes by witnesses. More often, it is material traces that mark the presumed ownership. The third type corresponds to dense urban areas regulated by municipal actions of urban management and development. Two devices in particular make it possible to register these presumed properties, or even to regularize them: (1) the affirmation of sales agreements, and (2) the subdivision-consolidation. The affirmation procedure consists of the opposition of the Mayor's signature on the agreements, making it possible to date and record the transactions in the communal registers of state affairs. The subdivision-consolidation corresponds to a parcel consolidation after the land transactions and then to a "resettlement" of the presumed owners. It must

allow the rationalization of the road network and the reservation of land rights of way for public facilities, and opens up the possibility for presumed owners to apply for a residence permit. These two methods of administrative registration theoretically make it possible to fill in the municipal tax cadastre and thus to apply property taxation, which is also proof of the presumption of ownership. Finally, the fourth type corresponds to the rare plots covered by a legal land title. This land regulation is then organized by state institutions.

The socialist regime of the 1970s and 1980s nationalized the land without any real intervention apart from the production cooperatives in the south of the country. At the end of the 1980s, the financial crisis of the State led Benin to enter into structural adjustment negotiations and to restructure its administration. In 1991, the World Bank, the French Development Agency (AFD) and the German Technical Cooperation (GTZ) prepared a natural resource management project (PGRN), which was part of a strategy to restructure agricultural services and should demonstrate the relevance of rural development actions carried out by teams independent of the administration (Lavigne-Delville 2010). AFD and the World Bank propose to integrate a "Rural Land Plan" (PFR) approach, i.e. identification and mapping of local land rights (Lavigne-Delville 2010; Lavigne-Delville et al. 2003).

Today, Benin is at a pivotal period in terms of land policies, insofar as the reform envisaged since the 1990s (Simonneau 2017), actively prepared since 2006 and voted in 2013 and modified in 2017, is in the process of being set up. This reform aims to unify land tenure systems through a simplified procedure for registering and issuing the equivalent of a land title, called "Certificat de Proprieté Foncière, (CPF)", and in English, land ownership certificate. It is accompanied by the creation in 2015 of public institutions, in particular the "Agence Nationale du Domaine et du Foncier (ANDF)", and the establishment of a national cadastre fed by the departmental and communal cadastre offices. It reflects a real desire to simplify procedures and fight against fraud.

Despites all these measures, the issuance of land titles has remained an extremely marginal practice in Benin, with little change since the colonial period. Only 1,980 titles were issued between 1906 and 1967, and in 1998 there were less than 10,000 land titles in the whole country, with less than 1% of households in rural areas possessing a land title (Comby 1998; Rochegude 2000; Le Meur 2008). With the establishment of the ANDF, between 2016 and 2022, 12,249 land titles were issued, however, the fact remains that less than 1% of Benin's population holds a land title.

3 Empirical approach

Farmers decision to adapt to climate change fall under the general framework of expected utility and profit maximisation (Seo and Mendelsohn 2008; Bahinipati and Venkatachalam 2015; Soglo and Nonvide 2019). It is assumed that a rational farmer decide to use *j* adaptation strategy (As = 1) to climate risks if the expected utility is greater than in the case of non-adaptation (As = 0). Mathematically, this is expressed as follows:

$$E\left(U\left[\left(As_1\right)\right]\right) > E\left(U\left[\left(As_0\right)\right]\right) \tag{1}$$

Since, utility is not directly observed, the effect of land tenure on the choice of a specific adaptation strategy is analyzed using the following model:

$$Y_{ij} = \beta_j X_{ij} + \gamma R_{ij} + \varepsilon_{ij} \tag{2}$$

where Y_{ij} is the probability that a farmer i chooses strategy j ($j=1$, ……, 6). X_{ij} the vector of the explanatory variables (including land tenure variables) that influence the adoption decision. R_{ij} represents region level dummies. β, andγ are the vector of the parameters to be estimated.

Due to the categorical nature of the outcome variable, a multivariate probit model is estimated. This model is preferable to the simple or multinomial probit or logit model used in several studies including Ali and Erenstein (2017), Belay et al. (2017) and Jiri et al. (2017). Other advantage of the multivariate probit model is that it simultaneously estimates the adaptation strategy choices and allows the error term (unobserved and unmeasured factors) of each equation to be correlated (Bahinipati and Venkatachalam 2015; Soglo and Nonvide 2019). Thus, estimations of multinomial logit or separate univariate probit equations are biased in the presence of such correlations (Mwinkom et al. 2021). The multivariate probit model provides more efficient estimates because it controls for the selection bias associated with the adoption of climate change adaptation strategies (Velandia et al. 2009; Abay et al. 2018; Soglo & Nonvide 2019; Nonvide 2021).

In the multivariate probit model, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity, i.e., $(\mu_1, \mu_2, \mu_3, \mu_4, \mu_5, \mu_6) \rightarrow MVN(0, \Omega)$. The covariance matrix (Ω) is given by:

$$\Omega = \begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} & \rho_{16} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} & \rho_{25} & \rho_{26} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} & \rho_{36} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} & \rho_{46} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 & \rho_{56} \\ \rho_{61} & \rho_{62} & \rho_{63} & \rho_{64} & \rho_{65} & 1 \end{pmatrix} \tag{3}$$

where ρ (rho) denotes the pairwise correlation coefficient of the error terms corresponding to any two adaptation strategies. If these correlations in the off-diagonal elements in the covariance matrix become non-zero, then it justifies the use of a multivariate probit instead of a univariate probit for each adaptation strategies (Aryal et al. 2018; Nonvide 2021). If ρ is significantly positive, then there is a complementary association between different adaptation strategies. But if ρ is significantly negative, then there is a substituted relationship between different adaptation strategies.

Equation (2) was estimated by the simulated maximum likelihood method (Cappellari and Jenkins 2003) which used Geweke-Hajivassiliour-Keane smooth recursive conditioning simulator procedure to evaluate the multivariate normal distribution. The land security variables considered include family land, rented land and own land. The control variables included in the model are: age, male, education, household size, land size and northern region. These variables were selected based on previous studies including Deressa et al. (2009), Ali and Erenstein (2017), Belay et al. (2017), Soglo and Nonvide (2019) and Marie et al. (2020).

4 Data and descriptive statistics

Data used in this study were collected in 2020 under the projet « Plan National d'Adaptation aux changements climatiques (PNA)» of the « Ministère du Cadre de Vie et du Développement Durable». The project covered seven municipalities located along the borders

of Benin and Togo. These include the municipalities of Aplahoué, Athiémé, Grand Popo, Savalou, Bassila, Ouaké et Copargo. A proportional random sample of 450 households was selected in the seven municipalities of the study. Indeed, 100 households were selected from each of the largest communes (Aplahouè and Savalou), and 50 households from each of the smaller communes (Athiémè, Grand-Popo, Bassila, Ouaké and Copargo). However, the analysis is based exclusively on the agricultural households totaling 341 households.

The summary statistics of the surveyed respondents are reported in Table 1. The mean age for the selected farmers was 45 years. About 69% of farmers were male, indicating that men were more involved in farming compared to women. About 55% of farmers are educated, meaning that they attained at least a primary school. On average, 10 people are in a household and the mean farm size is 3.4 hectares. Three (03) major land tenure arrangements were identified in the study area. These include family land, own land and rented land. The own land are under full control of farmers, while the family land are under the control of the family head. It was observed that 35% of the respondents had their own land while 48% used family land and 15% rented the land. In terms of location, it was observed that 34% of the households surveyed are from the northern region of Benin. The main crops produced are maize, rice, sorghum, cassava, cotton, and soybean, however, majority (91%) of surveyed farmers produced maize.

5 Results and discussion

5.1 Main climate change adaptation strategies

Figure 1 presents the strategies adopted by farmers to cope with climate change in Benin. The main strategies identified are: adjustment in sowing time, tree planting, crop and livestock integration, use of irrigation, use of improved variety, endogenous beliefs (prayers, consultation of diviners, libations, among others). About 52% of the respondents adjust the sowing time to respond to late rainfall and floods; 38% used tree planting in response to the variability of temperature. Belay et al. (2017) argue that tree planting provides natural shade for the crops during a long dry season. About 47% of farmers used improved varieties as strategy for climate variability; 31% practiced crop and livestock integration, while 36% used irrigation.

Table 1 Description of variables

Variables	Description	Mean	Std. dev
Age	In years	44.64	14.61
Male	Dummy (yes = 1)	0.69	0.45
Educated	Dummy (yes = 1)	0.55	0.49
Household size	In number	10.1	6.22
Land size	In hectares	3.37	2.60
Family land	Dummy (yes = 1)	0.48	0.50
Rented land	Dummy (yes = 1)	0.15	0.36
Own land	Dummy (yes = 1)	0.35	0.47
Northern region	Dummy (yes = 1)	0.34	0.47
Maize as main crop	Dummy (yes = 1)	0.91	0.28

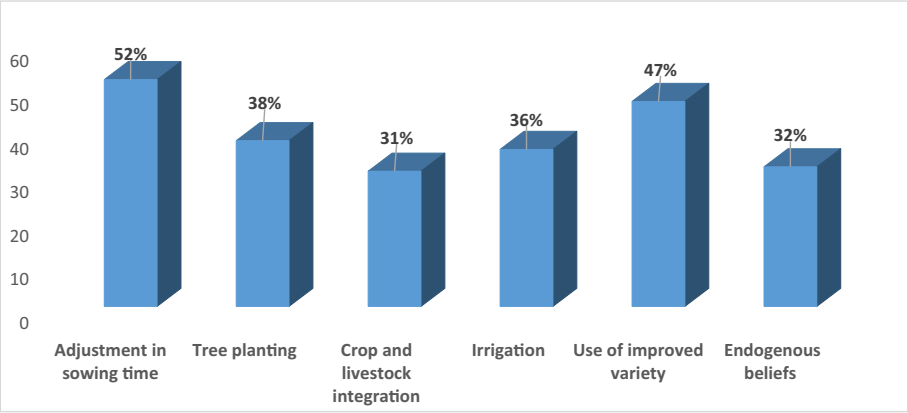

Fig. 1 Climate change adaptation strategies by farmers in Benin

To cope with climate change, farmers also use endogenous beliefs, in particular prayers, consultations of diviners, libations, etc.… These findings corroborate previous studies such as Deressa et al. (2009), Alauddin and Sarker (2014); Ali and Erenstein (2017); Elum et al. (2017), and Soglo and Nonvide (2019). For instance, For instance, in Pakistan, Ali and Erenstein (2017) found adjustment in sowing time, use of drought-tolerant varieties and shifting to new crops as the three main adaptation strategies used by farmers. In South Africa, the use of drought-tolerant varieties is the most common climate-response strategy used by farmers (Elum et al. 2017), while in Ethiopia, farmers attempt to adapt to climate change using strategies including crop diversification, planting date adjustment, soil and water conservation and management, intensity of input use, integrating crop with livestock and tree planting (Deressa et al. 2009; Belay et al. 2017). A study by Soglo and Nonvide (2019) found that adjustment in sowing time, use of improved crop varieties, crop and livestock integration and tree planting, are the main adaptation strategies used by maize farmers in the municipality of Zè in Benin.

5.2 Effect of land tenure on climate change adaption strategies choice

Results of the multivariate probit model are reported in Table 2. Three land tenure variables (family land, own land and rented land) were included in the model. The estimated model is globally significant as showed by the significance of the Wald $\chi 2$. The null hypothesis of the absence of correlation between the equations is strongly rejected as indicated by the likelihood ratio test (Prob = 0.000). This supports the correlation assumption of error terms between equations and validates the use of multivariate probit model. The pairwise correlation between the adaptation strategies equations in the multivariate probit model indicated that eight correlation coefficients out of fifteen are significant. Positive correlation shows complementarities and negatives correlation indicates substitutability among the adaptation strategies (Soglo and Nonvide 2019). For instance, the results revealed that farmers who planted tree tended to not adjust the sowing time. Those who use improved variety were likely to use the following strategies: adjustment in sowing time, tree planting, crop and livestock integration, and irrigation, suggesting a complementarity between improved variety and these strategies.

Table 2 Effects of land tenure on climate change adaptations strategies choices

Variables	Adjustment in sowing time	Tree planting integration	Crop and livestock	Irrigation	Use of improved variety	Use of endogenous knowledge
Age (in years)	0.0265	0.000766	0.105***	0.0154	-0.0227	0.0444
	(0.0295)	(0.0301)	(0.0338)	(0.0316)	(0.0293)	(0.0340)
Age square	-0.000144	-3.27e-05	-0.00101***	-0.000176	0.000332	-0.000272
	(0.000293)	(0.000297)	(0.000335)	(0.000317)	(0.000288)	(0.000329)
Male (yes = 1)	-0.262	-0.127	0.247	-0.128	-0.251	-0.620***
	(0.175)	(0.177)	(0.193)	(0.186)	(0.185)	(0.198)
Educated (yes = 1)	0.0799	0.221	0.246	0.488***	0.128	0.222
	(0.150)	(0.154)	(0.160)	(0.160)	(0.160)	(0.170)
Household size (number)	-0.00887	0.0357***	-0.0154	0.0390***	-0.0130	0.000543
	(0.0124)	(0.0127)	(0.0142)	(0.0128)	(0.0138)	(0.0146)
Land size (ha)	0.0991***	0.0641**	0.0375	-0.0447	0.117***	0.122***
	(0.0293)	(0.0312)	(0.0320)	(0.0318)	(0.0302)	(0.0321)
Family land (yes = 1)	0.140	1.117***	0.663***	-0.132	0.828***	0.758***
	(0.231)	(0.268)	(0.230)	(0.234)	(0.237)	(0.258)
Rented land (yes = 1)	0.409*	-0.0127	0.902***	0.546**	0.775***	1.580***
	(0.234)	(0.251)	(0.236)	(0.247)	(0.240)	(0.272)
Own land (yes = 1)	0.260	0.998***	0.309	-0.477**	0.168	0.641**
	(0.235)	(0.275)	(0.238)	(0.241)	(0.241)	(0.265)
Northern region (yes = 1)	0.450***	-0.273*	0.673***	0.663***	0.935***	1.000***
	(0.152)	(0.156)	(0.163)	(0.165)	(0.160)	(0.172)
Constant	-1.263*	-1.404*	-4.232***	-1.331*	-1.021	-3.439***
	(0.727)	(0.754)	(0.869)	(0.789)	(0.728)	(0.875)
Correlation measures						
Tree planting	− 0.307***	-	-	-	-	-
	(0.085)	-	-	-	-	-
Crop and livestock	0.530***	0.131	-	-	-	-
Integration	(0.075)	(0.095)	-	-	-	-

Table 2 (continued)

Variables	Adjustment in sowing time	Tree planting integration	Crop and livestock	Irrigation	Use of improved variety	Use of endogenous knowledge
Irrigation	-0.021 (0.096)	0.365*** (0.083)	0.146 (0.094)	- -	- -	- -
Use of improved variety	0.423*** (0.084)	0.186** (0.091)	0.352*** (0.083)	0.213** (0.091)	- -	- -
Use of endogenous knowledge	0.145 (0.096)	-0.116 (0.095)	0.147 (0.092)	-0.012 (0.095)	0.247*** (0.091)	-
Log likelihood	− 1085.604	Wald chi^2 (60) = 271.27			Prob (chi^2) = 0.000	
Likelihood ratio test	-	Ch^2 (15) = 115. 177			Prob (chi^2) = 0.000	
N	341					

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; Standard errors in parentheses

Results indicated that the use of family land increases the likelihood of adopting tree planting, crop and livestock integration, use of improved variety, and endogenous beliefs. Farmers using own land are more likely to adopt tree planting and endogenous beliefs as adaptation strategies, while they are less likely to adopt irrigation. The use of rented land are positively correlated with the likelihood of adjusting the sowing time, crop and livestock integration, use of irrigation, use of improved variety, and endogenous beliefs. Farmers using rented land do not plant tree. This is consistent to the fact that the land does not belong to them. Secure land tenure is crucial for long term investment in land and climate change adaptation (Antwi-Agyei et al. 2015).

Other variables also have a significant influence on the adaptation strategies choice. Age is positively associated with crop and livestock integration; however, age square turned out to be negatively correlated. A unit increase in farmer's age increases the probability of adopting crop and livestock integration up to about 53 years, after which the probability decreases. This nonlinear relationship implies that younger farmers are more likely to adopt crop and livestock integration as adaptation strategy compared to older farmers. Being male decreases the probability of using endogenous beliefs (prayers, consultation of diviners, libations, among others) compared to women. Educated farmers are more likely to use irrigation as an adaptation strategy. This confirms previous study by Deressa et al. (2009). Indeed, in area with high rainfall variability, irrigation is an alternative solution to secure water for food production. It also allows crop production throughout the year, and have a great potential of increasing yield (Nonvide 2017). Household size also is positively correlated with tree planting and use of irrigation, suggesting that farmers with large family members are more likely to adopt these strategies. Land size has a positive relationship with majority of the adaptation strategies considered in this study. That is, as the farm size increases, the probability of adjusting sowing time, plant tree, use of improved variety, and use of endogenous beliefs increases. Therefore, farmers with large farm size are more likely to adapt to climate change. These findings are in line with those found by Belay et al. (2017). Finally, the results reveal a regional disparity in adapting to climate change. Being in northern region decreases the probability of planting tree while increasing the likelihood of adjustment in sowing time, crop and livestock integration, use of irrigation, use of improved variety, and endogenous beliefs.

Overall, the findings suggest that the choice of the adaptation strategies depend on the land tenure arrangements. An interesting result is that an insecure land tenure arrangement such as rented land lead farmers to adopt more strategy compared to those who have more secure land tenure (such as own land and family land) arrangements. These results, contrary to Antwi-Agyei et al. (2015), Lambrecht and Asare (2016), Bedeke et al. (2019), and Murken and Gornott (2022), may be probably due to the nature of leasing contract. Indeed, if the contract covers several years, farmers could invest more on the land; this may be the case. Furthermore, the land being leased, farmers incur higher costs than others, and therefore to meet the fulfillment, they must necessarily increase productivity. The increase in productivity can be effective through the adoption of climate change adaptation strategies.

While this study come at important results, it may be limited. First, some important variables may not be included in the analysis due to data limitation. For example, access to credit may be vital for the choice of adaptation strategies. Past studies by Deressa et al. (2009), Temesgen et al. (2014), and Soglo and Nonvide (2019) argue that availability of credit plays a significant role in the process of climate change adaptation. Second, further studies should explore the possible reverse causality between the land tenure variables (categorical variable) and the adaptation strategies (also categorical variable).

6 Conclusion

Benin being dependent on rain-fed agriculture is highly affected and vulnerable to climate change. It is therefore necessary for farmers to adapt to the climate change. However, they are constrained by several factors. The objective of this paper is to assess the effect of land tenure on the choice of climate change adaptation strategies in Benin. Six major adaptations strategies have been identified. These are adjustment in sowing time, tree planting, crop and livestock integration, use of irrigation, use of improved variety, and endogenous beliefs. The major land tenure arrangements found in the study area are, family land, own land, and rented land. For the econometrics analysis, a multivariate probit model was estimated.

Results show that the use of family land increases the likelihood of planting tree, crop and livestock integration, use of improved variety, and endogenous beliefs. Farmers using own land are more likely to adopt tree planting and endogenous beliefs as adaptation strategies, while they are less likely to adopt irrigation. The use of rented land increases the likelihood of adjusting the sowing time, crop and livestock integration, use of irrigation, use of improved variety, and use of endogenous beliefs. An interesting point is that farmers who use rented land are more likely to adopt more strategies compared to the others. These findings imply that the choice of climate change adaptation strategies depends on the type of land tenure arrangements. Farmers need strong institutional supports in the process of adapting to climate change. Land policy reforms, and education should be the key policy variables. Indeed, land policy reforms should help farmers access to more secure land and also facilitate long-term contract for the land leasing. Farmers' education may be done through regular contact with extension agents.

Author Contribution Not applicable.

Data Availability Data will be available upon reasonable request.

Declarations

Ethical Approval The submitted manuscript is our original work and has not been published elsewhere in any form or language.

Consent to Participate Verbal informed consent was obtained from respondents prior to the interview.

Consent for Publication Not applicable.

Competing interests The authors declare no competing interests.

References

Abay KA, Berhane G, Taffesse AS, Abay K, Koru B (2018) Estimating input complementarities with unobserved heterogeneity: evidence from Ethiopia. J Agric Econ 69(2):495–517. https://doi.org/10.1111/1477-9552.12244

Alauddin M, Sarker MAR (2014) Climate change and farm-level adaptation decisions and strategies in drought-prone and groundwater-depleted areas of Bangladesh: an empirical investigation. Ecol Econ 106:204–213

Ali A, Erenstein O (2017) Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Clim Risk Manag 16:183–194

Antwi-Agyei P, Dougill AJ, Stringer LC (2015) Impacts of land tenure arrangements on the adaptive capacity of marginalized groups: the case of Ghana's Ejura Sekyedumase and Bongo districts. Land Use Policy 49:203–212. https://doi.org/10.1016/j.landusepol.2015.08.007

Aryal JP, Jat ML, Sapkota TB, Khatri-Chhetri A, Kassie M, Rahut DB, Maharjan S (2018) Adoption of multiple climate-smart agricultural practices in the Gangetic plains of Bihar, India. Int J Clim Change Strategies Manage 10(3):407–427. https://doi.org/10.1108/IJCCSM-02-2017-0025

Bahinipati CS, Venkatachalam L (2015) What drives farmers to adopt farm-level adaptation practices to climate extremes: empirical evidence from Odisha, India. Int J Disaster Risk Reduction 14:347–356

Bedeke S, Vanhove W, Gezahegn M, Natarajan K, Van Damme P (2019) Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. NJAS: Wageningen J Life Sci 88(1):96–104

Belay A, Recha JW, Woldeamanuel T, Morton JF (2017) Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agric Food Secur 6:24. https://doi.org/10.1186/s40066-017-0100-1

Cappellari L, Jenkins SP (2003) Multivariate probit regression using simulated maximum likelihood. Stata J 3(3):278–294

Comby J (1998) Réforme du droit foncier au Bénin. Etude de faisabilité. SERHAU-SEM, Cotonou

Deressa TT, Hassan RMR, Alemu CT, Yusuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Chang. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Durand-Lasserve, A, Mattingly, M, Mogale, T (2004) La Nouvelle Coutume urbaine. Évolution comparée des filières coutumières de la gestion foncière urbaine dans les pays d'Afrique subsaharienne. Rapport de Synthèse Pour Le Programme de Recherche Urbaine Pour Le Développement. https://www.gemdev.org/old/prud/rapports/rapport19_2.pdf

Elum ZA, Modise DM, Marr A (2017) Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. Clim Risk Manag 16:246–257

Fagariba CJ, Song S, Baoro SKGS (2018) Climate change adaptation strategies and constraints in northern Ghana: evidence of farmers in Sissala West District. Sustain 10(5):1–18

Gbaguidi AN (1997) La Revendication Du Monopole Foncier De L'état, L'intangibilité Du Titre Foncier Et L'accès à La Terre Au Bénin. The J Legal Pluralism Unofficial Law 29(39):43–68

Ige, GO, Akinnagbe, OM, Odefadehan, OO, Ogunbusuyi, OP (2021) Constraints to farmers' choice of climate change adaptation strategies in Ondo State of Nigeria. In: Oguge, N., Ayal, D., Adeleke, L., da Silva, I. (eds) African Handbook of Climate Change Adaptation. Springer, Cham. https://doi.org/10.1007/978-3-030-45106-6_103

IPCC (2014) Climate change 2014. Impact, adaptation, and vulnerability. Part A: global and sectoral aspect. Switzerland. https://www.ipcc.ch/

IPCC (2022) Climate Change Impacts, adaptation, and vulnerability; contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change. IPCC, Geneva, Switzerland.

Jiri O, Mtali-Chafadza L, Mafongoya PL (2017) Influence of smallholder farmers' perceptions on adaptation strategies to climate change and policy implications in Zimbabwe. Change Adapt Socio-Ecol Syst 3:47–55

Le Meur, P-Y (2008) L'information foncière, bien commun et ressource stratégique. Le cas du Bénin. Programme Zones Arides, IIED, Dossier no. 147. https://www.iied.org/sites/default/files/pdfs/migrate/12547FIIED.pdf

Lambrecht, I, Asare, S (2016) Smallholders and land tenure in ghana: aligning context, empirics, and policy. IFPRI Discussion Paper 1492, https://doi.org/10.2139/ssrn.2741867

Lavigne-Delville P, Ouedraogo H, Toulmin C, Le Meur PY (2003) Pour une sécurisation foncière des producteurs ruraux. Actes Du Séminaire International D'échanges Entre Chercheurs Et Développeurs, Paris, GRAF/GRET/IIED 2003:35–48

Lavigne-Delville, P (2010) « Sécurisation foncière, formalisation des droits, institutions de régulation foncière et investissements. Pour un cadre conceptuel élargi ». *Revue Des Questions Foncières,* 1(10), 5–34

Le Roy E, Hesseling G (1990) Le Droit et ses pratiques. Politique Africaine 40:2–11

Marie M, Yirga F, Haile M, Tquabo F (2020) Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwestern Ethiopia. Heliyon 6(4):e03867

Mittal S, Mehar M (2016) Socio-economic factors affecting adoption of modern information and communication technology by farmers in India: analysis using multivariate probit model. J Agric Educ Ext 22(2):199–212. https://doi.org/10.1080/1389224X.2014.997255

Murken L, Gornott C (2022) The importance of different land tenure systems for farmers' response to climate change: a systematic review. Clim Risk Manag 35:100419

Mwinkom, FXK, Damnyag, L, Abugre, S, Alhassan, SI (2021) Factors influencing climate change adaptation strategies in North-Western Ghana: evidence of farmers in the Black Volta Basin in Upper West region. SN Appl Sci, 3(5). https://doi.org/10.1007/s42452-021-04503-w

Nonvide GMA (2017) Effect of irrigation adoption on rice yield in the municipality of Malanville. Benin Afr Dev Rev 29(2):109–120

Nonvide GMA (2021) Adoption of agricultural technologies among rice farmers in Benin. Rev Dev Econ 25(4):2372–2390. https://doi.org/10.1111/rode.12802

Prindex (2020) Prindex comparative report - a global assessment of perceived tenure security from 140 countries. https://www.prindex.net/reports/

Rochegude, A (2000) Décentralisation, acteurs locaux et foncier. Cotonou: PDMSERHAU. https://www.foncier-developpement.fr/wp-content/uploads/Rochegude-Alain-Synth%C3%A8se-d%C3%A9centralisation-acteurs-locaux-et-foncier.pdf

Satishkumar N, Tevari P, Singh A (2013) A study on constraints faced by farmers in adapting to climate change in rain-fed agriculture. J Hum Ecol 44(1):23–28

Seo SN, Mendelsohn R (2008) Analysis of crop choice: adapting to climate change in South American farms. Ecol Econ 67(1):109–116

Simonneau C (2015) Gérer la ville au Bénin. La mise en oeuvre du Registre foncier urbain à Cotonou, Porto-Novo et Bohicon. Thèse de doctorat en aménagement. Université de Montréal, Canada. https://papyrus.bib.umontreal.ca/xmlui/handle/1866/13501

Simonneau C (2017) Stratégies citadines d'accès au sol et réforme foncière au Bénin La pluralité comme enjeu ? Métropolitiques.Eu, Métropolitiques. https://metropolitiques.eu/IMG/pdf/met-simonneau.pdf

Soglo YY, Nonvide GMA (2019) Climate change perceptions and responsive strategies in Benin: the case of maize farmers. Clim Change 155:245–256. https://doi.org/10.1007/s10584-019-02452-3

Temesgen D, Yehualashet H, Rajan DS (2014) Climate change adaptations of smallholder farmers in South Eastern Ethiopia. J Agric Ext Rural Dev 6(11):354–366

Velandia M, Rejesus RM, Knight TO, Sherrick BJ (2009) Factors affecting farmers utilization of agricultural risk management tools: the case of crop insurance, forward contracting, and spreading sales. J Agric Appl Econ 41(1):107–123

Yegbemey RN, Yegbemey EO, Yabi JA (2017) Sustainability analysis of observed climate change adaptation strategies in maize farming in Benin. West Afr Outlook Agric 46(1):20–27. https://doi.org/10.1177/0030727016689638