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Socio-economic indigenous drivers of soils and water conservation practices use to cope with climate change in the region of Plateau Central in Burkina Faso

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ABSTRACT

Continuous soil degradation and recurrent droughts caused by climate change are challenging agricultural production in the Central Plateau region of Burkina Faso. Some management techniques were developed and disseminated to farmers, in order to reduce the effects of drought and restore degraded soils. However, the adoption rate of these techniques is still low. The present study aimed at identifying and analysing the indigenous determinants of the adoption of zaï and stone rows techniques by farmers. *Zaï* is a small planting pit of about 20–30 cm in width, 10–20 cm deep, and filled with organic matter (manure, compost or dry biomass). Stone row is an anti-erosive device built of blocks of rubble assembled by a series of two to three. Data were collected through a survey carried out on 135 heads of households in four municipalities in the provinces of *Kourwéogo* and *Oubritenga*. A binary logistic regression model was used to analyse the factors determining the adoption of *zaï* and stone rows practices. The results showed that the level

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of education, membership to a local organization and cattle ownership positively influenced the adoption of *zaï*. In addition, membership to a local organization positively affected the adoption of stone rows. In contrast, the practice of small trading negatively affected the adoption of *zaï*. Therefore, it is essential for institutions, policymakers and NGOs to consider these factors in order to make their interventions more efficient in a global change context.

Keywords: climate change, indigenous determinants, logit model, trading, stone rows, *zaï*.

INTRODUCTION

Soil degradation remains one of the global threat. 33% of the Earth's soils are already degraded and over 90% could become degraded by 2050 (FAO and ITPS, 2015; IPBES, 2018). Erosion has been identified as the greatest threat to soil; 75 billion tons of soil and 10% of agricultural production could be lost by 2050. Burkina Faso is facing significant and continuous degradation of its natural resources (Kagambèga et al., 2011). Low fertility of soils remains disquieting. Based on pedological studies, the measurement of mineral and organic balances of cultivated soils and vegetation observations, the evolution of soil fertility shows worrying states of depletion and degradation. Most common soil-related problems include low organic matter, general deficiency in phosphorus, nitrogen and potassium, low cation exchange capacity, fairly advanced physical degradation, insufficient water retention capacity, exposure to erosion phenomena, difficulties in supplying fertilizers and low fertilizer use (Koulibaly et al., 2014; Somda et al., 2017). The main causes of this decline in fertility are population growth (Pay et al., 2001; Hartmink et al., 2008), the effects of climate change and certain poor farming practices such as continuous cultivation of the soil, the use of very few or no inputs, and the export of crop residues (Ouattara et al., 2022). Farmers however use soil and water conservation techniques to adapt to this context of soil degradation and recurrent droughts. Many studies have focused on soil and water conservation practices (SWCPs). Most of them highlighted the positive effects of these techniques on crop yields, soil physical and chemical properties. Concerning straw and grain yields, studies have shown that *zaï* can increase yields. Simple *zaï* and *zaï* with compost or phosphate application recorded sorghum yield gains of 300 to 1244 $kg.ha^{-1}$ (Sawadogo et al., 2008; Bayen et al., 2012). The stone rows combined with *zaï* resulted in yield gains ranging from 655.2 $kg.\ ha^{-1}$ to 1,151.43 $kg.ha^{-1}$ compared to the control (Yaméogo et al., 2013) and the addition of compost boosted yields by up to 142% and a cash flow generation of 145,000 to 180,000 FCFA. $ha^{-1}.year^{-1}$ (Zougmoré et al., 2004). With stone barriers, run-off was reduced by 53% (Gnissien et al., 2021). Also, stone rows, stones rows with combining organic manure or cereal straw mulching slowed down erosion, regularized slopes level, improved soil chemical characteristics and soil carbon stock, reduced nutrient and fine sediments losses (Barry et al., 2008) and resulted in a carbon stock of 77% when combined with *zaï* (Yaméogo et al., 2019). Regarding the effects of SWCPs on the soil, stone rows and *zaï* pits remain alternative to recover degraded land. Despite the large number of research results highlighting the beneficial effects of SWCPs, low adoption rates remain one of the major problems of rural actors in Burkina Faso. These rates of adoption are 13.5% for all techniques combined, 7.90% for stone barriers and 1.29% for *zaï* pits (MAAHMA, 2021). Further investigation is needed to determine the factors that could influence the decision of farmers to adopt these water and soil conservation techniques in some areas of Burkina Faso. Hence, this study aimed at identifying and evaluating the socio-economic and environmental determinants of *zaï* and stone rows techniques in four municipalities of the Plateau Central region of Burkina Faso. A knowledge of these determinants will allow a better understanding of the situation at the level of farmers to better target future interventions in these localities in terms of soil management in this context of climate change.

MATERIALS AND METHODS

Study area

The survey was carried out from May to June 2021 in the Plateau Central region of Burkina Faso. Of the three provinces in this region, the study covers two provinces with an area of 5,392 km^2, and includes four municipalities: *Boussé, Dapélogo, Laye and Zitenga* (Table 1). In each municipality, one village was selected after consulting with agricultural extension officers and according to the accessibility to the village, the receptiveness of innovations, and the use of soil and water conservation practices.

The bedrock comprised of two geological units stemming from the middle Precambrian: metamorphic rock formations and crystalline units. Many branched watercourses that relate to the Nakanbe basin formed the hydrographic networks. The woody and shrubby Savannah park dominated the vegetation.

The population of the two provinces of Oubritenga and Kourwéogo totals 495, 851 (INSD, 2022), and the estimated density is roughly 92 persons per square kilometre. The area's main economic activity is agriculture with the population cultivating red and white sorghum, millet, maize, rice, cotton, sweet potato, groundnut, cowpea, sesame during the rainy season. Sorghum and groundnut production respectively are 125,724 tons and 26, 737 tons in this region during raining season of 2020-2021 (MAAHMA, 2021).

Data collection and factors considered

Two communes were selected in each province. Based on accessibility, adoption level of soil and water conservation practices and acceptability to innovations, one village was selected in each commune. Thirty (30) households were chosen in three villages (*Dayagretenga*, *Gantin* and *Poedogo*), and forty-five households in one village (*Sandogo*) according to their use of soil and water conservation techniques. Forty-five (45) households were sampled in village of Sandogo due to its higher number of households than others, and the selection of households heads to conduct the survey was randomly done. The local leaders and the agricultural extension officers assisted us in the selection of farmers to survey.

Data were collected from May to June 2021 using focus group, individual survey and direct observation, which are participatory rural approaches. For the individual survey, a structured questionnaire with closed and opened questions was administered to respondent. Information collected through individual interviews with the respondents in the dominant dialect (Moore) included local peoples' perception of climate change impacts, age, gender, education level, household activity, causes of natural resources degradation. For focus group, open questions were discussed with the village leaders (traditional and religious leaders, village development committees, and farmers), women's agricultural production organization, and local representation of the regional farming council.

Conceptual framework

Agricultural technology adoption theory is a multidisciplinary field that combines elements of decision theory and diffusion of innovations theory in an attempt to explain why some farmers adopt new technologies and others do not. According to the lessons from the literature related to the adoption of agricultural technology three paradigms exist: the innovation-diffusion, the economic constraints and the adopter-perception (Sidibé, 2005; Sigué et al., 2018) and three types of models often are used: linear probability, Logit and Probit models.

Linear probability models have disadvantages, as the probability can often exceed 1. Logit and Probit models are the most commonly used in most adoptions studies. Farmers go through a phase where they are aware or familiar with a new technology, where they develop a positive or negative attitude toward the agricultural technology, and where they finally decide whether to adopt the technology.

Model specification

In most studies on soil and water conservation techniques adoption, the logit model is commonly used (Sigué et al., 2018). In this study, it was used because of its compatibility and evidence shown by many authors (Neupane et al., 2002; Yabi et al., 2016). Adoption can be defined as the fact that a farmer freely practices one or more SWCPs on his farm. The resoluteness to adopt is considered like dependent variables in the regression, of whom is 0 or 1. Denoting P as the probability of reaching an option among the predictors X1 to X12, the mathematical formulation of the binary logit model used in this study is expressed in equation:

$$Y = Logit(P) = Ln\left(\frac{P}{1-P}\right) = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \cdots \beta zXz$$

Where P: Probability that respondent use stone rows or *zaï* pits techniques, 1-P: Probability that respondent use any technique, Y: respondent group (with 1= technique user, 0=no technique user), X1: Age of respondent (in years), X2: Gender of respondent (with 0=female, 1=male), X3=Marital status (with 1=unmarried, 2=married, 3=widowed), X4= Education level (with 1=non-educated, 2=non-formal educated, 3=primary school, 4=secondary school, 5=high school), X5: Membership into a local organization (with 0=No, 1=Yes), X6: household size (Number of persons in the household), X7=Active household size (number of active persons in the household), X8: Type of landownership (with 1=landowner, 2=loaning, 3= purchase, 4= donation), X9: Equipment size (with 1=0, 2= [1-5], 3= >5), X10: Number of cattle and X11: secondary activity.

In the model, the notations β1, β2, β10 (generally termed as βk) denote the slope coefficients of the explanatory variables X1, X2,…., X12 (generally termed as Xk) and α is the intercept term (constant). The exponential (ExpB) of the slope coefficient βk associated to the explanatory variable Xk is interpreted as the Odds Ratio (OR) of the occurrence of the event 2 (using SR or Z) for each adoption in the predictor. In this model, a positif coefficient means that the probability increases with rise of the independent variable correspondent (Neupane et al., 2002). The factors being able to influence *zaï* pits or stone rows practices adoption are illustrated in Table 2.

The empirical definition of the farm-specific variables that are expected to determine the probability of adopting *zaï* and stone row is: where adoption is a dummy variable and the dependent variable indicates the decision to adopt the technology or not. The βs are the coefficients of the independent variables Xi (Table 2 give the definition and expected influence of the variables) indicating the influence of these variables on the probability of adoption. Therefore, if the estimated coefficients for these variables are positive and significant, it can be inferred that farmers with higher values for these variables were more likely to adopt soil and water conservation practices.

Data analysis

The survey data were analysed using quantitative methods involving rankings with the Statistical Package for Social Sciences (SPSSs) version 23. A logistic regression was used to assess the factors that significantly influenced the decision of people to adopt soil and water conservation practices in the study area.

Table 1: Distribution of respondents in the different municipalities of the study area.

Province	Municipality	Village	Number of farmers surveyed
Kourwéogo	Boussé	Sandogo	45
	Laye	Gantin	30
Oubritenga	Dapélogo	Poédogo	30
	Zitenga	Dayagretenga	30
Total			135

Table 2: The factors identified as likely to influence the decision to adopt soil and water conservation practices.

Variable	Type	Description	Expected influence
Gender	Qualitative	Respondent's gender, male or female	Negative
Age	Quantitative	Respondent's age (years)	Negative
Marital status	Qualitative	The condition of being married or unmarried	Positive/negative
Education level	Qualitative	Respondent's years of formal education (years)	Positive
Household size	Quantitative	Number of persons living in household	Positive
Active household size	Quantitative	Number of active persons in the household	Positive
Landownership type	Qualitative	Farmer's rights on the land	Positive
Agricultural equipment	Quantitative	Agricultural equipment owned by household head	Positive
Number of cattle	Quantitative	Number of cattle in the household	Positive
Organization membership	Qualitative	Farmer is member of a local organization	Positive
Secondary activity	Qualitative	The secondary activity of the head of household	Positive

RESULTS

Socio-economic characteristics of respondents

The results of the analysis of the socio-economic characteristics are shown in Table 3. The parameters studied were gender, major activity, age, level of education, affiliation to organization, type of land tenure, size of the household, active members of the household, number total of equipment, number of small ruminants, number of big ruminants and types of big ruminants. The results showed that the main activity remained agriculture and the secondary activities included breeding, trade, market gardening and arts and crafts. The ages of farmers varied between 23 and 86 years, with an average of 50 years. The majority of farmers are between 41–60 years (54.81%). However, the ages of the farmers using the stone rows technique ranged from 40 to 59 years, representing 55.9% of all farmers.

Agro-pedological characteristics

Table 4 showed that crops' yields are decreasing (59.3%). Drought, low fertility of soil, and low fertilization are the most important causes of crops' yields dynamics. Sorghum (98.5%) and cowpea (97.8%) were mostly cultivated, in compare to pearl millet and groundnut. Local seeds were largely used than improved seed. Cereals' farmers mostly used stone rows and ridge tillage techniques. Ridge tillage was mostly used in legumes production (88.37% in Cowpea). Straws, panicle and seed shells were used in breeding like fodder, in composting, selling and household energy.

Environment and soil management situation

The results presented in Table 5 showed that soil, vegetation and fauna degraded. Soil fertility was low. To cope with the situation, respondents suggested to use *zaï* (67.91%), stone rows (84.33%), assisted natural regeneration (63.43%), and mulching (35.82%). According to the respondents, the best technique to use in order to cope with water erosion was stone rows (84.44%) followed by assisted natural regeneration (11.11%). The most difficult techniques for respondents to practice were the stone rows (79.51%) followed by the *zaï* pits (18.03%). Drought (91.85%), flooding (39.26%), locust attacks (29.63%) and strong winds (26.67%) were disaster risks mentioned by the respondents. These disasters led to decrease crops productivity, and to solve it the respondents suggest techniques such as stone rows (77.04%), *zaï* pits (65.93%), traditional and religious ritual (61.19%), assisted natural regeneration (57.04%), forecast monitoring (34.81%), and *zaï* pits associate to stone rows (20.74%).

Determinants of the adoption of the *zaï* pits and stone rows practices

The estimated model was globally significant for both practices (p= 0.002 and 0.022 for *zaï* and stone rows, respectively). It could be concluded that the estimation results were efficient, as the overall prediction percentages are 66.70% for *zaï* and 81.50% for stone rows. On its part, the binary logistic regression analysis revealed that some variables significantly affect the decision to adopt soil and water conservation techniques in the study area. Thus, the variable affecting the adoption of stone barriers was membership of a local organization (5%). As for the *zaï* technique, its adoption was significantly affected by the level of education (1%), membership to a local organization (1%), possession of cattle (5%) and small trading (10%). Indeed, factors such as level of education, membership to a local organization and number of cattle significantly and positively influenced the decision to adopt *zaï* and stone rows techniques (Tables 6, 7). On the other hand, the practice of small trading in its forms reduced the probability of adoption of *zaï* technique.

Table 3: Socio-economic characteristics of respondents.

Characteristic	Modalities	Value
Gender	Male	89.63% (121)
	Female	10.37% (14)
Major Activity	Agriculture	99.26% (134)
	Breeding	0.74% (1)
Secondary activity (more than one activity can be carry out by respondent)	Breeding	99.26% (134)
	Arts & crafts	2.22% (3)
	Trade	11.85% (16)
	Gold mining	0.74% (1)
	Market gardening	14.07(19)

	others	7.41% (10)
Age (Years)	20-40	25.92% (35)
	41-50	27.41% (37)
	51-60	27.41% (37)
	>60	19.26% (26)
Level of education	Illiterate	42.22% (57)
	Primary school	6.67% (9)
	Secondary school	2.96% (4)
	No formal education	48.15% (65)
Affiliation to organization	Yes	46.67% (63)
	No	53.33% (72)
Type of land tenure (more than one answer is possible)	Landowner	87.41% (118)
	Loaning	17.04% (23)
	Acquisition	1.48% (2)
	Donation	5.92% (8)
Size of the household	Average	11
	Minimum	3
	Maximum	25
Active members of the household	Average	6
	Minimum	2
	Maximum	18
Number total of equipment	Average	3
	Minimum	1
	Maximum	8
Number of small ruminants	Average	11
	Minimum	0
	Maximum	55
Number of big ruminants	Average	3
	Minimum	1
	Maximum	14
Composition big ruminants	Donkey & bovine	53.33% (72)
	Donkey	35.55% (48)
	Bovine	11.11% (15)

Table 4: Agro-pedological characteristics given by respondents.

Characteristic	Sorghum	Pearl millet	Cowpea	Groundnut
Sorghum and Pearl Millet Yields dynamics	Yields increase (11.9%), yield declines (59.3%), mixed evolution (28.9%)			
Causes of Sorghum and Pearl Millet yields dynamic	Drought (77.8%), low fertility of soil (58.5%), less technical (13.3%), pest damage (11.9%), flooding (11.1%), violent winds (8.9%)			
Crop grown	Yes= 133 (98.5%) No= 2 (1.5%)	Yes= 96 (71.1%) No= 39 (28.9%)	Yes= 133 (97.8%) No= 2 (2.2%)	Yes= 83 (61.5%) No= 52 (38.5%)
Crop area	Mean=1.86, median=2,	Mean=0.89, median=0.50,	Mean=0.60, median=0.50,	Mean=0.48, median=0.50,

	min=0.5, max=6.	min=0.2, max=4.	min=0.12, max=2.	min=0.1, max=3.
Crop seed nature	Local (89.5%), improved (38.35%)	Local (90.63%), improved (11.46%)	Local (71.97%), improved (56.06%)	Local (95.12%), improved (7.32%)
SWCP in Crop farm	*Zaï* (39.85%), SR (78.95%), RT (86.47%), *Zaï* _SR (16.54%), Half-moon (6.01%), Mulching (4.51%), SR_RT (55.64%)	*Zaï* (9.38%), SR (61.46%), RT (91.67%), *Zaï* _SR (1.04%), Mulching (3.13%)	*Zaï* (3.03%), SR (43.94%), RT (88.37%), SR_RT (32.58%), SR_FP (1.51%)	SR (20%), SR_FP (3.75%), SR_RT (18.75%)
Straw use	Mulching (3.76%), Composting (55.64%), Household energy (51.13%), Fodder (94.74%), Selling (9.92%), Potash fabrication (39.77%), Others (2.04%)	Mulching (3.16%), Composting (55.79%), Household energy (47.37%), Fodder (93.68%), Selling (5.32%), Potash fabrication (14.91%), Others (3.51%)	Composting (5.38%), Fodder (98.46%), Selling (37.69%), Others (1.50%)	Fodder (92.50%), Selling (58.23%)
Panicle/rachis/ seed shell/ use	Composting (42.10%), Fodder (88.72%), Others (2.27%)	Composting (93.68%), Others (36.36%)	Composting (9.23%), Fodder (95.38%), Selling (39.23%)	Composting (30%), Fodder (13.75%), Others (31.07%)

Table 5: Environment status and soil management propositions by farmers.

Characteristic	Modalities	Value
Lands status	Degraded	77.78% (105)
	Improved	22.22% (30)
Vegetation status	Degraded	79.26 (107)
	Improved	20.74 (28)
Fauna status	Degraded	80% (108)
	Improved	20% (27)
Level of soil fertility	No fertile	77.04% (104)
	Fertile	22.96% (31)
SWCPs to use and cope with that situation (Several answers are possible)	*Zaï* (Z)	67.41% (91)
	Stone rows (SR)	83.70% (113)
	Natural assisted regeneration (NAR)	62.96% (85)
	Mulching	35.56% (48)

	Half-moon	8.89% (12)
	Others	30.37% (41)
Best technique for conserve soil face to water erosion	SR	76.30% (103)
	Z	11.11% (15)
	NAR	10.37% (14)
	SR_NAR	4.44% (6)
	Grass Strips	5.18% (7)
	Others	9.63% (13)
Technique roughly for use	SR	71.85% (97)
	Zaï	16.30% (22)
	Others	11.85% (8)
Disaster risk (DR) (several answers are possible)	Drought	91.85% (124)
	Flooding	39.26% (53)
	Locust attacks	29.63% (40)
	Strong winds	26.67% (36)
DR effect on crops production	Decrease	99.26% (134)
	Increase	0.74% (1)
SWCPs to use and cope with DR (several answers are possible)	SR	77.04% (104)
	Zaï	65.93% (89)
	Half-moon	11.85% (16)
	NAR	57.04% (77)
	SR_*Zaï*	20.74% (28)
	Forecast monitoring	34.81% (47)
	Traditional & religious	60.74% (82)
	Others	14.07% (19)

Table 6: The binary logistic regression on the determinants of respondents of the adoption of stone rows practice.

Variable	B	S.E.	Wald	df	Sig.	Exp.(B)	95% C.I for Exp.(B)	
							Lower	Upper
Sex (male)	-117	0.869	0.018	1	0.893	0.889	0.162	4.884
Age			4.018	3	0.259			
[20-40]	0.320	0.620	0.267	1	0.606	1.377	0.409	4.641
[41-50]	1.612	0.860	3.518	1	0.061*	5.015	0.930	27.044
[51-60]	-0.034	0.686	0.002	1	0.960	0.966	0.252	3.705
Education level (Non educated)	0.552	0.509	1.174	1	0.279	1.736	0.640	4.709
Membership of farmers' association (No)	1.415	0.586	5.831	1	0.016**	4.117	1.305	12.986

Cattle	-0.087	0.124	0.497	1	0.481	0.917	0.719	1.168
Trading	1.642	1.168	1.977	1	0.160	5.166	0.524	50.962
Landownership			1.750	2	0.417			
Borrowing	0.579	1.133	0.261	1	0.610	1.783	0.194	16.427
Landowner & Borrowing	1.524	1.229	1.537	1	0.215	4.589	0.412	51.062
Constant	0.326	0.941	0.120	1	0.729	1.386		

*significant at 10%, **significant at 5% ***significant at 1%; Omnibus tests of model Coefficients: Chi-square = 20.851; df = 10; P = 0,022; -2log likelihood = 105.511; Cox et Snell R^2 = 0.143; Nagelkerke R^2 = 0.235; prediction overall percentage = 81.50 %.

Table 7: The binary logistic regression on the determinants of respondents of the adoption of *zaï* pits practice.

Variable	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp.(B)**	**95% C.I for Exp.(B)**	
							Lower	Upper
Sex (male)	-0.868	0.687	1.596	1	0.206	0.420	0.109	1.614
Age			1.817	3	0.611			
[20-40]	-0.408	0.531	0.591	1	0.442	0.665	0.235	1.883
[41-50]	0.312	0.549	0.324	1	0.569	1.367	0.466	4.006
[51-60]	0.046	0.624	0.005	1	0.942	1.047	0.308	3.556
Education level (Educated)	1.040	0.400	6.769	1	0.009***	2.829	1.292	6.194
Membership of farmers' association (Yes)	1.139	0.409	7.769	1	0.005***	3.124	1.402	6.961
Cattle	0.214	0.103	4.288	1	0.038**	1.239	1.012	1.516
Trading (Yes)	-1.139	0.659	2.989	1	0.084*	0.320	0.088	1.164
Landownership			1.678	2	0.432			
Borrowing	-0.343	0.751	0.209	1	0.648	0.710	0.163	3.090
Landowner & Borrowing	-0.827	0.656	1.589	1	0.208	0.437	0.121	1.583
Constant	-0.088	0.776	0.013	1	0.910	0.916		

*significant at 10%, **significant at 5% ***significant at 1%; Omnibus Tests of Model Coefficients: Chi-square = 28.318; df = 10; P = 0,002; -2log likelihood = 156.685; Cox et Snell R^2 = 0.189; Nagelkerke R^2 = 0.254; prediction overall percentage = 66.70 %.

DISCUSSION

Socio-economic characteristics of respondents

The results of the survey showed that the majority of farmers in Kourwéogo and Oubritenga provinces were men. Most of them aged between 31 and 70 years (92.59%). Therefore, they were able to give credible information on the agro-pedological characteristics, the current environmental situation and how to manage the land and cope with climate change and its negative impacts. Their level of education was acceptable (9.63% have primary and secondary education, other forms of education represent 48.15%) for the four villages of the study area.

The level of education influenced the ability of farmers to use *zaï* and stone rows techniques to adapt or mitigate the negative effects of climate change. This could be explained by their access to information through mass media (Kabore et al., 2019), increased likelihood of adaptation to the effects of climate change, their awareness of accessibility, understanding, acceptance and belief in climate change information and improved technologies. Farmer's level of education has been found to have a significant relationship with intensive knowledge of climate change (Kone et al., 2022). Thus, education, whether normal or abnormal, contributes to the fight against global changes including climate.

Membership to a local organization significantly influenced the practice of *zaï* pits and stone rows, as it increased the chances of practicing *zaï* pits or stone rows. It also permitted the member to be informed and gain knowledge about soil and water conservation techniques applicable in the area, depending on the channels used to share information and experiences.

The number of agricultural equipment owned by the farmer also appeared to be a determinant of techniques practiced for the recovery of degraded soils for adaptation to climate change in the area. This result corroborated those of Kabore et al. (2019) who stated that the possession of small agricultural tools such as picks and shovels has a strong impact on the practice of *zaï*, stone rows and the construction of manure pits in the north-central region of the country. The possession of cattle statistically conditioned the practice of *zaï*. This would be due to the reuse of cattle waste in *zaï* pits. It is therefore necessary to empower farmers with educational skills, knowledge, and support them to organize themselves and access small-scale farming equipment.

Agro-pedological characteristics

In the present study sites, out of a total of 135 farmers surveyed, 133 reported producing sorghum, 96 pearl millet, 133 cowpeas and 83 groundnuts. Sorghum and pearl millet remained the main cereal crops in the region, despite the promotion of other cereals such as rice and maize by the government and some non-governmental organizations. This is because sorghum and millet are more drought resistant and require less fertilization than maize and rice, which are less resistant to drought and low fertilization. Nationally, the fertilization of sorghum and pearl millet are 87 and 91 $kg.ha^{-1}$ compared to 129 and 123 $kg.ha^{-1}$ for maize and rice respectively (MAAHMA, 2021). In sorghum and pearl millet fields, the cultivation techniques adopted are ridge ploughing (89.07%) and stone rows (70.20%). The *zaï* is not widely used by farmers in this area. This high rate of adoption of stone rows is comparable to those obtained by Kabore et al. (2019) and Sigué et al. (2018).

Crop residues were mainly used for fodder (42-98.46%), domestic energy (47.37-51.13%), composting (30-55.79%), potash production (14.91-39.77%) and sale (9.92-58.23%). Sanou et al. (2016) had already mentioned the use the major part of crop residues as fodder, supplementary feeding and domestic energy production. The sale of crop residues also played an important role, with legumes leading the way (cowpea 37.69%, groundnut 58.23%). They were the most sold and eaten by animals because, they were abundantly available in the dry season and their total nitrogen content respectively were 12.47% and 12.46% (Sanou et al., 2016). This sale of crop residues could also be explained by the proximity of the study area to the urban area such as Ouagadougou and Ziniaré. Thus, awareness raising and training on post-harvest management of residues and their processing to increase their benefit would be very important in this area.

Environment and soil management situation

The results showed that the respondents had a good perception of the degradation of natural resources. This degradation was perceptible in the land, vegetation, fauna and soil. According to the respondents, the degradation of the soil, which translates into a drop in fertility, was attributable to factors such as climate change(climate variability), soil erosion, wood cutting, use of pesticides, poor fertilization, long-term monoculture, non-use of organic fertilizer, failure to follow the advice of the extension services, lack of rituals before the start of the season, collection of aggregates for urbanization, population growth, failure to protect the bush and failure to return crop residues. These same causes were revealed by the work of Ouattara et al. (2022) and Kabore et al., (2019) in studies carried among the populations of the Centre-West, North Central, North, South-Eastern and East regions of Burkina Faso. Of all factors that reduce agricultural soil fertility, erosion, drought sequences, aggregate collection and the non-use of organic fertilizer were the most important in this part of the country. It is true that erosion and drought remain phenomena observed throughout the territory and are natural. However, the collection of aggregates and the non-application of organic fertilizer could be explained by the concern about being able to pay for food during the food gap period by selling aggregates, the competition for raw materials and the lack of means to produce organic fertilizer in quantity.

The majority of farmers in our study area had become aware of the degradation of the quality of agricultural soils. To cope with this situation, certain water and soil conservation techniques such as *zaï*, stone rows, assisted national regeneration, mulching, ridge tillage and the use of organic manure were practiced. However, according to them, the technique that best conserved the soil against water erosion remained the stone rows (76.30%), *zaï* pits (11.11%), assisted national regeneration (10.37%). This showed their knowledge and attention to these techniques in the area. This soil conservation function had been mentioned by Zougmoré et al. (2004). Also, stone barriers and *zaï* had a strong impact on the development of vegetation cover (Savadogo et al., 2016), probably due to the reduction of water erosion and the loss of elements through stone barriers. However, the practice of stone rows and *zaï* techniques remained very difficult due to unavailability and transport of raw materials (rubble, organic fertilizer), lack of small equipment, and lack of knowledge of the *zaï* practice.

In the provinces of Kourwéogo and Oubritenga, climate change was manifested through disaster risks: reduced and irregular rainfall, late start of the rainy season, early cessation of rainfall, higher frequency of dry sequences, water stagnation sequences, locust attacks and strong winds. These results corroborate those found by Kabore et al., (2019) in the Central-Northern and South Western regions of the country. Frequent average (8-14 days) and major (15 days) ordinary rainfall breaks have been reported in the Sudanian and Sahelian zones of West Africa (Salack et al., 2014). In addition, the sudden cessation of rains before the end of the rainy season constituted one of the major agro-climatic constraints to rained agricultural production, as it causes the shortening of the subsequent vegetative growth period. Declines in yields and grain production of more than 60% were attributed to these climatic anomalies. This in turn hindered social and economic development.

Determinants of the adoption of zaï and stone rows techniques

The determinants that conditioned the adoption of the *zaï* and stone rows techniques in the present study were level of education, membership to a local farmers' organization, number of cattle and small trading.

The level of education.

It was significant at the 1% level and positively determines the adoption of the *zaï* practice. Both formally and informally educated farmers used the *zaï* technique. These results corroborate those found by certain authors on the adoption of agricultural techniques, among others Sawadogo et al. (2022), Afouda et al. (2020), Napon et al. (2020). This could be explained by the understanding and openness of the educated to innovations (Yabi et al., 2016). Furthermore, education improves the technical efficiency of households due to their much greater propensity to adopt new and more productive agricultural techniques (Sawadogo et al., 2022). Thus, increasing the level of education in all its forms could increase the rate of adoption of *zaï* in this study area.

Membership to a local farmers' organization.

It was a determining factor in the adoption of *zaï* and stone rows techniques. This result was similar to those obtained by Mwangi and Kariuki, (2015) on the adoption of other agricultural practices. Indeed, being members of an organization that could obtain support from NGOs, they will have access to transport and construction equipment for the techniques, and may be trained in soil restoration activities. They are also able to ask each other for help in carrying out activities that are considered difficult for one person to do alone. Also, local organizations stimulated their members to adopt agro-ecological techniques through training on agricultural techniques, knowledge sharing and innovations (Iyabano et al., 2021; Sigué et al., 2018). Jaza et al. 2020 found that farmers who had attended training or restitution meetings were more likely to adopt environmental protection practices than those who had not. Thus, with the synergy of action of different NGOs towards local farmers' organizations under their supervision, soil management techniques to adapt to the adverse effects of climate change can be widely adopted.

Number of cattle

The number of cattle available in the household significantly influenced the adoption of agricultural technologies by different actors in rural areas in a context of climate change. This correlation was highlighted by (Afouda et al., 2020). According to him, the number of cattle in the household strongly increased the probability of adoption. Indeed, the possession of cattle facilitated the adoption of *zaï*. This could be explained by the fact that owning cattle allowed farmers to have dung for the production of organic manure that could be used to enrich the *zaï* pits. Furthermore, Danne and Musshoff (2017) found that herd size significantly affected the decision of agro-pastoralists to participate in land degradation reduction programs. Thus, cattle ownership accompanied by training could be a source of recovery of degraded soils in this part of the country.

Small trading

This was identified as a restraining factor in the decision to adopt *zaï* technology. The results indicated that producers who traded at the same time had a low level of *zaï* practice. This finding was contrary to reports by Sigué et al. (2018) who found that farm income correlated positively with the adoption of the microdose technique. It could be that these farmers were more interested in their trade during the period of digging *zaï* pits.

Conclusion

The present study identified and analysed the indigenous drivers of the adoption of stone rows and *zaï* practices by farmers in four municipalities of the Plateau Central region, all of which face the same challenges of climate change. The study showed that the socio-economic drivers of the adoption of soil and water conservation techniques (stone rows and *zaï*) are the level of education, membership to a local farmers' organization, ownership of cattle and the practice of small trading, with the practice of the small trading limiting the practice of *zaï* technology in these localities. The level of education, membership to local farmers' organization and ownership of cattle were positively correlated with the adoption of *zaï*. As for the adoption of stone rows, only membership to a local farmers' organization positively influenced it. In terms of policy and intervention strategies of partners in the area, these results required a synergy of actions in order to maintain the adoption of these techniques for an effective adaptation to the disastrous effects of climate change. This would improve soil quality in the region.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

HO designed the survey instruments, supervised the data collection, analysed the data and prepared the manuscript. EH, YD PLY and UN corrected the manuscript and approved the final version.

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