Climate variability, agroecological practices and household food security in Burkina Faso

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Abstract

Purpose – Climate shocks are one of the major causes of persistent food insecurity in Sub-Saharan Africa, through their negative impact on the performance and progress of the agricultural sector. To enable farm households to adapt to these shocks, the adoption of agroecological practices that enable sustainable production is considered one of the best alternatives. Yet little work has examined the contribution of this technology in the Sahelian zone of this region. This article aims to analyze the effect of adopting agroecological practices on the food security of farm households in Burkina Faso in the context of climatic variability.

Design/methodology/approach – The analysis is based on a linear regression model with endogenous treatment effects, using data collected from 2,000 farm households by the current Thomas SANKARA University.

Findings – The results show that, in the context of climatic variability, adopting agroecological practices is part of the production strategy of rural households and has a positive effect on food security. This effect becomes more significant when these practices are combined, and the most common combinations are crop diversification/association, soil and water conservation techniques, and organic manuring.

Research limitations/implications – Given the persistence of extreme weather events, the research findings suggest that authorities should adopt a holistic approach to extending agroecological practices to strengthen farmers' resilience and food security, rather than a piecemeal approach.

Originality/value – The study highlights the food security achieving role of agroecological practices for rural households. Unlike previous studies, the results show that households are adapting to climate variability by adopting agroecological practices, thus ensuring their food security.

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Keywords Climate variability, Agroecological practices, Farm households, Food security, Burkina Faso

Paper type Research paper

1. Introduction

Food security remains a top priority for development policies in Sub-Saharan Africa (SSA). In this region, food insecurity is even more worrying. In 2022, FAO (2024) data revealed that more than one person in four (26.6%) suffered from severe food insecurity in SSA, compared with, for example, 12.6% in Latin America and the Caribbean and 2.6% in Southeast Asia. This high level of food insecurity in SSA, especially among rural households (FAO *et al.*, 2023), who derive most of their nutrition and income from agricultural activities, is partly explained by low agricultural productivity. Indeed, the average yield was 1.2 t/ha in 2017 and reached only 1.6 t/ha in 2022, far from the global level estimated at 4.2 t/ha (World Bank, 2024).

This low agricultural productivity recorded in these countries is partly explained by climate change, which is considered a major threat to agriculture. Climate change is at the root of difficulties such as water stress, ongoing land degradation, and low soil fertility (Maré *et al.*,

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2022). Several authors argue that climate variability has negative effects on agricultural production by reducing agricultural productivity in developing countries, particularly those in SSA (Dell *et al.*, 2014; Emediegwu *et al.*, 2022).

In recent years, faced with the persistent adverse effects of climate change in SSA, farmers are attempting to meet the challenge of food insecurity by employing various adaptive strategies likely to improve productivity. Economic literature identifies two types of adaptation strategies: strategies targeting a change in the production method or inputs and strategies focusing more on a change in the final product (Vodounou, 2016). This research is based on the first strategy, of which the most familiar to farmers in SSA are the use of inputs, soil and water conservation techniques (SWCT), tree planting, etc. (Deressa *et al.*, 2009).

The adoption of this class of strategies makes it possible to adapt to the negative effects of climate change (Pamuk *et al.*, 2014). Among these technologies used, Raseduzzaman and Jensen (2017) recommend the agroecological practices, which are considered to have limited negative effects on the environment and whose practice in SSA countries can strengthen farmers' resilience in the face of climate change and the demographic pressure fueling arable land constraint. Agroecology is considered an approach that applies ecological principles to the food system, through methods such as diversification, improving energy, water, and nutrient flows, maintaining soil health, and maximizing beneficial interactions between organisms to minimize toxic external inputs (Gliessman, 2015). Kerr *et al.* (2021) have shown that agroecological practices include crop diversification, intercropping, agroforestry, crop-livestock integration, and soil management measures.

Theoretically, the sustainable rural livelihoods approach proposed by Scoones (1998) and Carney (1998) shows that livelihood strategies such as agroecology enable households to adapt to climate change and thus contribute to achieving strategic objectives like eliminating poverty and food insecurity. Empirically, agroecological practices positively influence the food security of farming households in developing countries. Through a literature review, Kurukulasuriya and Rosenthal (2003) showed that the adoption of SWCT is suggested as an adaptation strategy for countries in SSA to mitigate increasing water shortages, worsening soil conditions, drought and desertification. Kerr *et al.* (2021) reviewed work in 56 papers between 1998–2019 and found that most of these studies (78%) demonstrated a positive effect of the use of agroecological practices on household food security and nutrition in low- and middle-income countries.

Kangmennaang *et al.* (2017) and Kerr *et al.* (2019) have already shown through econometric methods that agroecological approaches including intercropping and diversification, and organic manure contribute to improved well-being, both in terms of food security and income for farming households in Malawi. Kristjanson *et al.* (2012) showed that in East Africa, farming households introduced innovations such as intercropping to adapt to climate change were the most food secure. Malézieux *et al.* (2022) have shown that agroecological practices such as agroforestry, intercropping, and crop rotation significantly increase production in regions vulnerable to climate change and with growing food needs.

What these empirical studies have in common is that they show that agroecological practices help to ensure food security for farming households in developing countries, particularly those in SSA. This research can help to reinforce previous work on at least one main point. Previous authors analyzed the effect of agroecological practices on household food security without considering the fact that these practices are linked to climatic variability in the sense that they enable producers to adapt to sustain and improve their production and consumption. Furthermore, to the best of our knowledge, only a limited number of studies have specifically analyzed the impact of agroecological practices on food security using econometric methods covering the Sahelian zone of SSA. These methods enable causal relationships to be established on the basis of large-scale data (for example national) making the results generalizable. On the other hand, recent years have been marked by extreme climatic events that are becoming more frequent and widespread in SSA. Their negative effects are clearly visible and threaten more than ever the achievement of food security by farming households (Coumou and Robinson, 2013). The use of recent data in the present study therefore provides a better understanding of the current dynamics of the subject.

To carry out our analyses in SSA, we have chosen Burkina Faso as the framework for our investigations. In Burkina Faso, agriculture is the main source of employment and income. Despite this importance, achieving food self-sufficiency remains a challenge (Ministère de l'Économie et des Finances, 2016). In the Burkina Faso context, this means self-sufficiency, mainly in food crops. According to statistics, 16.2% of the population is undernourished. However, the problem of hunger is greater in rural areas despite agricultural practices. Indeed, 36.5% of households have experienced hunger in rural areas versus 25.3% in urban areas (Institut National de la Statistique et de la Démographie [INSD], 2021). This situation is partly explained by the poor performance of the agricultural sector, which affects the availability of food resources, particularly for households dependent on agriculture.

The poor performance of the agricultural sector is partly explained by climatic change and variability and the use of rudimentary technologies (Sawadogo, 2021), which further reduce agricultural yields and exacerbating food insecurity given the rain-fed nature of agriculture. Droughts are becoming increasingly regular, the most recent of which occurred in 2014 and 2020 (Crawford *et al.*, 2016). The need to adopt adaptation strategies in Burkina Faso is even more urgent if agricultural yields are to be increased and stabilized in the long term.

This research postulates that the practice of agroecology has a positive effect on food security. The aim of the research is therefore to analyze the effect of agroecological practices, arising from climate variability, on the food security of farming households in Burkina Faso. The remainder of the article is organized into four sections. The first section presents the analytical framework. The second section outlines the data source, variable selection, and description. The third section discusses the research results. The fourth section concludes the article and draws out the policy implications.

2. Framework for analyzing the effect of agroecological practices on food security

Two points are addressed in this section to describe respectively the theoretical and empirical models used for the investigation.

2.1 Theoretical model specification

The analysis of the effect of agroecological practices on household food security is based on the sustainable rural livelihoods analytical framework proposed by Scoones (1998) and Carney (1998). In accordance with this analysis framework, a livelihood comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base (Scoones, 1998; Ellis, 1998). In this analytical framework, rural economic agents - in this case, households - pursue three main types of livelihood strategy: agricultural intensification/expansion, livelihood diversification and migration. These strategies enable households to adapt to certain conditions, such as climate change and variability, in order to achieve certain important results, such as reducing poverty and improving their capabilities and living conditions. The pursuit of these strategies is possible thanks to the combination of different livelihood resources (Scoones, 1998; Carney, 1998).

Previous empirical studies similar to the present research have applied this analytical framework (Ellis, 1998; Asfaw *et al.*, 2019; Matsuura *et al.*, 2023). In these works, agroecological practices are considered as a livelihood strategy encompassing both agricultural intensification/expansion strategies and livelihood diversification that farm households adopt with the aim of improving their food security. The present research adopts the same approach but emphasizes the fact that the adoption of these practices enables farm households to adapt to climatic variability in line with the analytical framework proposed by

Scoones (1998). Thus, agroecological practices are counted among the main strategies enabling farm households to manage the negative effects on food security due to extreme weather events and unpredictable market shocks (Barrett *et al.*, 2001). This research then examines the effect of these practices on the food security of farm households, which is measured by per capita calorie intake.

Lagged weather shocks therefore affect decisions to adopt agroecological practices, while agroecological practices contribute to improving farm household food security. Several factors can also contribute to the adoption of these practices. Following Matsuura *et al.* (2023), the analysis model is specified as follows:

$$Y = f(X, A(C, X), Z) \tag{1}$$

with Y the food security indicator, X the vector of explanatory variables, Z the vector of unobserved factors, A the agroecological practice and C the vector of lagged weather shocks. Following Mulwa and Visser (2020), we accept that climate variability impacts agroecological practice decisions $A(C, X)$. In this model, agroecological practices constitute a strategy for adapting farm households to climate change and variability, thus mitigating the negative effects of extreme weather shock events (Barrett *et al.*, 2001). We therefore assume that: $\frac{\partial Y}{\partial A} > 0$

In the economic literature (Makate *et al.*, 2016; Kangmennaang *et al.*, 2017), the link between agroecology practices and food security is represented by a linear regression or a binary model depending on the nature of the indicator used. In the present research, this link can therefore be represented through a linear model written as follows:

$$Y_i = X_i\beta + \varepsilon_i \tag{2}$$

with Y_i an indicator that measures the level of food security of household i and ε_i the normal random error term with mean 0 and variance σ^2. X_i is a vector that groups all the explanatory variables.

As formalized, all explanatory variables (X_i) are assumed to be exogenous. However, a farm household's decision to practice agroecology is not random; rather, it is potentially endogenous due to the voluntary nature of the decision. According to Teklewold *et al.* (2017), farmers may, for example, endogenously self-select into adoption decisions, so these decisions are likely to be influenced by unobservable characteristics such as management skills and motivation. These skills can be correlated with the outcome of interest, i.e. food security. Building on the work of Makate *et al.* (2016), some farm households may also decide to practice agroecology because they are more aware of the benefits of these practices. Estimating a model under these conditions gives biased and not very robust results (Wooldridge, 2010).

Wooldridge (2010) shows that the linear regression model with endogenous treatment is a better alternative for dealing with endogeneity problems of any kind: omission of variables correlated with the variable of interest, errors in the measurement of this variable, reverse causality between this variable and the dependent variable, correlation problems between explanatory variables and errors. The model also makes it possible to jointly estimate the factors influencing the adoption of agroecology and the effect of this adoption on food security.

2.2 Empirical model specification

The linear regression model with endogenous treatment was introduced into the modern literature by Heckman (1978). Maddala (1983) who described the model as an endogenous switching model, subsequently derived maximum likelihood estimators and the model's control function. Barnow *et al.* (1980) worked on accounting for the self-selection bias of the simple OLS estimator of the treatment effect. Wooldridge (2010) discuss the endogenous variable binary model as an endogenous treatment effect model and relate it to recent work.

Formally, the linear regression model with endogenous treatment is composed of an equation for the outcome Y_i and an equation for the endogenous treatment A_i. Variables X_i are used to model the outcome (the dependent variable). When there are no interactions between A_i and X_i, we obtain:

$$Y_i = X_i\beta + \delta A_i + \varepsilon_i \tag{3}$$

$$\text{with } A_i = \begin{cases} 1, \textit{if } W_i\gamma + \mu_i > 0 \\ 0, \textit{otherwise} \end{cases} \tag{4}$$

Where W_i represents the vector of variables used to model treatment assignment (adoption of agroecological practices). In addition, X_i, W_i contains instrumental variables, more precisely climatic variability (represented by the average number of rains and temperature of the six years preceding the survey recall period; 2015/2016 season) and the proportion of adopters in the same village. The error terms ε_i and μ_i are bivariate normal with mean zero and covariance matrix: $\begin{bmatrix} \sigma^2 & \rho^\sigma \\ \rho^\sigma & 1 \end{bmatrix}$

The covariates X_i and W_i are unrelated to the error terms; in other words, they are exogenous. This model is a constrained model because the variance and correlation parameters are identical across the treatment and control groups.

This model can be generalized as a potential-outcome model with separate variance and correlation parameters for the treatment and control groups. The generalized model is:

$$\begin{cases} Y_{0i} = X_{0i}\beta + \varepsilon_{0i} \\ Y_{1i} = X_{1i}\beta + \varepsilon_{1i} \\ A_i = \begin{cases} 1, & \textit{if} W_i\gamma + \mu_i > 0 \\ 0, & \textit{otherwise} \end{cases} \end{cases} \tag{5}$$

where Y_{0i} is the outcome that individual i obtains if individual i does not adopt agroecological practice (which corresponds to 0), and Y_{1i} is the outcome that individual i obtains if individual i adopt agroecological practice (which corresponds to 1). We never observe both Y_{0i} and Y_{1i}, only one or the other. We observe:

$$Y_i = A_iY_{1i} + (1 - A_i)Y_{0i} \tag{6}$$

In this unconstrained model, the vector of error terms $(\varepsilon_{0i}, \varepsilon_{1i}, \mu_i)'$ comes from a mean zero trivariate normal distribution with covariance matrix:

$$\begin{bmatrix} \sigma_0^2 & \sigma_{01} & \sigma_0\rho_0 \\ \sigma_{01} & \sigma_1^2 & \sigma_1\rho_1 \\ \sigma_0\rho_0 & \sigma_1\rho_1 & 1 \end{bmatrix}$$

It should be noted, however, that the covariance σ_{01} cannot be identified because Y_{0i} and Y_{1i} are not observed simultaneously. However, the identification of σ_{01} is not even necessary to estimate the other parameters since all the covariates and the result are observed in the observations of each group. The variance of the treatment error is normalized to 1 because it is only observed if an outcome occurs under treatment.

Finally, it should be noted that the average treatment effect (ATE) and average treatment effect on the treated (ATET) are similar and directly given by the estimated coefficients, as there are no interactions between the endogenous variable and the other variables.

3. Data, choice, and description of variables

The present section deals with two points. The first outlines the data used for the analyses, and the second presents the choice and description of variables.

3.1 Data description

This research uses data from a nationwide survey conducted in 2017 by a team of researchers from the current Thomas Sankara University. The main objective of the survey was to evaluate the Programme National de Gestion des Terroirs in its second phase (PNGT2) in Burkina Faso. The project was financed by the country's Ministry of Agriculture and two partners, including the International Fund for Agricultural Development (IFAD) and the World Bank. The choice of targets (villages and households) was based on a multi-stage sampling strategy. In the first stage, villages were selected by cluster sampling according to the PNGT's mode of action and based on population representativeness at national and regional level, to enable spatial comparison between Burkina Faso's 13 regions and 45 provinces. Two to seven villages were selected in each province according to the PNGT mode of action, based on a complete list of villages provided by INSD.

In the second stage, households in each village were selected by two-stage stratified random sampling. Firstly, household ownership and use of animal traction was used as the stratification criterion and comprised three levels: (1) ownership and use of animal traction as equipment, (2) non-ownership and use of animal traction (rental), and (3) non-ownership and non-use of animal traction as equipment (manual only). Secondly, households within each group were selected at random. The sample size was set at 84 communes with an average of 3 villages each, for a sample of 250 villages. A total of 2,000 households were surveyed, i.e. 8 households in each village. Information collected included data on household socio-demographic characteristics, consumption, agricultural production, human (education, health), social, physical (equipment), and natural (land, livestock assets) capital.

The meteorological data used in the estimates in support of the survey data comes from the INSD data portal (2024) [1].

3.2 Variable selection and description

Dependent variable. As food security is a multidimensional concept, it is thus apprehended according to a variety of definitions, dimensions, time frames, and units of analysis according to Maxwell *et al.* (2014). In the present research, per capita calorie consumption is used to measure household food security (dependent variable). This indicator is relevant because most studies (IFPRI, 2006; World Food Programme, 2012; Maxwell *et al.*, 2014) have confirmed a significant correlation between caloric consumption and other benchmark food safety indicators, including food consumption score and household dietary diversity score. As a result, this measure would capture both the quality and quantity of food consumed by households. In addition, we chose this indicator because it is the main indicator of success in eliminating food poverty in Burkina Faso (INSD, 2024). The use of this indicator enables comparisons with national food security statistics provided by INSD. Calorific intake measures the quantity of calories or nutrients available for consumption (including all sources: own farm production, purchase and/or donation/loan/salary) by household members during the last seven days before the survey (Swindale and Punam, 2004). This therefore corresponds to the quantity of kilocalories (kcal) consumed by each household member per day. This indicator has been used and linked to agroecological practices in several studies, including those by Mideksa *et al.* (2023).

Following the World Food Programme approach (Swindale and Punam, 2004), data on the quantities of each type of food consumed per day (over the last few days) by household members were collected on the basis of declarations by the cooking responsible. The formula below was used to calculate the total amount of calories consumed in the household.

Let DC_{iP}, denote the caloric availability for each product p consumed by the household i.

$$\sum_{p=1}^{N} DC_{ip} = \sum_{p=1}^{N} Cal_p * D_P \text{ with } D_p = Q_c * T_t * T_e$$

Where Q_c is the quantity consumed; T_t is the processing rate; T_e is the extraction rate. Cal_p is the amount of energy in kilocalories per 100 g of product and D_p is the availability of the product. Dividing the total amount of calories consumed by the size of the household gives the calorific intake per capita.

Explanatory variables. As a reminder, the present research focuses on the link between agroecology and food security for farm households in Burkina Faso. Eight types of agroecological practices used mainly in Burkina Faso, grouped into three categories were identified in this research based on literature (Tankoano and Sawadogo, 2022; Gaye, 2019). These are crop diversification/intercropping, soil and water conservation techniques (SWCT) and the use of organic manure. Diversification refers to the use of several crops during the same agricultural season. Intercropping refers to the use of at least two crops on the same plot of land during the same agricultural season. The main types of SWCT practiced in Burkina Faso are zaï, half-moons, stone cordons, dikes, living hedges, etc. (Bambio and Agha, 2018). This research focuses on the exclusive use of agroecological practices, without chemical inputs. A household's adoption of agroecology is therefore defined as the use of at least one of these three techniques/practices during the 2016–2017 cropping season. It is therefore a binary variable that takes 1 if the household adopted this technology on at least one of these plots during the agricultural season under consideration, and 0 otherwise. The plot corresponds to a portion of land farmed by the producer.

The remaining explanatory variables, which are control variables, are chosen based on recommendations in theoretical and empirical literature (Scoones, 1998; Asfaw *et al.*, 2019; Kerr *et al.*, 2019). These variables include institutions/infrastructures and assets (natural capital, economic and financial capital, human and social capital, etc.) as recommended in the sustainable livelihoods analytical framework used by farm households to improve their food security. In this research, institutions and infrastructures were apprehended by access to market and extended service, natural capital by livestock ownership and land used and owned; economic and financial capital by household off-farm income and human capital by active member education. This analytical framework also recommends considering the relevant dimensions of household difference. In the Burkina Faso context, the gender, age and marital status of the head of household, as well as household size, are differentiating characteristics likely to influence household food security (Asfaw *et al.*, 2019).

In addition, we address the endogeneity of agroecology adoption in the model, using three instrumental variables. The first two variables are the average number of rains and the average temperature in the six years preceding the survey, in line with the work of Matsuura *et al.* (2023). The second variable is measured by the percentage of households in the same village that have adopted agroecology, excluding the household under consideration. In similar studies, Birthal *et al.* (2015), Maggio *et al.* (2021) all used the proportion of adopters within the producers' union. The other control variables are described in Table 1 below.

Table 1. Description and descriptive statistics of variables

Variables	Description	Moyenne/ proportion
Dependent variable		
Calorific value	Quantity of calories (in Kilocalories) consumed per capita per day in adult equivalent	2734.21
Independent variables		
Gender - male (%)	Sex of head of household: 1 man and 2 woman	93.48
Age	Number of completed years of the head of household	47.08
Active member education	Average years of education of active members of the household	0.60
Marital status - married (%)	Marital status of head of household: 1 married 0 otherwise	92.58
Household size	Number of people living regularly in the household	7.88
Proportion of land owned	Proportion of area over which household has formal or traditional ownership rights about the total area farmed	88.09
Livestock ownership	Number of animals owned by the household (cattle, sheep, goats)	17.28
Extended service (%)	1 if household has access to extended services and 0 otherwise	07.02
Land size	Total area of plots farmed during the agricultural season in ha	3.93
Household off-farm income	Non-farm income obtained by household in CFA francs	514242.10
Access to market (%)	1 if the village has a market and 0 otherwise	31.63
Average annual rainfall	Average annual rainfall in the locality between 2010/2011 and 2015/2016	63.06
Temperature	Average temperature (degree Celsius) between 2010/2011 and 2015/2016	29.24
Share of adopting households (%)	Share of households adopting agroecological practices within the village	19.43
Crop diversification (%)	1 if household practices crop diversification or intercropping on at least one of its plots and 0 otherwise	8.96
Soil and water management (%)	1 if household practices soil and water management on at least one of its plots and 0 otherwise	4.33
Organic manure (%)	1 if household uses organic manure only (no chemical) on at least one of its plots and 0 otherwise	11.73
Adopting single practice	1 if household uses only single agroecological practice on at least one of its plots and 0 otherwise	67.34
Adopting two practices	1 if household combines two agroecological practices on at least one of its plots and 0 otherwise	22.14
Adopting all practices	1 if household combines all the agroecological practices (crop diversification/intercropping, SWCT and organic manure) on at least one of its plots and 0 otherwise	3.12

Source(s): Authors based on literature and Survey data from PNGT2, 2017

4. Results and discussion

4.1 Descriptive statistics

Using calorific intake as a measure of farm household food security, survey data reveals that less than half (31.66%) of farm households were food secure during the 2016–2017 season in Burkina Faso. On average, per household, each member's consumption provided in terms of calories, 2734.21 kilocalories (kcal); synonymous with food security when compared to the national norm set at 2283 kcal. However, for households that adopted at least one agroecological practice, each member consumed more calories than members of non-adopting households, respectively 3145.78 kcal versus 2634.92 kcal.

Without chemical inputs, the agroecological practices most widely used by farmers are the organic manure (11.73%), followed by crop diversification/intercropping (8.96%) and SWCT (4.33%). Most adopting farmers (59.33%) combine agroecological practices. Descriptive statistics also show that over three-quarters of households (93.51%) are headed by men.

Household heads are generally adults, with an average age of 47.11 years. The data also show that although agriculture is the main activity of household heads, they farm small areas, estimated on average at 3.93 ha. Given the agroclimatic context, most households adopted at least one agroecological practice during the agricultural season. Only 7.40% of households adopted no agroecological practices at all. The remaining control variables used in the analyses are summarized in Table 1 above.

4.2 Econometric results

The results of estimating equation (3) are given in Table 2. The test of equation independence (likelihood ratio) indicates a rejection of the null hypothesis of no correlation between main and auxiliary equations at the 1% threshold, whatever the agroecological practice. The negative relationship given by this test indicates that unobservable variables that improve the level of food security of farm households in Burkina Faso tend to occur with unobservable variables that reduce the adoption of agroecological practices. The adoption of agroecology is therefore endogenous. Furthermore, the model specification is adequate, as the calculated robustness test statistic for each estimate is above the theoretical value ($\chi^2(12) = 26.22$) at the 1% threshold. All the explanatory variables therefore contribute significantly to explaining the level of food security of farming households.

4.2.1 Agroecology is a way for households to adapt to climate variability. The estimates show that climatic variability, particularly rainfall, significantly influences the adoption of agroecological practices at the 1% threshold. Specifically, an increase in the average number of rains in previous years reduces the probability of adopting these practices. This result means that farm households are more inclined to adopt these practices when, on average, the amount of rainfall in previous years tends to decrease. For example, when considering Burkina Faso's two agroclimatic zones, survey data show that 31.70% of farm households in the low-rainfall zone have adopted at least one agroecological practice, compared with only 17.87% in the high-rainfall zone. According to the work of Sawadogo *et al.* (2022), in the low-rainfall zone, farmers are continually confronted with the scarcity of rainfall and the problem of land fertility.

We also know that, as a Sahelian country, climate variability intensifies in Burkina Faso, and the need for water and soil conservation, for example, increases from one year to the next. Survey data show that SWCT (without any chemical inputs) is adopted by 14.74% of farming households in the low-rainfall zone, while this proportion is only 3.01% in the high-rainfall zone. This suggests that agroecological practices are being used by farmers to adapt to climatic variability, such as the scarcity of rainfall observed in recent years. In economic literature, several studies have reached similar conclusions. In Burkina Faso, Sawadogo *et al.* (2022) have shown that low rainfall favors the adoption and intensification of intercropping. Matsuura *et al.* (2023) found that climatic variability (drought, temperature) increased the probability of adoption of crop and income diversification among Bangladeshi households.

4.2.2 Agroecology enables farming households to enhance their food security. The estimates also show that agroecological practices positively and significantly affect household food security in the face of climate variability at the 1% threshold. The estimated ATE (which is identical to ATET) shows that, when a non-adopting household adopts crop diversification/intercropping, caloric intake for each of its members increases by 0.77%. This increase rises to 0.923% and 0.884% respectively for the adoption of SWCT and the use of organic manure. In line with the hypothesis put forward by this research, households that adopted agroecological practices were more food secure. There are several possible reasons for this. As demonstrated in the present research, agroecology enables farmers to adapt to climate change and variability. For example, SWCTs help reduce surface water runoff (Wolka *et al.*, 2021) and also improve soil moisture while protecting it from drought. Adopting these techniques also helps to protect the soil from erosion and store water, thereby reducing soil degradation and improving soil fertility (Sileshi *et al.*, 2019). Crop diversification/intercropping enables farmers to moderate production risks linked to climate change or unpredictable market prices, and to improve

Table 2. Explanatory factors for agroecological practices and household food security

Variables	(1) Food security	Crop diversification	(2) Food security	Soil and water management	(3) Food security	Organic manure
Gender	0.030	0.036	0.032	0.196	0.114	−0.530**
	(0.104)	(0.219)	(0.100)	(0.198)	(0.103)	(0.206)
Age	0.001	0.002	0.001	0.006	0.001	0.002
	(0.001)	(0.004)	(0.001)	(0.005)	(0.001)	(0.003)
Active member education	−0.001	−0.011	−0.010	0.022	−0.005	0.031
	(0.021)	(0.061)	(0.021)	(0.066)	(0.021)	(0.054)
Marital status	−0.032	0.151	−0.033	0.168	−0.039	0.085
	(0.091)	(0.215)	(0.088)	(0.202)	(0.093)	(0.183)
Household size	−0.060***	−0.014	−0.060***	−0.003	−0.061***	0.006
	(0.007)	(0.015)	(0.007)	(0.016)	(0.007)	(0.013)
Proportion of land owned	−0.001	−0.000	−0.001	0.002	−0.001	0.002
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Livestock ownership	0.016**	−0.021	0.019***	−0.040**	0.011	0.019
	(0.007)	(0.017)	(0.007)	(0.019)	(0.007)	(0.018)
Access to extended service	0.040	−0.038	0.056	−0.160	0.056	−0.099
	(0.066)	(0.161)	(0.072)	(0.211)	(0.067)	(0.157)
Land size	0.060**	−0.033	0.047*	0.072	0.093***	−0.210***
	(0.028)	(0.057)	(0.028)	(0.065)	(0.028)	(0.057)
Household off farm income	0.003*	−0.016***	0.002	−0.006	0.003*	−0.011***
	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)	(0.004)
Access to market	−0.013	−0.160	−0.023	−0.029	−0.023	−0.042
	(0.039)	(0.105)	(0.039)	(0.128)	(0.040)	(0.095)
Crop diversification	0.770***					
	(0.112)					
Soil and water management			0.923***			
			(0.139)			
Organic manure					0.884***	
					(0.094)	
Average annual rainfall		−0.016***		−0.022***		−0.007**
		(0.004)		(0.006)		(0.003)
Temperature		0.080		0.088		0.041
		(0.066)		(0.091)		(0.061)
Share of adopting households		2.609***		2.085***		2.832***
		(0.166)		(0.197)		(0.175)
Constant	7.729***	−3.595*	7.787***	−4.493*	7.637***	−2.473
	(0.192)	(2.033)	(0.186)	(2.655)	(0.195)	(1.875)
athrho	−0.511***		−0.750***		−0.811***	
	(0.142)		(0.145)		(0.116)	
lnsigma	−0.249***		−0.238***		−0.222***	
	(0.029)		(0.030)		(0.032)	
Wald $\chi^2(12)$	142.81***		132.41***		167.52***	
Prob > χ^2	0.0000		0.0000		0.0000	
Log pseudolikelihood	−2541.880		−2405.141		−2585.999	
LR test of indep. eqns. (rho = 0)/ $\chi^2(1)$	13.02***		26.81***		48.67***	
Observations	1,873	1,873	1,873	1,873	1,873	1,873

Note(s): Standard errors in parentheses
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source(s): STATA 17.0 estimate based on PNGT2 data, 2017

yields and farm income in the context of arable land constraints (Sawadogo *et al.*, 2022). Intercropping also reduces the need for pesticides, chemical fertilizers, and excessive water use, which are often difficult for poorer farmers to access, given their acquisition costs (Raseduzzaman and Jensen, 2017).

It has also been shown that agroecological practices can help improve agricultural yields and in turn food security (Gadana and Amenew, 2021). These results are in line with those found in the review by Kerr *et al.* (2021) who indicated that agroecological practices contribute to household food and nutritional security in low- and middle-income countries. Hashmiu *et al.* (2024) has also shown that crop diversification improves household food security in Ghana. Mideksa *et al.* (2023) have shown that SWCT enhances household food security in Ethiopia.

Moreover, in practice, farm households can choose whether or not to combine agroecological practices in order to optimize production. Estimates in this sense show that although households that adopted a single agroecological practice on at least one of their plots saw their food security level improve significantly at the 1% threshold, when these practices were combined, the effect was even greater (Table 3). This means that the combined adoption of agroecological practices further enhances the food security of farm households. This can be explained by the fact that the agroecological practices selected in this research are almost complementary. The adoption of SWCT or crop diversification/intercropping would be more effective with an input such as organic manure (if we want to remain in the field of agroecology). Teklewold *et al.* (2017) also found that due to deteriorating climatic variables (rising temperature, falling rainfall), farmers are more inclined to adopt a combination of practices that further strengthens their farm income. El Chami *et al.* (2020) showed that the integration of different farm management techniques offers greater benefits than the application of a single practice.

4.2.3 Unfavorable factors for food security in farming households. On the other hand, estimates show that household size contributes to reducing the food security level to the 1% threshold. In fact, household size often contributes to increasing the risks of not achieving food self-sufficiency and food insecurity in SSA countries (Yabile, 2013). Indeed, when a higher household size is synonymous with a greater weight of economically inactive members, this can contribute to increasing the risk of household food insecurity. In this case, the survey data show an average dependency ratio (1.26) greater than 1, which may be an obstacle to achieving food security. Bitana *et al.* (2023) also found that larger households are more likely to be food insecure in Ethiopia.

All the results obtained and discussed have implications in terms of economic policies, which are set out in the following section.

5. Conclusion and agricultural policy implications

This research aimed to analyze the effect of the adoption of agroecological practices on the food security of farming households in Burkina Faso in the context of climatic variability. The analysis was based on a Linear regression with endogenous treatment effects model applied to nationwide survey data collected from 2,000 farm households. We find that farming households adapt to climatic variability by adopting agroecological practices, and that the adoption of these practices contributes to their food security. In addition, the combined adoption of agroecological practices has an even greater effect on food security. The results also revealed that assets (land size, livestock, non-agricultural income) contribute to enhancing the food security of farming households in Burkina Faso. However, household size is an obstacle to achieving food security. Also, low adoption of agroecological practices, low non-agricultural income, limited animal stock and small farm size are obstacles to achieving food security.

The results of the present research have crucial policy implications in agrarian economies and particular in Burkina Faso, where achieving food security continues to be a challenge. But

Table 3. Effects of the combination of agroecological practices on the food security of farm households

Variables	Food security	Adoption single practice	Adoption two practices	Adoption all practices
Gender		−0.444**	−0.225	−0.023
		(0.224)	(0.199)	(0.246)
Age		0.001	−0.001	0.007
		(0.003)	(0.003)	(0.005)
Active member education		−0.110	−0.014	0.045
		(0.073)	(0.057)	(0.074)
Marital status		0.042	−0.037	0.410
		(0.203)	(0.177)	(0.329)
Household size		−0.026	−0.006	0.007
		(0.017)	(0.015)	(0.016)
Proportion of land owned		0.001	0.003*	−0.000
		(0.002)	(0.002)	(0.002)
Livestock ownership		−0.024*	0.035*	−0.028
		(0.014)	(0.021)	(0.021)
Access to extended service		−0.706**	−0.074	−0.122
		(0.307)	(0.163)	(0.228)
Land size		−0.351***	−0.115**	0.019
		(0.065)	(0.057)	(0.071)
Household off farm income		−0.014***	−0.006	−0.009
		(0.005)	(0.004)	(0.006)
Access to market		0.052	−0.009	−0.019
		(0.099)	(0.097)	(0.146)
Adoption single practice	0.812***			
	(0.130)			
Adoption two practices	1.079***			
	(0.085)			
Adoption all practices	0.919***			
	(0.163)			
Average annual rainfall		−0.001	−0.004	−0.025***
		(0.004)	(0.003)	(0.007)
Temperature		−0.208***	0.051	0.114
		(0.075)	(0.062)	(0.117)
Share of adopting households		2.186***	2.608***	2.003***
		(0.160)	(0.162)	(0.221)
Constant		4.923**	−3.294*	−5.158
		(2.330)	(1.917)	(3.409)
athrho		−0.571***	−0.958***	−0.695***
		(0.154)	(0.089)	(0.160)
lnsigma		−0.238***	−0.215***	−0.245***
		(0.030)	(0.032)	(0.030)
Wald $\chi^2(12)$		144.04***	244.17***	120.76***
Prob > χ^2		0.0000	0.0000	0.0000
Log pseudolikelihood		−2545.161	−2513.953	−2350.874
LR test of indep. eqns. (rho = 0)/$\chi^2(1)$		13.69***	115.26***	18.81***
Observations	1,873	1,873	1,873	1,873

Note(s): Standard errors in parentheses
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source(s): STATA 17.0 estimate based on PNGT2 data, 2017

it is becoming increasingly difficult to meet this challenge due to the persistence of the negative effects of extreme weather events such as climate variability, to which households must adapt. The results show firstly that agroecological practices are a way for farming households to adapt to climate variability. These practices are seen as sustainable production technologies which, in practice, help to protect farmland while improving its fertility. Some of them enable farmers to moderate production risks and reduce the need for chemicals inputs, given their acquisition costs, thus relieving the burden on the poorest. The results then show that the adoption of these technologies enables farming households to strengthen their food security in the long term. This implies that the adoption of agroecological practices contributes not only to increasing the quantity of food available to the household, but also its quality. Despite their importance, survey data reveal a lack of effective adoption of these practices in some areas of Burkina Faso. It is therefore important to continue encouraging and supporting the use of these practices for greater extension throughout the country. Finally, the results show that the combined use of these practices further enhances the food security of farming households. However, only about a third of adopting households have followed this practice. Research therefore suggests an integrated approach to promoting agroecological practices.

On the other hand, vocational training programs in rural areas also need to be strengthened, with an emphasis on short-, medium- and long-term training components in animal husbandry and income-generating activities, since the results show that off-farm income and animal ownership improve the food security status of farm households.

According to the results of this research, one of the main levers for ensuring food security for farming households in the context of recurring climatic shocks would be to strengthen the popularization of agroecological practices through an integrated approach. These practices should therefore be included in agricultural development programs and strategic plans. Finally, although this research has produced some interesting results, it does not address the gender dimension, even though women generally have less access to and control over productive resources. This situation makes them even more vulnerable to climatic variability. The adoption of agroecological practices and their effects on food security may therefore differ according to gender and should be analyzed.

Notes

1. https://burkinafaso.opendataforafrica.org/

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