UNDERSTANDING THE IMPLEMENTATION OF AGROECOLOGICAL PRACTICES IN EASTERN BURKINA FASO: THE ROLE OF RESOURCE ACCESS AND FARMER PROFILES

Abstract

In the context of ongoing land degradation in the Sahel, agroecological practices such as soil and water conservation structures and organic amendments are increasingly promoted for sustainable soil fertility management. Nevertheless, the adoption and effectiveness of these practices remain constrained by the socio-economic realities of farming communities. A study conducted in 2017 in eastern Burkina Faso aimed to (i) assess the socio-technical conditions underpinning the implementation of selected agroecological practices and (ii) evaluate their effects on the aboveground biomass production of three herbaceous species. Data were collected through semi-structured interviews with 292 farmers and biomass measurements using yield quadrats. Two combinations of practices were analyzed: (1) Stone Rows (SR) + Burial of Crop Residues (BCR) + Organic Manure (OM); and (2) SR + Zaï pits + OM. Farmers were grouped into four socio-economic classes, with Classes 1–3 representing the least endowed, and Class 4 the most affluent. The level of agroecological integration and intensification followed the order: Class 2 > Class 1 > Class 3 > Class 4. Herbaceous biomass production averaged 5310 ± 3914 kg·ha^{-1} under SR + ICR + OM, and 4900 ± 1158 kg·ha^{-1} under SB + Zaï + OM. These findings raise the question of whether the level of agroecological intensification is influenced by the farmer's economic status.

Keywords: Zaï pits, Stone rows, Organic manure, Agroecological intensification, Burkina Faso.

Introduction

In sub-Saharan Africa, family farming remains the dominant agricultural system, accounting for the majority of food production and rural employment (FAO, 2013). In Burkina Faso, this form of agriculture is predominantly labor-intensive, relying on family members to meet household food needs. The average farm size ranges between 3 and 6 hectares (MARH, 2008). Despite its importance, family farming is under increasing pressure due to multiple constraints, including land degradation, declining soil fertility, climate variability, low agricultural incomes, and the persistence of suboptimal farming practices (MARH, 2008; Ouédraogo & Hien, 2015).

While some of these challenges are linked to natural factors, others such as land degradation and soil fertility decline are primarily anthropogenic. Expansion of cultivated land to increase yields, continuous cropping without fallow periods, excessive reliance on chemical fertilizers, and the removal of crop residues with limited organic matter return have led to reduced soil productivity and deteriorated vegetation cover (Hien, 2004; Koulibaly et al., 2010; Sidibé & Havard, 2015). These dynamics have contributed to declining crop yields and household incomes.

In response, farmers often in partnership with development organizations have implemented soil fertility improvement practices, especially in the driest regions of the country (Dialla, 1992; Reij et al., 2009). These practices include various soil and water conservation (SWC) and land restoration techniques such as *zaï* pits, stone rows, live hedges, incorporation of crop residues, and the production and use of organic manure. These interventions, which enhance natural soil fertility processes, are increasingly recognized as agroecological in nature (McIntyre et al., 2009).

Empirical studies have highlighted the effectiveness of these practices in rehabilitating degraded soils and improving crop productivity (Zougmoré et al., 2004; Yaméogo et al., 2013; Palé et al., 2021; Koumbem et al., 2022). Their success is particularly evident in the North and Centre-North regions of Burkina Faso, where smallholder farmers apply them on crusted soils (Hien et al., 2012). In these contexts, spontaneous herbaceous species such as *Andropogon gayanus Kunth* are often preserved along stone rows to reinforce their ecological function and are also harvested for domestic uses, including granary construction (Sawadogo et al., 2008).

Despite well-documented agronomic and ecological benefits, scaling up these practices remains a challenge. Previous studies note that implementation is often hindered by limited access to appropriate equipment and the labor-intensive nature of the work (Bationo & Sankara, 2006; Clavel et al., 2008). Moreover, most available data pertain to specific regions and do not provide detailed insights into the quantities of inputs (e.g., stones, organic manure, crop residues) and labor requirements under agroecological conditions.

To address these gaps, this study aims to (i) assess the conditions under which agroecological practices are implemented focusing on the resources mobilized, constraints faced by farmers, and their motivations and (ii) evaluate the dry matter production of three herbaceous species under two commonly adopted agroecological systems in the study area.

Material and methods

Study area

The present study was conducted in the Bilanga rural district, located in the Eastern region of Burkina Faso. This district lies between 12°54'50" and 12°54'72" North latitude and 0°03'89" and 0°01'33" West longitude, at an elevation of 271 meters above sea level (Figure 1). Data were collected from the villages of Bilanga Yanga, Tiguili, and Kolokomi. The study area is part of the northern Sudanian sector (Fontès and Guinko, 1995), characterized by a Sudanian-Sahelian climate with an average annual rainfall of approximately 700 mm. The dominant soil types are tropical ferruginous soils (BUNASOLS, 2000).

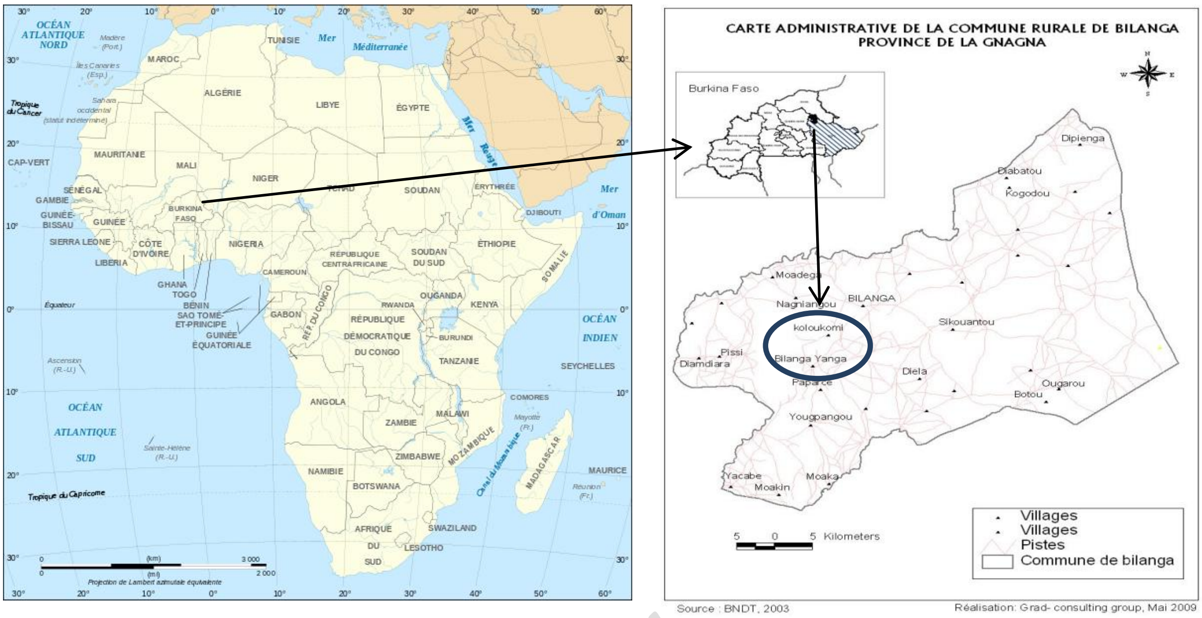

Figure 1: Location of study area

Data Collection

The Participatory Rural Appraisal (PRA) approach was used for data collection. This included semi-structured interviews conducted both in focus groups and individually, as well as tools such as village historical profiling, Venn diagrams, and interviews with technical and development services, along with other key informants, to gather and/or cross-check socio-economic and agro-environmental information. The selection of farming households for the interviews (focus groups and individual surveys) was based on a preliminary typology developed during the diagnostic study of the research area by Levard and Mathieu (2018).

Characterization of agroecological practices and structural features of Ffarming households

The characterization of agroecological practices among farming households was conducted through interviews with 292 farmers and representatives from development organizations (Non Governemental Organisations (NGOs) and agricultural technical services). The sample size for the farmers (n = 292) was determined using Dagnelie's formula (1998): n= $\frac{Pi(1-Pi){U^2}_{1-\alpha/2}}{d^2}$ where *n* is the number of farmers practicing agroecological methods and receiving support from development organizations; *Pi* is the proportion of such farmers within the population; and ${U^2}_{1-\alpha/2}$=1.96, the value of the normal distribution for a confidence level of 95% (α = 0.05).

The data collection was carried out in three phases. The first phase involved individual interviews with development structures engaged in promoting agroecological practices, particularly NGOs and technical agricultural services. These interviews aimed to collect data on the total number of farmers, the number of farmers supported by NGOs in implementing agroecological practices, and the challenges faced by these NGOs. The second phase consisted of three focus group discussions involving ninety-seven (97) farmers from the three study villages. These discussions helped identify the agroecological practices in use and the periods during which they were introduced or adopted. Additional surveys were conducted with one hundred and thirty-seven (137) randomly selected farmers to classify their fields based on location (compound fields vs. bush fields), estimate their sizes, and identify the agroecological practices being implemented. Together, the focus group discussions and complementary surveys provided a robust dataset for selecting fifty-eight (58) farmers for in-depth individual interviews. These individual interviews, forming the third phase of data collection, gathered detailed information on the structural characteristics of the farms, such as the farmer's age, the number of years implementing agroecological practices, total field area and area by practice, number of active household members, level of farm equipment, and livestock holdings. Information on constraints and benefits associated with the implementation of agroecological practices was also collected during these interviews.

Agroecological practices implemented by farmers

The main agroecological practices identified in the study area include stone rows, the use of organic manure, and agroforestry (practiced across all farmer categories), as well as the incorporation of crop residues (practiced by categories 1, 2, and 3), and *zaï* pits (practiced by categories 1 and 2). Stone rows are constructed in the fields along contour lines, with spacing between bunds varying from 25 to 33 meters. The bunds are arranged either in triple-stone systems (for small to medium-sized stones) or in single alignments (for larger stones). During the rainy season, they become vegetated with numerous herbaceous species and some woody species. Crop residues, particularly a portion of cereal straw, are left on the plots as mulch and later incorporated into the soil through plowing during the rainy season. *Zaï* involves the manual digging of planting pits each year, typically during the dry season or at the onset of the rainy season. Organic manure is placed into the pits afterward. The organic matter used is diverse and includes compost, farmyard manure, fodder leftovers, and household waste. It is generally broadcast as a basal fertilizer each year. Agroforestry is practiced by maintaining trees and shrubs of various species within the fields. These species serve multiple purposes, including food, income generation, and soil fertility enhancement.

Estimation of input quantities and labor time for farming operations

Inputs refer to the trees present in the fields, crop residues particularly cereal straw, stone fragments, and organic manure (OM), all used by farmers to combat land degradation and improve soil fertility.

Inputs such as cereal straw and OM are applied annually, whereas the collection of stone fragments used for constructing stone rows takes place over several years. The number of trees was estimated by farmers by field type and total area, then standardized per hectare. Cereal straw was estimated in kilograms per hectare (kg/ha). The quantity of stone fragments was estimated by farmers in cartloads. The amount of OM produced was also estimated by farmers in cartloads per hectare. The carts used are tipping carts (dump-type). The quantity of OM was then converted into kilograms using the method of Berger (1996), who indicated that 1 cartload of OM = 150 kg. The estimation of labor time covered the following farming operations: digging *zaï* pits, applying organic manure into the pits, collecting stone fragments, constructing stone rows, broadcasting organic manure, plowing, sowing, weeding, ridging using animal traction, manual ridging, and harvesting cereals. Labor time, initially estimated by farmers in hours, was converted into Man-Days (MD) using the conversion factor from MAHRH (2004): 1 MD = 8 working hours.

Farmers' perception of cereal self-sufficiency

This information was collected through individual interviews with fifty-eight (58) farmers. The farmers were asked whether, between 2012 and 2016, their cereal production (millet and sorghum) met their household cereal needs. Three types of responses were recorded: (i) cereal production met household needs regardless of the year, (ii) cereal production met household needs in certain years only, and (iii) cereal production did not meet household needs in any year. Farmers reporting a cereal deficit indicated that they procured additional cereals from the local market, specifying both the quantities purchased and the purchase costs.

Agroecological practices and aboveground biomass assessment of three herbaceous species

This assessment focused on three herbaceous species: *Andropogon gayanus* Kunth., *Pennisetum pedicellatum* Trin., and *Pennisetum violaceum* (Lam.) L. Rich. The agroecological practices (combination of agroecological practices) considered were: (1) Stone rows (SB) + Incorporation of Crop Residues (ICR) + Organic Manure (OM), and (2) SB + Zaï + OM. For each practice, three plots were selected for measurements. On each plot, three yield quadrats were established. Each quadrat measured 5 meters along the length of the stone bund and extended 2 meters upstream and downstream of the bund. This design was chosen because the three herbaceous species are commonly maintained by farmers along the bunds, particularly within a 1-meter strip on both the upstream and downstream sides. The dimensions also accounted for the influence of zaï on the respective plots. All three herbaceous species within each quadrat were harvested at ground level. A sample from each lot was collected and weighed to determine the fresh weight. The samples were then oven-dried at 75 °C for 72 hours to determine the dry weight using the following formula:

$$DW = \frac{\text{DWs}}{\text{FWs}} \times FWt$$

Where: DW = total dry weight, FWt = total fresh weight, DWs = dry weight of the sample; FWs = fresh weight of the sample

Statistical analysis of data

Statistical analyses of the collected data were performed using XLSTAT software, version 2017. Principal Component Analysis (PCA) and Hierarchical Ascending Classification (HAC) were used to group farmers into homogeneous classes. The variables considered for these analyses included: farmer age, total cultivated area and field types, level of equipment, number of active household members, and livestock size.

To test the significance of mean differences between farm classes, both analysis of variance (ANOVA) for normally distributed variables and non-parametric tests specifically the Kruskal-Wallis test for non-normally distributed variables were applied at a 5% significance level. The Shapiro-Wilk and Levene tests were used to assess the normality and homogeneity of variances, respectively. Variables analyzed using the Kruskal-Wallis test included: bush fields, carts, manure sheds, compost pits, cattle, sheep, goats, and labor time for stone collection, stone bund construction, plowing, sowing, weeding, and harvesting. The remaining variables were analyzed using ANOVA with the Student-Newman-Keuls post-hoc test at the 5% threshold.

Results

Determinants of agroecological practice adoption

General characteristics of surveyed farming households

Principal Component Analysis (PCA) and Hierarchical Ascending Classification (HAC) allowed for the identification of four (04) classes of farmers (Table 1). Classes 1 and 3 consisted of the youngest farmers, with average ages of 44 ± 17 years and 44 ± 12 years, respectively. These two groups also cultivated the smallest field areas, averaging 2 ± 1 ha for Class 1 and 2 ± 2 ha for Class 3. They also had fewer active household members, with averages of 6 ± 3 (Class 1) and 6 ± 2 (Class 3). Class 2 comprised farmers with an average age of 50 ± 11 years and had the highest average number of sheep (10 ± 12 head). Class 4 (n = 4) was composed of the oldest farmers (80 ± 8 years), who had the largest field areas (7 ± 2 ha), the highest number of active household members (25 ± 8), and larger livestock holdings, including cattle (9 ± 6 head), goats (15 ± 13 head), and donkeys (3 ± 2 head). All farmers in Class 4 (100%) owned at least one cart, and 75% had at least one compost pit. With the exception of the number of sheep and donkeys, statistical analysis revealed significant differences ($P < 0.05$) among the classes for all other variables.

Table 1: Characteristics of the farm class structure

	Classe 1 (n= 23)	Classe 2 (n= 24)	Classe 3 (n= 7)	Classe 4 (n= 4)	Pr	Si
Age (years)	44 ± 17 ^{b}	50 ± 11 ^{b}	44 ± 12 ^{b}	80 ± 8 ^{a}	0.0001	S
Experience as farm manager (years)	16 ± 14 ^{b}	18 ± 11 ^{b}	12 ± 9 ^{b}	49 ± 10 ^{a}	<0.0001	S
Average field size (ha)	2 ± 1 ^{b}	3 ± 2 ^{b}	2 ± 2 ^{b}	7 ± 2 ^{a}	<0.0001	S
Nombre of bush fields	1 ± 0 ^{a}	1 ± 0.30 ^{a}	0 ± 0 ^{b}	1 ± 0 ^{a}	<0.001	S
Number of workers	6 ± 3 ^{b}	8 ± 6 ^{b}	6 ± 2 ^{b}	25 ± 8 ^{a}	<0.0001	S
Farmers with carts (%)	26.08 ^{b}	66.67 ^{b}	71.42 ^{b}	100 ^{a}	0.0004	S
Farmers with stables (%)	30.43 ^{d}	66.67 ^{b}	57.14 ^{c}	75 ^{a}	<0.0001	S
Farmers with manure pits (%)	52.17 ^{b}	66.67^{a}	28.57 ^{b}	75 ^{a}	0.02	S
Number of cattle	1 ± 1 ^{b}	4 ± 4 ^{b}	1 ± 2 ^{b}	9 ± 6 ^{a}	<0.0001	S
Number of sheep	4 ± 4	10 ± 12	5 ± 3	7 ± 12	0.091	NS
Number of goats	3 ± 4 ^{b}	10 ± 7 ^{ab}	5 ± 6 ^{b}	15 ± 13 ^{a}	0.004	S
Number of donkeys	2 ± 2	2 ± 1	1 ± 1	3 ± 2	0.378	NS

Legend :Pr: Probability; Si: Significance; S: Significant; NS: Not Significant, n= number of farmers per class

Input quantities and labor time under agroecological conditions

Table 2 presents the quantities of inputs used per hectare. Class 2 recorded the highest amounts of straw incorporated into the soil (1500.77 ± 984.20 kg/ha), organic manure (2921.24 ± 1120.88 kg/ha), and stone fragments (35 ± 22 cartloads/ha). Class 4 used the lowest quantity of organic manure (1856.24 ± 549 kg/ha). Class 1 showed the highest density of trees and shrubs (28 ± 14 per hectare). The most frequently encountered tree and shrub species were *Lannea microcarpa* Engl. & K. Krause, *Vitellaria paradoxa* Gaertn. f., *Piliostigma reticulatum* (DC.) Hochst., *Balanites aegyptiaca* (L.) Del., and *Azadirachta indica* A. Juss. Among these, *Piliostigma reticulatum* and *Azadirachta indica* were the most conserved within fields and benefited from Assisted Natural Regeneration (ANR). Except for *Vitellaria paradoxa*, the other species also grew along the stone rows. ANOVA revealed a significant difference only for the density of trees and shrubs ($p < 0.05$) among the different classes.

Table 2 : Quantities of inputs used in the implementation of agro-ecological practices

Classes	Straw (kg per ha)	Organic Manure (kg per ha)	Rubbles (number of carts per ha)	Trees and shrubs (number per ha)
Classe 1	790 ± 674	2598± 668	23 ± 9	28 ± 14 ^{a}
Classe 2	1500± 984	2921± 1120	35 ± 22	20 ± 11 ^{a}
Classe 3	950 ± 685,	2520± 1316	22 ± 8	13 ± 7 ^{ab}
Classe 4	--	1856± 549	26 ± 10	16 ± 10 ^{ab}
Probability	0.184	0.482	0.728	0.018

Significance	NS	NS	NS	S

Legend :Farmers in this class do not bury crop residues; NS: Not Significant. Values preceded by a ± sign indicate standard deviations within the same class.

Labor Time for Different Farming Operations

Labor times for various farming operations are presented in Table 3 Class 2 devoted the most time to digging *zaï* pits (12.58 ± 7.38 Man-Days, MD), localized application of organic manure (2.58 ± 1.75 MD), and stone collection (6.32 ± 5.52 MD). Class 1 spent the most time on stone bund construction (4.25 ± 3.17 MD), organic manure spreading (2.10 ± 0.87 MD), plowing (3.82 ± 2.69 MD), sowing (2.52 ± 1.30 MD), weeding (5.80 ± 2.84 MD), and ridging with animal traction (2.22 ± 0.79 MD). Class 3 recorded the highest labor times for manual ridging (3.96 ± 2.11 MD) and cereal harvesting (4.99 ± 1.94 MD). Conversely, Class 4 devoted the least time to stone bund construction (0.75 ± 0.46 MD), plowing (1.22 ± 0.82 MD), sowing (1.33 ± 0.82 MD), weeding (4.09 ± 2.54 MD), and cereal harvesting (2.09 ± 1.64 MD). Except for stone bund construction and plowing, ANOVA did not reveal significant differences between farmer classes in labor times for the other operations.

Table 3: Work time for cultivation operations by class of farmers under agro-ecological conditions (Man Day / ha)

Classes	Zaï pit digging an	Application OM in Zaï	Stones collecting	Construction SR	Spreading OM	Ploughing	Sowing	Weeding	Harnessed ridging	Manual ridging	Cereal harvest
Classe 1	11.98 ± 7.09	2.34 ± 1.75	5.48 ± 3.64	4.25 ± 3.17	2.10 ± 0.87	3.82 ± 2.69	2.52 ± 1.30	5.80 ± 2.84	2.22 ± 0.79	3.30 ± 0.8	4.71 ± 2.70
Classe 2	12.58 ± 7.38	2.58 ± 2.13	6.32 ± 5.52	3.63 ± 2.18	1.88 ± 0.90	1.88 ± 1.12	1.73 ± 0.86	4.51 ± 2.25	1.78 ± 0.70	3.96 ± 2.11	3.83 ± 2.57
Classe 3	--	--	2.38 ± 0.18	0.91 ± 0.57	0.88 ± 0.40	2.08 ± 1.01	1.96 ± 0.90	5.43 ± 2.80	1.21 ± 0.31	4.58 ± 0.72	4.99 ± 1.94
Classe 4	--	--	3.77 ± 3.28	0.75 ± 0.46	1.56 ± 1.37	1.22 ± 0.87	1.33 ± 0.82	4.09 ± 2.54	1.29 ± 1.09	--	2.09 ± 1.64
Probability	0.923	0.711	0.476	0.004	0.122	0.009	0.074	0.384	0.154	0.386	0.063
Significance	NS	NS	NS	S	NS	S	NS	NS	NS	NS	NS

Legend: -- denotes not filled in because the farmers belonging to this class are not involved in the cultivation operation. The figures preceded by a ± sign indicate the standard deviations within a class; 1 Man Day = 8 hours of work ; S : significant ; NS : Non Significant ; OM : Organic Manure ; SR : Stone Ro

Constraints in the implementation of agroecological practices

Challenges faced by NGOs and Associations in promoting agroecological practices

The difficulties encountered by NGOs in disseminating agroecological practices include the low repayment capacity of farmers, land tenure insecurity, and reluctance from government authorities who had long viewed these actors as lagging in development. According to an NGO official, loans in the form of equipment (carts, plows) were granted twice in the past to farmers, but only about 30% of the beneficiaries were able to repay. This NGO effort was halted due to the implementation of Structural Adjustment Programs, which transferred agricultural credit provision to microfinance institutions, the official added. Furthermore, NGOs report that farmers, who have only usufruct rights to the land, hesitate to adopt agroecological practices because landowners can reclaim the land at any time.

Constraints faced by farmers in implementing agroecological practices

The most frequently cited constraints by farmers across all classes were primarily the lack of equipment and financial resources needed to carry out techniques such as *zaï*, stone row construction, and compost production. Other significant challenges included competition between woody plants and associated crops in agroforestry systems, as well as the intercropping of sorghum-cowpea and millet-cowpea, and a shortage of labor (Figure 2).

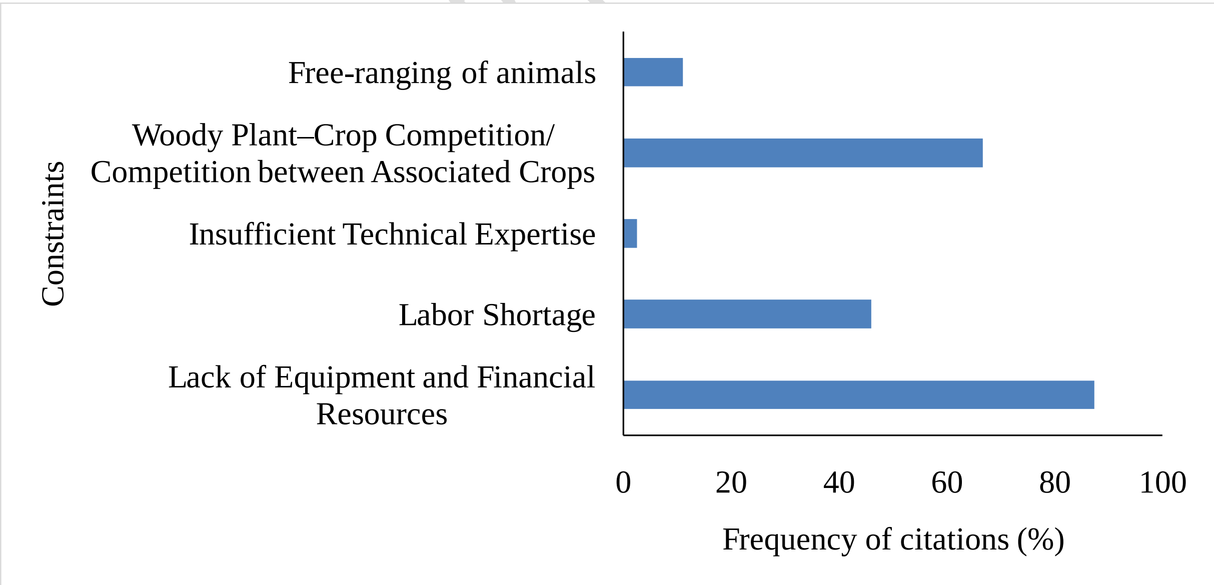

Figure 2: Main Constraints to the Implementation of Agroecological Practices According to Farmers, Across All Classes

Farmers' perception of cereal self-sufficiency

Farmers whose cereal production met household cereal needs from 2012 to 2016, regardless of the year, accounted for 42.86%, 44%, 42.86%, and 50% of Classes 1, 2, 3, and 4, respectively (Figure 3). Those whose production did not meet cereal needs in any year during the same period represented 33.33%, 20%, 28.57%, and 25% of Classes 1, 2, 3, and 4, respectively. The average quantities of sorghum purchased from the local market to fill the cereal deficit ranged from 403.64 kg (Class 1) to 660 kg (Class 4), corresponding to average purchase costs of 114 dollars US (Class 1) and 202 dollars US (Class 4), respectively (Figure 4).

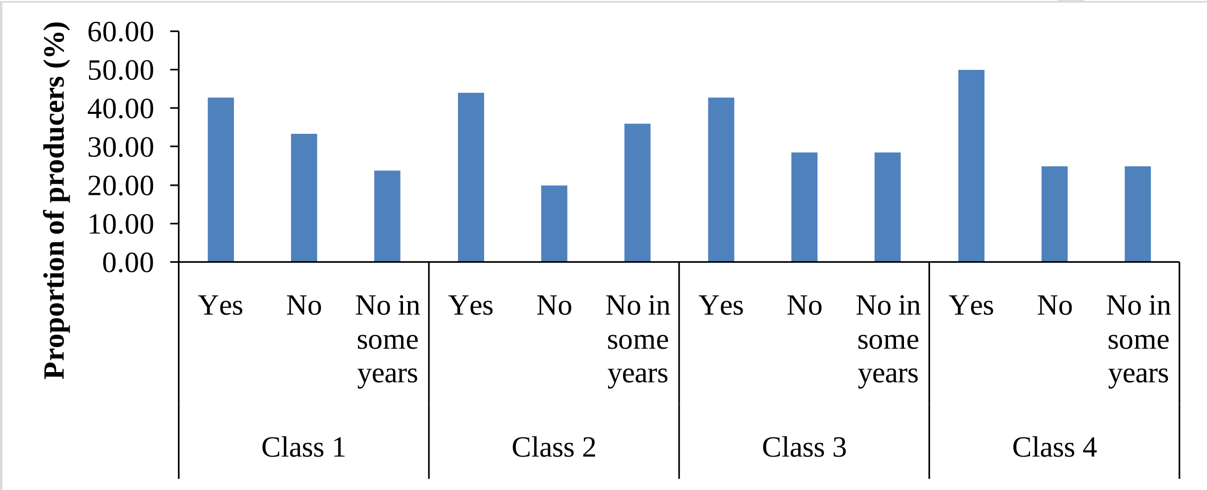

Figure 3: Farmers' perception of cereal self-sufficiency

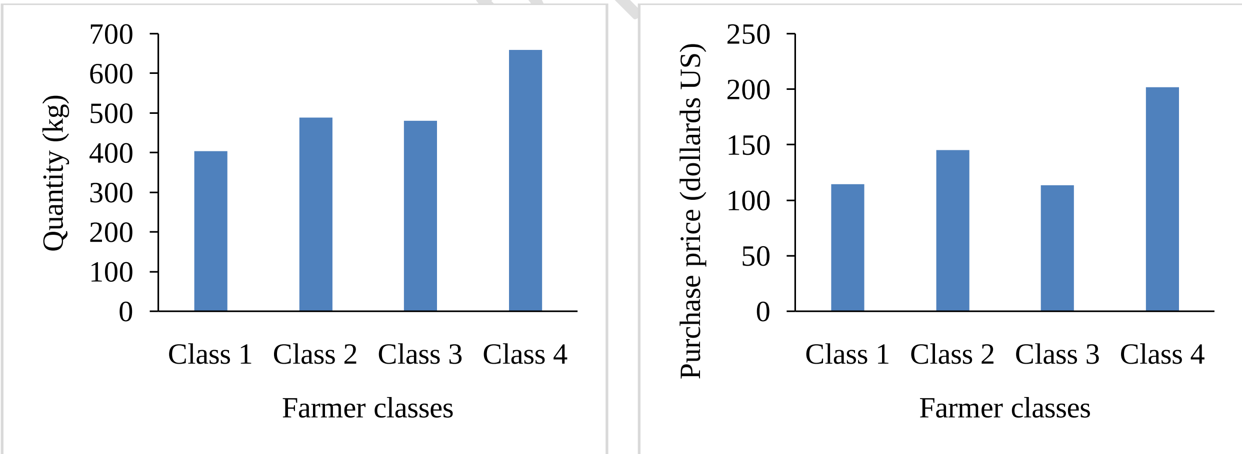

Figure 4: Variation in the quantity and purchase price of sorghum by farmer class

Evaluation of the above-ground biomass of three herbaceous species

Figure 5 presents the above-ground biomass of the three herbaceous species: *Andropogon gayanus* Kunth., *Pennisetum pedicellatum* Trin., and *Pennisetum violaceum* (Lam.) L. Rich. The practice combining Stone rows (SR) + Burial of crop residue (BCR) + Organic Manure (OM) recorded an average dry matter yield of 5310 ± 3914 kg/ha, compared to 4900 ± 1158 kg/ha for the practice SB +

Zaï + OM. Both types of agroecological practices showed statistically similar levels of herbaceous biomass production.

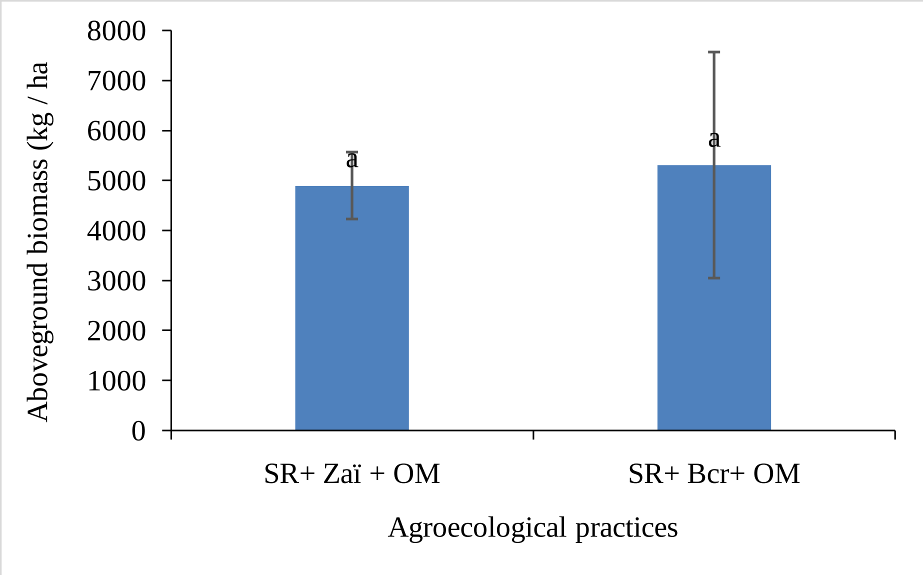

Figure 5: Variation of herbaceous aboveground biomass according to agroecological practices

Legend : SR : Stone rows ; OM : Organic Manure ; Bcr : Burial of crop residue

Discussion

Less-endowed farmers in terms of labor, equipment, and livestock exhibit higher levels of agroecological integration and intensification

Integration of crop and livestock farming, stone rows, and agroforestry are common practices across all farmer classes (Tables 1, 2, and 3). In the study area, crop-livestock integration occurs through organic manure production, use of feeding refusals for field fertilization, and animal traction for transporting stones and organic manure, as well as plowing and ridging activities. Vall et al. (2012) reported that crop-livestock integration, besides being common among both farmers and agropastoralists, was more intensified among farmers in terms of production efficiency, organic manure application rates, and fulfillment of farm organic manure needs.

The characteristics of Class 4 confirm the findings of Vall et al. (2012), who showed in the Sudanian zone of Burkina Faso that cultivated area is proportional to the number of active household members, equipment level, and livestock size. However, less-equipped farmers (Classes 1, 2, and 3) display a higher degree of agroecological integration by implementing a greater number of agroecological practices (Rosset et al., 2011). This tendency to adopt technological innovations among these farmers aims to compensate for insufficient equipment and livestock for transporting and recycling crop residues into organic manure. This perception contrasts with the findings of Koutou et al. (2016), who argued that wealthier farmers are the most innovative. However, their results may be explained by the fact that wealthier farmers are more willing to "take the risk" of innovation.

Similarly, there is a trend toward agroecological intensification among less-endowed farmers (Classes 1, 2, and 3). The organic manure application rates on annually manured areas among these farmers conform to the national research recommendations of 2.5 t/ha. Wealthier farmers (Class 4) attribute their lower level of agroecological intensification to their tendency to cultivate larger areas.The higher number of agroecological practices and farming operations associated with lower levels of equipment and labor observed in Classes 1, 2, and 3 could explain why these farmers devote more time to various farming operations. Our results differ from those of Vall et al. (2023), who reported better agroecological intensification on farms with a higher number of active workers per hectare and equipment dedicated to implementing agroecological practices in the Sudanian zone of Burkina Faso. This discrepancy may be explained by peasant logic in our study area, where limited resources and perceived vulnerability of lands to degradation require combining different strategies to ensure agricultural production. This peasant logic aligns with the work of Pouya et al. (2013), who justified the higher adoption of soil and water conservation techniques (CES/DRS) in the northern Sudanian zone compared to the southern Sudanian zone, where adoption was lower due to a less acute perception of natural resource degradation by farmers in the northern zone.

However, the stone rows exhibited heterogeneous levels of grass cover, which explains the high standard deviations observed for the same practice. This variability appears to be more related to environmental conditions than anthropogenic factors, especially since herbaceous species grow spontaneously along the bunds. The biomass production is comparable to that reported by Kiema et al. (2012), who obtained an herbaceous aboveground biomass yield of 5856 kg/ha dry matter in half-moon structures in grazing areas of the Sahelian zone in Burkina Faso. According to farmers, the three herbaceous species provide dual benefits. During the rainy season, they reinforce the effect of stone rows in reducing runoff, confirming the findings of Zougmoré et al. (2004), who noted a 45% reduction in runoff by grass strips. At the end of the rainy season, the grasses are cut and used for building granaries for harvest storage and roofing for houses, illustrating the role these herbaceous plants play in providing ecosystem services, as highlighted by Sawadogo et al. (2008).

Material and financial constraints are the most limiting factors in the implementation of agroecological practices by farmers

Material and financial constraints limit the capacity for agroecological intensification at the farm scale. Due to the lack of appropriate soil working equipment (mechanization tools), the zaï technique is practiced on less than 30% of the total cultivated area, using hand tools such as planting hoes and, in better cases, pickaxes. However, case studies conducted in the northern Sudanian and sub-Sahelian zones of Burkina Faso have shown that mechanizing the zaï with a specific tine plow can reduce labor time by up to 900% (Barro et al., 2005), thereby allowing farmers to cultivate larger areas.

Furthermore, insufficient equipment for collecting and transporting stones (pickaxes, crowbars, carts, wheelbarrows), combined with the remoteness of stone collection sites, limits coverage of the entire cultivated area. Bationo and Sankara (2006) identified the distance to stone collection sites as a major obstacle to the adoption of stone rows by farmers lacking transport equipment. Moreover, the areas that are covered are not sufficiently so, as farmers estimate that about 30 cartloads of stones are needed to cover one hectare, whereas most of them (except Class 2) are unable to mobilize such quantities. The lack of equipment for producing and transporting organic manure (carts and manure pits), low livestock numbers, and the distance to water points were mostly cited by farmers in Classes 1 and 3 as constraints to organic manure production. This perception aligns with previous studies (Noufé et al., 2018; Coulibaly et al., 2019; Mekuria et al., 2022), which highlighted that lack of equipment and insufficient labor constitute barriers to the development of soil and water conservation techniques (CES/DRS).

A form of social assistance enables farmers without carts to borrow them from relatives or acquaintances for transporting organic manure. However, this solidarity does not extend to stone transport, as cart owners, fearing accelerated wear and tear, refuse to lend their equipment to those without carts. Consequently, these farmers must hire tricycle drivers, paying transportation fees.

The cereal deficit faced by most farmers is another impediment to the adoption of CES/DRS techniques. Indeed, according to the farmers, they are forced to spend their savings, obtained from the sale of poultry and small ruminants, which were meant to improve the implementation of these techniques, on purchasing cereals to fill the deficit. Furthermore, an insufficient level of agroecological intensification, combined with the low productivity of the predominantly used local cereal varieties, may help explain cereal deficit which is the more pronounced among farmers with higher levels of equipment and labor. The limited yield potential of these local cereal varieties under similar agroecological conditions has also been reported by Ganémé et al. (2021). Financial constraints were also reported by Kohio et al. (2017) and Sakandé et al. (2022) as major obstacles to sustainable land management technologies.

The depressive effect of trees/shrubs on associated crops manifests at two levels, according to farmers: a direct effect through shading, which causes growth delays and yield reductions; and an indirect effect because some tree/shrub species serve as refuges for granivorous birds that damage crops. Several studies have reported the depressive effects of trees on crop production, explaining this as the result of competition between trees and associated crops for light and nutrients, as well as allelopathic effects caused by inhibitory compounds secreted by certain woody species (Bazié et al., 2012; Cathy-

Clermont et al., 2019; Abeje et al., 2023). Reij and Winterbottom (2015) also noted that, fearing that trees might attract crop-damaging birds, farmers limit tree expansion in their fields.

Conclusion

Our study revealed the existence of diverse farming systems. The wealthiest farmers in terms of number of active members, equipment level, and livestock (Class 4) own the largest cultivated areas, but they are less innovative in adopting agroecological practices, have low intensification of agroecological practices and are more impacted by cereal deficit. Conversely, less-endowed farmers (Classes 1, 2, and 3) exhibit a higher level of agroecological intensification and devote more time to various farming operations. Moreover, the main challenges encountered in implementing agroecological practices are predominantly material and financial, which may compromise the cereal self-sufficiency reported by the farmers. Nevertheless, the role of agroecological practices as climate change adaptation strategies constitutes a favorable factor for their development in the Eastern region. The adoption of agroecological practices by farmers strongly depends on the number of active members, level of equipment, and livestock they possess. Thus, the farmer's socioeconomic status largely determines their commitment to sustainable land management practices. Support for farmers through advisory services and agricultural credit could enable the mechanization of certain practices, such as zaï, and promote better intensification of agroecological practices.

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