Vol. 14(2), pp. 50-59, April-June 2022
DOI: 10.5897/JDAE2021.1317
Article Number: 475BDF369189
ISSN 2006-9774

http://www.academicjournals.org/JDAE

ACADEMIC JOURNALS
expand your knowledge

Journal of Development and Agricultural Economics

*Full Length Research Paper*

# Diffusion of water harvesting for rainfed agriculture in sub-Saharan Africa: Case of zaï practice in Burkina Faso

**Beteo Zongo[1,2*], Omer S. Combary[3], Souleymane Ouédraogo[4], Patrice Toé[5] and Thomas Dogot[2]**

[1]University of Dedougou, 03 P. Box BP 176 Dedougou 03, Burkina Faso.
[2]Rural Development and Economic United, Gembloux Agro-Bio Tech, University of Liege, P. Box 5030, Gembloux, Belgium.
[3]Department of Economics and Management, University Ouaga II, Ouagadougou, Burkina Faso.
[4]Institute for environmental and Agricultural Research, 01 P. Box 476 Ouagadougou 01, Burkina Faso.
[5]Institute for Rural Development, University Nazi BONI, Bobo-Dioulasso, 01 P. Box 1091 Bobo 01, Burkina Faso.

Received 27 October, 2021; Accepted 12 January, 2022

**After the droughts of the 1970s, the so called zaï technique (small water harvesting pits), which is a water harvesting technique, has been promoted to farmers in several Sahelian countries to allow rainfed crops to adapt to dry spells. Its temporal diffusion remains a subject of little research. This study highlights the determinants of zaï diffusion in the Sahelian and Sudano-Sahelian zones in Burkina Faso. It is based on a survey of 629 farmers divided into different categories according to the diffusion theory analyzed by using a multinomial logit model. The analysis reveals that 49.1% of sampled households have adopted the practice of zaï in the past four decades on a fraction of their farm. The adopters can be classified as such: innovators (0.5%), early adopters (2.5%), late adopters (8.3%) and laggards (37.8%). Factors determining diffusion of zaï practice are the characteristics of agro-climatic zones, membership in farmers' organization and age of households' heads.**

**Key words:** Agriculture, adoption, spread, rainwater, zaï.

## INTRODUCTION

In the Sahelian countries, the dramatic effects of the 1970s drought led governments, researchers and farmers to develop and scale up several agricultural innovations (Marchal, 1986; Jouve, 1991; Sweileh, 2020). Various innovations for sustainable agricultural water management and soil fertility restoration have been proposed to farmers by extension services and NGOs (Zougmoré et al., 2014; Partey et al., 2018). Zaï is one

*Corresponding author E-mail: beteozongo@yahoo.fr.

such innovations that has been promoted for more than four decades in response to dry spells and soil degradation (Roose et al., 1993; Wildemeersch et al., 2015). It was developed by farmers in Burkina Faso in the early 1960s (Reij et al., 2009) and widely scaled up in several countries (Bouzou and Dan, 2004; Ndah et al., 2014; Wildemeersch et al., 2015; Karidjo et al., 2018).

The terms "zaï" in Burkina Faso, "tassa" in Niger and "Towalen" in Mali refer to the same technique of peasant origin, which consists of digging basins to trap and concentrate runoff water and resources carried by water and wind to grow a cereal in arid and semi-arid environments, on degraded soils (Roose et al., 1993; Bouzou and Dan, 2004). In the Moore language (Burkina Faso), "zaï" comes from the word "zaïegré" which means "to hurry to prepare one’s land" again, "to hurry", "to do quickly", "to get up early and to hurry to work one’s land "," to work quickly and well"," to break and crumble the crust of soil by pockets before sowing "(Roose et al., 1993). In Hausa (Niger) language "tassa" or "taska" means a small cup used to collect water (Bouzou and Dan 2004). In English, terms such as "planting pocket", "planting basins", "micro-pits" and "small water harvesting pits" are used to describe the zaï technology (Danso-Abbeam et al., 2019).

Zaï is an agricultural technology that involves digging holes manually 20 to 40 cm in diameter and 10 to 20 cm deep every 70-100 cm to concentrate runoff and organic matter on farms (Maatman et al., 1998). The holes dug during the dry season trap windblown sands, silts and organic matter. As soon as the first rains, the farmer deposits organic matter (300 to 600 g / hole, equivalent to one to two handfuls of manure / compost per seed hole) in these holes, which are then covered with a thin layer of soil (5 cm). The termites, attracted by the organic matter, dig galleries at the bottom of basins which they transform into funnels. After the first rains, about two weeks after adding organic matter, the farmer sows in pockets, a dozen sorghum seeds on heavy soils or millet in sandy and gravelly soils.

Zaï has many advantages in terms of restoring degraded soils and biodiversity (Roose et al., 1993). The localized contribution of organic matter and the increase in the water stock in the soil leads to a better functioning of the plant root system. The water and mineral supply of plants is thus improved (Danso-Abbeam et al., 2019). Increasing the roughness of the field surface slows runoff and wind at ground level, traps organic debris and fine particles at the bottom of the throughs and protects young seedlings. This practice also boots biological activity in the soil, in particular a resumption of the activity of micro-organisms: seedlings grow faster as they benefit from the mineralization of manure brought at the end of the dry season, termites perforate the crust and woody vegetation regenerates (Amede et al., 2011). Zaï thus creates favourable conditions for the re-vegetation of degraded lands. Finally, zaï increases cultivated areas and cereal yields, particularly in years when crops are under stress periods during the sensitive periods of their cycle (tillering, heading, flowering, grain filling). It can reduce negative impact of climatic hazards and secure production (Maatman et al., 1998).

In the literature, the factors of zaï adoption are often analyzed through the use of different econometric models (Danso-Abbeam et al., 2019; Dagunga et al., 2020). From binary probit model, Sidibé (2005) showed that zaï adoption is a function of soil degradation perception, level of education, access to agricultural services, membership of a peasant organization and farmers' livestock. Ouédraogo et al. (2010) found that zaï adoption is influenced by access to credit, age, ownership of farm equipment, household size, education level and perception of climate change using a binary Logit model. Recently, results of Kpadonou et al. (2017) with the multinomial probit model indicated that the determinants of zaï adoption relate to household size, age, receipt of remittances, area, cash crop practice, access to support - tips and ethnicity. The converging results of these analyses are: age, membership of a farmer’s organization, level of education, access to agricultural services, perception of the frequency of dry spells and the agro-climatic zone are factors in the adoption of the zaï practice. However, even if the factors of zaï adoption are known, those of its temporal diffusion remain a subject of little research. Diffusion is reflected in the evolution of the zaï practice adoption on farms (Roose et al., 1993).

The objective of this article is to analyze the dynamics of zaï practice diffusion on farms of Burkina Faso. According to the diffusion theory analyzed using a multinomial logit model, we highlighted the determinants of zaï diffusion in the Sahelian and Sudano-Sahelian zones in Burkina Faso.

## MATERIALS AND METHODS

### Study area

The study was conducted in the Sahelian and Sudano-Sahelian agro-climatic zones of Burkina Faso. The Sahelian zone is located north of parallel 14°00'N; it is characterized by an average annual rainfall ranging from 300 to 600 mm distributed over three months (July to September) with sometimes less than two months of rainy season. The Sudano-Sahelian zone is located between the parallels 11 ° 30 'and 14 ° 00'N. It is characterized by an average rainfall of between 600 mm and 900 mm, spread over four to five months (June to October).

The agro-climatic zones of the study have in common less than 70 days of rainfall resulting in frequent water deficits for rainfed crops (SP / CONEDD, 2007). This deficit is caused by dry spells sometimes going beyond three weeks. Faced with these dry spells, farmers have adopted several techniques for conserving water and soil, including the practice of zaï on farms. The main crops in zaï are pearl millet (*Pennisetum glaucum*) and white and red sorghum

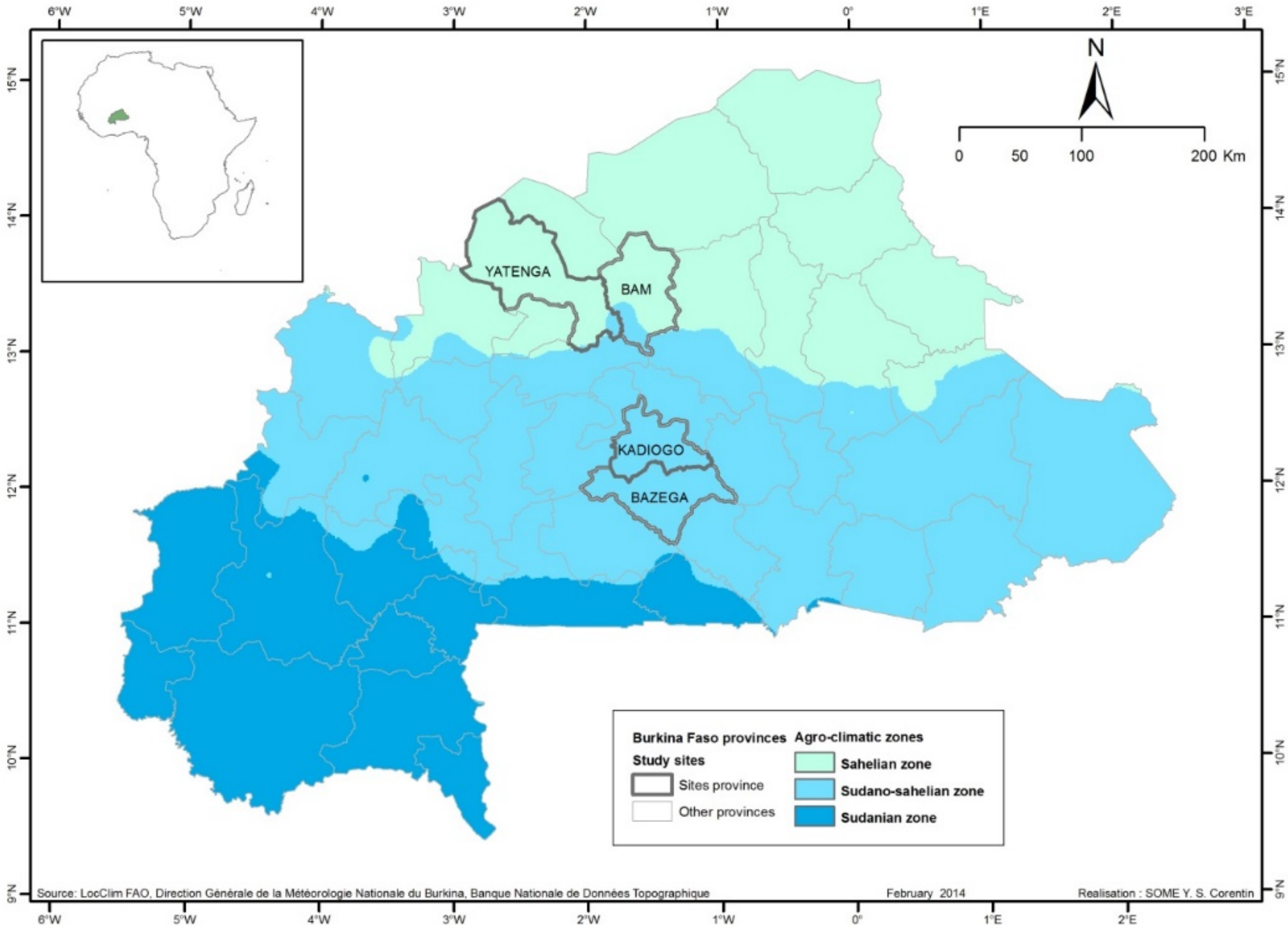


**Figure 1.** Study area.

(*Sorghum bicolour*), which provide the staple diet for households in the study area (Figure 1).

**Theoretical framework**

In Burkina Faso, the practice of zaï has mainly been diffused since the drought of the 1970s and 1980s (Reardon et al., 1988; Zoungrana, 1995). This diffusion is distinguished from the adoption of innovations; it corresponds to the temporal distribution of adoption rates. The decadal diffusion of zaï allows to establish a profile of farmers between 1970 and 2020. In accordance with diffusion theory (Rogers, 1995), these farmers can be divided into five categories: innovators, early adopters, late adopters, laggards extension service became the rural extension and animation service and saw the implementation of the agricultural extension strengthening test operation (MAHRH, 2010). This operation was an adaptation of the training and visits approach to local socio-cultural realities. It was based on the following principles: (i) empowerment of actors (ownership of actions); (ii) the separation of funding for extension structures and agricultural investments; (iii) and non-adopters (Table 1).

Farmers who practiced zaï four decades ago are considered innovators (before 1981 to 2020). During this period, the mode of dissemination of agricultural innovations was the training and visit approach (Bindlish and Evenson, 1997). The transfer of innovations was essentially ensured by a network of agricultural supervisors who received technological packages from research stations from their technical department (Pichot and Faure, 2008). The transfer sites were the pre-extension and multi-local experimentation support points and the young farmers' training centers. The national extension service coordinated all activities for the dissemination of agricultural innovations (MAHR, 2010).

Early adopters characterize farmers who have been practicing zaï on farms for three decades (1991 to 2020). The national agricultural advisory services and (iv) the execution by the State of its regalian missions. Farmer trainers (agro-trainers, farmer extension workers) were involved in the dissemination of agricultural innovations.

Late adopters are farmers who have adopted zaï for two decades (2001 to 2020). The period was marked by the adoption and generalization of the National Agricultural Extension System

**Table 1.** Temporal distribution of adopters of agricultural innovations.

| Categories of agricultural households (j) | Period of adoption of innovations (decades) |
|---|---|
| Innovators (d = 1) | > 3 |
| Early adopters (d = 2) | 3 |
| Late adopters (d = 3) | 2 |
| Laggards (d = 4) | ≤1 |
| Non-adopters (j = 0) | - |

Source: adapted from Rogers (1995).

(SNVA) for the whole country (MAHRH, 2010). SNVA was designed to consider mass extension and the individual approach to technology transfer. The targets concerned were village groups, cooperatives, as well as individual producers through group work activities and follow-up activities and farm visits. The research-development link was reinvigorated with the introduction of the triangular approach between researchers-extension workers-producers.

The laggards are the adopters of agricultural innovations over the past decade (2011 to 2020). This period is characterized by the continuation of the SNVA with following major facts: (i) the testing of demand-driven advisory support, (ii) the regression or even the abandonment of the extension system based on the training and visits approach, ( iii) the adoption of several strategies and policies with a confirmed priority for the rural world, and particularly the necessary production-market link, and (iv) the strengthening of local development approaches and the entrenchment of decentralization (MAHRH, 2010).

Non-adopters are farmers who have never adopted the practice of zaï. The production techniques of these farmers have remained unchanged over time.

With these categories of farmers and the mode of extension, it is evident that the rates of adoption of agricultural innovations differ from decade to decade. Various factors can explain the diffusion of agricultural innovations over time.

## Conceptual framework

The different categories of farmers are associated to a variable with five non-hierarchical modalities (Table 1). The terms do not reflect any underlying ranking or prioritization. The order in which the different occurrences of the farmers categories are arranged is irrelevant; it does not affect the probability of a farmer's belonging to a category $J$ (Läpple and Rensburg, 2011). In such a context, the multinomial Logit model is appropriate for analysis of farmers' choice of membership in categories (Amemiya,, 1981; Wheeler et al., 2009). Each farmer is assumed to be rational in his decision to belong to a category of farmers. It maximizes its usefulness when it chooses to belong to a category of farmers. For a farmer *i*, the expression of the utility function for category is:$U_{ij}j$.

$$U_{ij} = \beta_j{}' X_i + \varepsilon_{ij} \ , \qquad j \in J = 0;\ 1; \dots ; 4 \tag{1}$$

The farmer chooses to belong to the category $k$ when the utility$U_{ij}$ is higher than $U_{ik}$ provided by the category $k$, $\forall\ k \in J$. The farmer's choice results in:

$$U_{ij} = \beta_j{}' X_i + \varepsilon_{ij} \ > \ U_{ik} = \beta_k{}' X_i + \varepsilon_{ik} \tag{2}$$

In this expression, $X_i$ is a vector representing the characteristics of the household, $\beta_j{}'$and $\beta_k{}'$are the vectors of parameters to be estimated, $\varepsilon_{ij}$ and $\varepsilon_{ik}$are the random error terms.

The presence of terms $\varepsilon_{ij}$ in the utility function leads to solutions expressed in the form of the probability of farmers belonging to different categories. The probability of a farmer belonging to a category $j$ is:

$$P = P\left(U_{ij} > U_{ik}\right) = P\left(\beta_j{}' X_i + \varepsilon_{ij} \ > \ \beta_k{}' X_i + \varepsilon_{ik}\right)$$
$$= P\left(\varepsilon_{ij} - \varepsilon_{ik} > \beta_k X_i - \beta_j X_i\right) = P\left(\varepsilon_{ij} - \varepsilon_{ik}\right) > \left(\beta_k - \beta_j\right) X_i = P\left(\mu_{ij} > \beta X_i\right) \tag{3}$$

The error disturbances are independently distributed according to Gumbel's law:

$$F\left(\varepsilon_{ij}\right) = \exp(- \exp(\varepsilon)) \tag{4}$$

The structure of the model representing the probability that a farmer belongs to a category $j$ for the adoption or not zaï practice is formulated by the expression:

$$P\left(y_i = j\right) = P_{ij} = \frac{exp(\beta_j X_i)}{1 + \sum_{k=0}^{4} exp(\beta_j X_i)} \quad , j = 0; 1; \dots ; J \tag{5}$$

$y_i$ a random variable indicating the $i$ farmer's choice of membership; $B_j$ the vector of the parameters to be estimated for the category $j$, $X_i$ explanatory variables for farmer's membership in the category $j$

For reasons of redundancy, the model to be estimated must be reformulated taking into account a reference situation whose coefficients are normalized to zero $(\beta_0 = 0)$ (Greene, 2011). The reference situation in this study is that where the farmer has not adopted any zaï practice. The determinants associated with each category are interpreted in relation to the baseline situation, which

**Table 2.** Explanatory variables of zaï practice diffusion.

| Variables | Description of variables | Expected effects |
|---|---|---|
| Climate | Climate zone membership *(1 = Sahelian, 0 = Sudano-Sahelian*) | + |
| Age | Age of head of household (*1 = young (age <45); 0 = old*) | - |
| Instruction | Educational level (*1 = illiterate; 0 = literate*) | - |
| Grouping | *Membership of a farmers' organization (1 = yes; 0 = no)* | + |
| Training | Inaccessibility to agriculture services (*1 = yes; 0 = no*) | - |
| Drought | Perception of dry spells greater than two weeks (*1 = increased; 0 = decreased*) | + |

is non- adoption (Wooldridge, 2001). The probability that a $i$ farmer does not adopt the practice of zaï during the last four decades is written:

$$P\ (y_i = 0) = P_{i0} = \frac{1}{1 + \sum_{k=0}^{4} exp(\beta_j X_i)} \quad (6)$$

For a farmer to adopt the practice of zaï, the probability is:$i$

$$P\ (y_i = j) = P_{ij} = \frac{exp(\beta_j X_i)}{1 + \sum_{k=0}^{4} exp(\beta_j X_i)} \quad ,j = 1; 2, 3, 4 \quad (7)$$

The formulated model is estimated by the method maximum likelihood. The likelihood function is written:

$$L = \prod_{y_i=0}^{4} \frac{exp(\beta_j X_i)}{1 + \sum_{k=1}^{4} exp(\beta_j X_i)} \quad (8)$$

The log-likelihood is obtained by positing, for each farmer $i$ among$n$ farmers, $d_{ij} = 1$ whether he makes the choice $j$, and $0$ if not. It is the contribution of *i* to the likelihood. Then, assuming that each individual made a choice independently of the choices made by the others, the probability $n$ that the farmers in sample made observed choices is the product of the probabilities:

$$\prod_{i=1}^{n} \prod_{j=0}^{j} P_{ij}{}^{d_{ij}} = \prod_{i=1}^{n} \prod_{j=0}^{j} \left[\frac{exp(\beta_j X_i)}{1 + \sum_{k=1}^{4} exp(\beta_j X_i)}\right]^{d_{ij}} \quad (9)$$

By taking the logarithm of this quantity, the log-likelihood is finally equal to:

$$\ln L(\beta) = \sum_{i=1}^{n} \sum_{j=0}^{j} d_{ij} P_{ij} = \sum_{i=1}^{n} \sum_{j=0}^{j} d_{ij} \frac{exp(\beta_j X_i)}{1 + \sum_{k=1}^{4} exp(\beta_j X_i)} \quad (10)$$

$$\ln P_{ij} = \beta_j X_i - ln \left(1 + \sum_{k=1}^{4} exp(\beta_j X_i)\right) \quad (11)$$

The coefficients are obtained by maximizing the Log Likelihood of the estimation sample:

$$\underset{\beta_{1,\dots,\beta_j}}{\mathrm{Max}} \sum_{i=1}^{n} \sum_{j=0}^{j} d_{ij} P_{ij} = \underset{\beta_{1,\dots,\beta_j}}{\mathrm{Max}} \sum_{i=1}^{n} \sum_{j=0}^{j} d_{ij} \frac{exp(\beta_j X_i)}{1 + \sum_{k=1}^{4} exp(\beta_j X_i)} \quad (12)$$

where it is useful to remember that if $d_{ij} = 1$ farmer $i$ chooses the modality $j$ and $d_{ij} = 0$ otherwise. The first order condition is:

$$\frac{\partial LogL}{\partial \beta} = [d_{ij} - P_{ij}] X_{ij} \quad for\ j = 0,1,2,3,4 \quad (13)$$

These first-order conditions do not admit of an explicit solution. Newton's iteration procedure is used for estimating the coefficients. The coefficients $\beta_j$ multinomial Logit models are not interpreted directly in terms of effects following a change in the explanatory variables involved. We can only argue that a positive coefficient increases the probability of belonging to a category compared to the reference category and vice versa for a negative coefficient.

The explanatory variables considered are age, membership of a peasant organization, level of education, access to agricultural services, perception of the frequency of dry spells and the agro-climatic zone (Table 2). Previous studies show that belonging to the Sahelian zone (*climate*) and farmers who are members of framers' organizations (*grouping*) are variables that favour the adoption of zaï practice on farms (Ouédraogo et al., 2010; Sidibe, 2005). Similarly, farmers who perceive the increase in the frequency of dry spells during wintering (*drought*) are more likely to adopt zaï (Wouterse, 2017). On the other hand, the youthfulness of household heads (*Age*), illiteracy (*education*) and inaccessibility to agricultural services (*training*) do not encourage the zaï practice (Danso-Abbeam et al., 2019). Based on these findings of previous research, hypotheses were formulated for the explanatory variables of zaï diffusion.

## Data sources

Data were collected based on stratified sampling at three levels, namely provinces, villages and farmers. Data were collected from 627 farmers in 11 villages located in 4 provinces namely Yatenga, Bam, Kadiogo and Bazega (Figure 1). In each village, 57 farmers were randomly selected and questioned on the variables mentioned in the table.

Analysis of variance (ANOVA) was used to compare continuous variables with a normal distribution at the significance level p = 5%. The Kruskal-Wallis test and chi-square were used as an alternative to ANOVA when the assumption of normality of the variables was not accepted. The econometric model was evaluated based on the

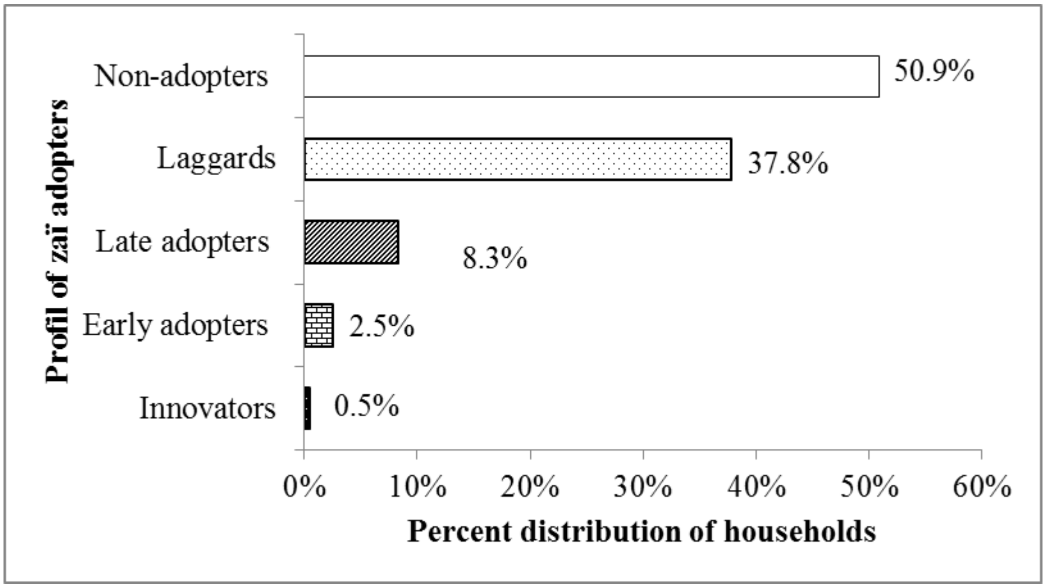


**Figure 2.** Distribution of categories of zaï practice adopters

likelihood ratio and goodness-of-fit tests at a threshold of 1% with the Stata 15 software. The regression parameters were tested by the Wald statistic which is distributed according to the chi-square law with one degree of freedom.

## RESULTS

### Profile of zaï adopters

The analysis shows that about half (49.1%) of the farm households in the sample have adopted the practice of zaï in the past four decades. Adopters are made up of 37.8% laggards, 8.3% late adopters, 2.5% early adopters and 0.5% innovators. The majority (37.8%) of adopters adopted the zaï practice during the third decade. Figure 2 illustrates the distribution of different categories of farm households. The differentiation in adopter rates reflects the pace of diffusion of the zaï practice. It shows the heterogeneity of this diffusion over the last four decades.

### Socio-economic characteristics

The ten-year distribution of adopters of zaï varies significantly according to the two agro-climatic zones of Burkina Faso ($\chi^2$ = 278.246; p = 0.000). Unlike those in the Sudano-Sahelian zone, most farm households (73.4%) in the Sahelian zone have adopted the zaï practice (Table 3). Late adopters (56.6%) constitute most adopters in this area. It thus emerges that the spread of the zaï practice depends on the agro-climatic zone.

The results show that the decennial distribution of adopters also differs according to the socio-economic characteristics of household head. It varies significantly according to age ($\chi^2$ = 28.370; p = 0.000), the level of education ($\chi^2$ = 11.100; p = 0.025), membership of farmers' organizations ($\chi^2$ = 51.147; p = 0.000) and access to agricultural services ($\chi^2$ = 10.669; p = 0.031). Most adopters are young heads (61.2%), educated (65%) and grouped into peasant organizations (68.1%) and those with access to agricultural services (64.1%). Adopters are mostly late adopters (44.7%).

The perception of drought is identical within the adopter categories ($\chi^2$ = 7.269; p = 0.122) (Table 3). The rate of adoption of zaï practice did not vary significantly according to the framers' perception of dry spells.

Except for the drought perception, the socio-economic characteristics of zaï adopters are significantly different. Their simultaneous effects on farm household decisions remain to be determined.

### Factors in the diffusion of zaï

The factors of zaï diffusion in farms are analyzed using the multinomial Logit model. The estimates are presented in Table 4. They show that the model is globally specified at the 1% threshold (Prob> chi2 = 0.000) insofar as the Wald statistic Chi-square at 24 degrees of freedom estimated at 1409,326 is greater than the theoretical Chi-square.

The analysis of the individual significance of the coefficients of the variables by the (z) statistics indicates that the factors of diffusion of zaï are the characteristics

**Table 3.** Characteristics of the categories of zaï adopters.

| Variable | Innovators | Early adopters | Late adopters | Laggards | Non adopters | $\chi^2$ | P-value |
|---|---|---|---|---|---|---|---|
| | Percent (%) | | | | | | |
| ***Climate*** | | | | | | | |
| Soudano | 0 | 0 | 0 | 3.7 | 96.3 | 278.24 | 0.000 |
| Sahelian | 0.7 | 3.9 | 12.7 | 56.1 | 26.6 | | |
| ***Age*** | | | | | | | |
| Young *(age <45)* | 0.3 | 2.2 | 10.0 | 44.7 | 42.8 | 28,370 | 0.000 |
| Old | 0.8 | 3.1 | 5.8 | 27.5 | 62.8 | | |
| ***Instruction*** | | | | | | | |
| Illiterate | 0.3 | 2.1 | 9.5 | 33.4 | 54.7 | 11,100 | 0.025 |
| Literate | 0.8 | 3.2 | 6.4 | 44.6 | 45.0 | | |
| ***Grouping*** | | | | | | | |
| No | 0.2 | 0.7 | 6.3 | 34.0 | 58.8 | 51.147 | 0.000 |
| Yes | 1.1 | 7.0 | 13.0 | 47.0 | 31.9 | | |
| ***Training*** | | | | | | | |
| No | 0.5 | 2.4 | 7.5 | 37.8 | 51.9 | 10.669 | 0.031 |
| Yes | 0.0 | 5.1 | 20.5 | 38.5 | 35.9 | | |
| ***Droughts*** | | | | | | | |
| Decreased | 0.7 | 3.9 | 11.1 | 41.8 | 42.5 | 7.269 | 0.122 |
| Augmented | 0.4 | 2.1 | 7.4 | 36.6 | 53.6 | | |

of agro-climatic zones, the inorganization of the farmers and the age of the heads of households. Variable that positively impacted diffusion of zaï practice is the characteristics of agro-climatic zones. In contrast, the inorganization of the farmers and the age of the heads of households affected the zaï practice diffusion.

The fact that agricultural households belong to the Sahelian zone has favored the diffusion of the practice of zaï compared to the Sudano-Sahelian zone over the past four decades. The lack of organization of agricultural households has hampered the diffusion of the zaï practice. Also, the youth of farm managers has had a negative effect on the spread of zaï over the past two decades. Education and training are not significant in the diffusion of zaï.

## DISCUSSION

The analysis showed that the cumulative adoption rate of zaï practice over the last four decades is 40.1% in the surveyed farms. The rate of adoption has increased from 0.5 to 2.5% then 8.5 and 37.8%. The rate of temporal diffusion of zaï depends on several factors analyzed using a multinomial logit model. The pseudo R2 obtained (0.3080) is low but does not call into question the validity of the model. It is in line with the results of several previous works. The Pseudo R2 obtained is 0.21 for Jara-Rojas et al. (2012), 0.4 for Läpple and Rensburg (2011), 0.154 to 0.506 for Amsalu and Graaff (2007) and 0.39 for Wheeler et al. (2009). The validity of multinomial logit models is mainly determined by the Wall test (Wall chi2) associated with the p-value (Prob> chi2 = 0.000), which makes it possible to measure the goodness of fit of the model (Greene, 2011).

The climatic zone determines the rate of diffusion of zaï. In the Sahelian zone, the practice of zaï is more widespread than in the Sudano-Sahelian zone. This differentiation in the rate of diffusion of zaï is linked to climatic conditions. In the Sahelian zone, average annual rainfall varies between 300 to 600 mm and extends over two to three months. The Sudano-Sahelian zone is characterized by an average rainfall of between 600 and 900 mm spread over four to five months. Compared to the Sudano-Sahelian zone, the low rainfall in the Sahelian zone has led agricultural households to adopt more zaï in order to limit the impact of dry spells on rainfed crop yields (Zorom et al., 2013). The pedological characteristics of the soil in agro-climatic zones also influence the spread of zaï (Ndah et al., 2014). According

**Table 4.** Determinants of dissemination of zaï practice.

| Variable | Coefficient | Standard error | z | P> \| z \| |
|---|---|---|---|---|
| ***Innovators*** | | | | |
| Climate** | 15.81289 | 5.914539 | 2.67 | 0.008 |
| Age | 0.58812 | 10.557090 | 0.06 | 0.956 |
| Education | 1.32434 | 13.539600 | 0.10 | 0.922 |
| Grouping** | -15.82901 | 5.572306 | -2.84 | 0.005 |
| Training | 1.27984 | 12.721560 | 0.10 | 0.920 |
| Drought | 2.54558 | 14.707430 | 0.17 | 0.863 |
| Constant | -21.38967 | 20.958160 | -1.02 | 0.307 |
| ***Early*** | | | | |
| Climate*** | 18.05562 | 0.928621 | 19.44 | 0.000 |
| Age | -0.37776 | 0.631716 | -0.60 | 0.550 |
| Education | 0.17641 | 0.631276 | 0.28 | 0.780 |
| Grouping | -0.12036 | 5.384478 | -0.02 | 0.982 |
| Training | 2.09020 | 3.946868 | 0.53 | 0.596 |
| Drought | 1.23276 | 9.162444 | 0.13 | 0.893 |
| Constant | -21.16612 | 3,803426 | -5.57 | 0.000 |
| ***Late*** | | | | |
| Climate*** | 19.01476 | 0.904744 | 21.02 | 0.000 |
| Age** | -1.37797 | 0.406613 | -3.39 | 0.001 |
| Education | -0.63939 | 0.437507 | -1.46 | 0.144 |
| Grouping | 0.63137 | 0.478983 | 1.32 | 0.187 |
| Training | 0.49783 | 0.384004 | 1.30 | 0.195 |
| Drought | 1.25857 | 0.873987 | 1.44 | 0.150 |
| Constant | -19.29589 | 0.989036 | -19.51 | 0.000 |
| ***Latecomers*** | | | | |
| Climate*** | 4,24446 | 0.494787 | 8.58 | 0.000 |
| Age*** | -1.15051 | 0.282362 | -4.07 | 0.000 |
| Education | 0.07552 | 0.238786 | 0.32 | 0.752 |
| Grouping | -0.34995 | 0.391980 | -0.89 | 0.372 |
| Training | 0.17465 | 0.279359 | 0.63 | 0.532 |
| Drought | -0.01070 | 0.742539 | -0.01 | 0.989 |
| Constant | -3.06355 | 0.463071 | -6.62 | 0.000 |

*** $p < 0.001$; ** $p < 0.05$; * $p < 0.1$; Number of observations = 627; Wald chi2 (24) = 862.456; Prob> chi2 = 0.000; Pseudo R2 = 0.3080; Log likelihood = -449,821

to Roose (1994), the practice of zaï is more suited to the soils of the Sahelian zone than those of the Sudano-Sahelian zone. Zaï is mainly practiced in Sahelian areas such as Niger, Burkina Faso, Ethiopia and northern Ghana (Ouédraogo et al., 2010; Wildemeersch et al., 2015; Karidjo et al., 2018; Danso-Abbeam et al., 2019).

The spread of zaï practice on farms is influenced by the age of the households. Unlike young heads of households, older heads of households have taken over zaï more. Anley et al. (2007) also found that older farmers were more supportive of adopting soil and water conservation techniques than younger people in the same country. The behavior of young household heads can be explained by the diversification of their activities (Karidjo et al., 2018). This behavior of young heads corroborates the research results of Danso-Abbeam et al. (2019) who shows that the orientation of young people towards non-agricultural income-generating activities limits the dissemination of zaï on farms. In contrast, Jara-Rojas et al. (2012) find that the impact of age is neutral on the adoption and diffusion of soil and water conservation technologies in Chile. For Amsalu and Graaff (2007), young farmers were more likely to adopt water and soil conservation technologies on farms.

The organization of farmers in groups plays a role in the dissemination of agricultural innovations (Zongo et al., 2015). The weak grouping of households into organizations has negatively affected the diffusion of zaï practice on farms in Burkina Faso. The works of Muchai et al. (2020) also suggest that the lack of farmer organization negatively influences the dissemination of Zaï practice.

This lack of organization does not allow exchanges between agricultural households on the dissemination of agricultural innovations and access to numerous benefits such as training, access to agricultural equipment (Sidibé, 2005). Danso-Abbeam et al. (2019) also argued that farmer organization facilitates their access to extension services provided by state structures and non-governmental organizations to improve the adoption of agricultural innovations, such as zaï. They noted that farm‑level policies oriented towards credit facilities, and the facilitation of farmer groups is essential to improve zaï adoption.

## CONCLUSIONS AND RECOMMENDATIONS

The dissemination of the practice of water harvesting techniques remains a challenge for African rainfed agriculture in the face of dry spells. This study showed that the diffusion of zaï practice, although slow in farms of the Sahelian and Sudano-Sahelian zones of Burkina Faso, has been significant. About half of the farm households (49.1%) sampled adopted the practice of zaï in the past four decades. Adopters are made up of 37.8% laggards, 8.3% late adopters, 2.5% early adopters and 0.5% innovators. Factors influencing the dissemination of zaï are the characteristics of agro-climatic zones, membership in farmer organization and age of household heads. Education and training are not significant in the diffusion of zaï. Based on these results, it is recommended to continue the extension of zaï practice via implementation of demonstration plots and organization of field days according to the agroecological zones through farmers' organization and the involvement of young farmers.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

### REFERENCES


Amede T, Menza M, Awlachew SB (2011). Zai improves nutrient and water productivity in the ethiopian highlands. Experimental Agriculture 47(1):7-20. https://doi.org/10.1017/S0014479710000803

Amemiya T (1981). Qualitative Response Models: A Survey. Journal of Economic Literature 19(4):1483-1536.

Amsalu A, Graaff J (2007). Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. Ecological Economics 61(2-3):294-302.

Anley Y, Bogale A, Haile-Gabriel A (2007). Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district , western Ethiopia. Land Degradation and Development 18(3):289-302. https://doi.org/10.1002/ldr

Bindlish V, Evenson RE (1997). The Impact of T&V extension in africa: the experience of kenya and burkina faso. World Bank Research Observer 12(2):183-201. https://doi.org/10.1093/wbro/12.2.183

Bouzou MI, Dan LN (2004). Le « Tassa » : une technique de conservation des eaux et des sols bien adaptée aux conditions physiques et socio-économiques des glacis des régions semiarides (Niger) / The « tassa », a soil and water conservation technique well adapted to the physical an. Revue de Géographie Alpine 92(1):61-70. https://doi.org/10.3406/rga.2004.2278

Dagunga G, Amoakowaa A, Ehiakpor DS, Mabe FN, Danso-Abbeam G (2020). Interceding role of village saving groups on the welfare impact of agricultural technology adoption in the Upper East Region, Ghana. Scientific African 8:e00433. https://doi.org/10.1016/j.sciaf.2020.e00433

Danso-Abbeam G, Dagunga G, Ehiakpor DS (2019). Adoption of Zai technology for soil fertility management: evidence from Upper East region, Ghana. Journal of Economic Structures 8(1):1-14. https://doi.org/10.1186/s40008-019-0163-1

Greene W (2011). Econometric Analysis: International Edition, 7th Edition. PEARSON.

Jara-Rojas R, Bravo-Ureta BE, Díaz J (2012). Adoption of water conservation practices: A socioeconomic analysis of small-scale farmers in Central Chile. Agricultural Systems 110:54-62. https://doi.org/10.1016/j.agsy.2012.03.008

Jouve P (1991). Secheresse au Sahel et strategies paysannes. Sécheresse 2(1):61-69.

Karidjo BY, Wang Z, Boubacar Y, Wei C (2018). Factors influencing farmers' Adoption of Soil and Water Control Technology (SWCT) in Keita valley, a semi-arid Area of Niger. Sustainability (Switzerland) 10(288):8-13. https://doi.org/10.3390/su10020288

Kpadonou RA, Owiyo T, Barbier B, Denton F, Rutabingwa F, Kiema A (2017). Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. Land Use Policy 61:196-207. https://doi.org/10.1016/j.landusepol.2016.10.050

Läpple D, Rensburg TV (2011). Adoption of organic farming: Are there differences between early and late adoption? Ecological Economics 70(7):1406-1414. https://doi.org/10.1016/j.ecolecon.2011.03.002

Maatman A, Sawadogo H, Schweigman C, Ouedraogo A (1998). Application of zaï and rock bunds in the northwest region of Burkina Faso: Study of its impact on household level by using a stochastic linear programming model. Netherlands Journal of Agricultural Science 46(1):123-136. https://doi.org/10.18174/njas.v46i1.502

MAHRH (2010). Le Système National de Vulgarisation et d4appui Conseil Agricoles ( SNVACA).

Marchal J (1986). Vingt ans de lutte antiérosive au nord du Burkina Faso. Cahier Orstom, Sér. Pédol 22(2):173-180.

Muchai SWK, Ngetich FK, Baaru M, Mucheru-Muna MW (2020). Adoption and utilisation of Zai pits for improved farm productivity in drier upper eastern Kenya. Journal of Agriculture and Rural Development in the Tropics and Subtropics 121(1):13-22. https://doi.org/10.17170/kobra-202002281030

Ndah HT, Schuler J, Uthes S, Zander P, Traore K, Gama MS, Nyagumbo I, Triomphe B, Sieber S, Corbeels M (2014). Adoption potential of conservation agriculture practices in Sub-Saharan Africa: Results from five case studies. Environmental Management 53(3):620-635. https://doi.org/10.1007/s00267-013-0215-5

Ouédraogo M, Dembélé Y, Somé L (2010). Perceptions et stratégies d'adaptation aux changements des précipitations: cas des paysans du Burkina Faso. Sécheresse 21(2):87-96. https://doi.org/10.1684/sec.2010.0244

Partey ST, Zougmoré RB, Ouédraogo M, Campbell BM (2018).

Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learnt. Journal of Cleaner Production 187:285-295. https://doi.org/10.1016/j.jclepro.2018.03.199
Pichot JP, Faure G (2008). Système d'innovations et dispositifs d'appui. In: J. C. Defère (Ed.), Défis agricoles africains, Karthala, pp. 265-284.
Reardon T, Matlon P, Delgado C (1988). Coping with household-level food insecurity in drought-affected areas of Burkina Faso. World Development 16(9):1065-1074. https://doi.org/10.1016/0305-750X(88)90109-X
Rogers EM (1995). Diffusion of innovations (4th edetion.). Division of Macmitlan Publishing. https://doi.org/citeulike-article-id:126680
Roose E (1994). Introduction à la gestion conservatoire de l'eau , de la biomasse et de la fertilité des sols. In Bullentin pédagogique. FAO.
Roose E, Arabi M, Brahamia K, Chebbani R, Mazour M, Morsli B (1993). Erosion en nappe et ruissellement en montagne méditerranéenne algérienne : réduction des risques érosifs et intensification de la production agricole par la GCES : synthèse des campagnes 1984-1995 sur un réseau de 50 parcelles d'érosion. Cahiers ORSTOM. Série Pédologie 28(2):289-308.
Sidibé A (2005). Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. Agricultural Water Management 71(3):211-224. https://doi.org/10.1016/j.agwat.2004.09.002
Sweileh WM (2020). Bibliometric analysis of peer-reviewed literature on food security in the context of climate change from 1980 to 2019. Agriculture and Food Security 9(1):1-15. https://doi.org/10.1186/s40066-020-00266-6
Wheeler S, Bjornlund H, Shanahan M, Zuo A (2009). Who trades water allocations ? Evidence of the characteristics of early adopters in the Goulburn – Murray Irrigation District, Australia 1998–1999. Agricultural Economics 40(6):631-643. https://doi.org/10.1111/j.1574-0862.2009.00404.x
Wildemeersch JCJ, Timmerman E, Mazijn B, Sabiou M, Ibro G, Garba M, Cornelis W (2015). Assessing the Constraints to Adopt Water and Soil Conservation Techniques in Tillaberi, Niger. Land Degradation and Development 26(5):491-501. https://doi.org/10.1002/ldr.2252
Wooldridge J (2001). Econometric Analysis of Cross Section and Panel Data. The MIT Press, Cambridge. https://doi.org/10.1515/humr.2003.021
Wouterse F (2017). Empowerment, climate change adaptation, and agricultural production: evidence from Niger. Climatic Change 145(3-4):367-382. https://doi.org/10.1007/s10584-017-2096-8
Zongo B, Diarra A, Barbier B, Zorom M, Yacouba H, Dogot T (2015). Farmers' practices and willingness to adopt supplemental irrigation in Burkina Faso. International Journal of Food and Agricultural Economics 3(1):101-117.
Zorom M, Barbier B, Mertz O, Servat E (2013). Diversification and adaptation strategies to climate variability: A farm typology for the Sahel. Agricultural Systems 3(9):436-347.
Zougmoré R, Jalloh A, Tioro A (2014). Climate-smart soil water and nutrient management options in semiarid West Africa: A review of evidence and analysis of stone bunds and zaï techniques. Agriculture and Food Security 3(1):1-8. https://doi.org/10.1186/2048-7010-3-16
Zoungrana TP (1995). Sécheresse et dynamique des agrosystèmes dans la plaine centrale du Burkina / Drought and dynamics of agrosystems in the central plain of Burkina. Revue de Géographie de Lyon 70(3):247-254. https://doi.org/10.3406/geoca.1995.4219