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Adaptation to climate change among transhumant herders: evidences from northern Benin (West Africa)

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Climate change and related effects such as water scarcity is a major issue for transhumant who need to develop sustainable adaptation strategies. We highlighted both the perceived climate change effects and the main socio-economic drivers of the decisions to use specific adaptation strategies. Our study used primary data collected through a survey approach from 100 transhumant randomly selected in two municipal areas in the northern of Benin. We used descriptive statistics and a multivariate regression model to analyze our data. Transhumant herders perceived climate change effects through variability of rainfall, of temperature and of wind direction. In response to the perceived changes, they adopted several strategies, including cattle complementary feed search, water for drinking and improving genetic performance for their cattle. The perceived changes and sociodemographic characteristics including religion, sociocultural group, etc. negatively influenced the adoption of some adaptation strategies such as forage reserves and changing transhumance area and routes. In the other hand, the perceived changes and socioeconomic characteristics including age, education, religion, etc. positively influenced the adoption of food stockpiling, of prayers and offering to deities, of changing the transhumance period, etc. The perception of the climate change effects and the sociodemographic characteristics of the transhumant herders affected the adoption of adaptation strategies in many ways. Policy makers could deliver climate information for strengthening the resilience of transhumant herders.

KEYWORDS

climate change, transhumance, adaptation strategies, perception, adoption

1 Introduction

Countries in Sub-Saharan Africa are among the most vulnerable to negatives effects of climate change (De Haan, 2016). The economic activities of these countries rely heavily on a rain-fed agriculture, including livestock farming, that is well-known to be highly sensitive to change in climate conditions. Livestock farming is second economic activity which contributes to gross domestic product (GDP) (5 and 15%) and 60% to agricultural GDP (De Haan, 2016). In West Africa, the livestock farming generates 10 billions of Franc CFA (Franc CFA = USD 550) each year to more than 20 billons of persons (Lesse et al., 2015; Corniaux et al., 2018). According to Economic Community of West African States (ECOWAS) and Sahel and West Africa Club (SWAC), livestock contributes more than 34% to income of rural households in Sahelian and coastal countries such as Benin (CSAO-OCDE/CEDEAO, 2008). In Benin, livestock contributes nearly 3.2% to GDP and 18.5% to agricultural GDP in 2014 with more than 60 billons of cattles (CSAO-OCDE/CEDEAO, 2008; MAEP, 2018). However, livestock farming is characterized by traditional and extensive production systems where the

productivity is based essentially on available natural resources such the surface water and pastures.

Transhumant farming is broadly acknowledged as a livestock production method that can help to address the issues of limited pastoral resources in sedentary farming systems. Transhumant farming consists in long displacement of the herds under the direction of a shepherd outside of the usual place of sedentarization, in search of the pastoral resources notably water and pastures (Kiema et al., 2014). This is observed in the sahelian, soudanian and soudano-guinean areas where geographic location and season are key factors influencing the availability and productivity of natural pastures (Kiema et al., 2014). It was also recognized by FAO (2012) as not only effective means of climate change adaptation but also sustainable management of natural resources. This practice has been for many years, beneficial strategy of pastoralists who effectively take advantage of ecological diversity and complementarity between different agroclimatic zones to counter the seasonal fodder crisis. Thus, it limits the land degradation through the seasonal destocking of often overcrowded pastures. It promotes the productivity and maintenance of livestock capital, and also contribute to the social relations improvement (Diouf et al., 2014). Moreover, transhumance is part of complex life systems (livestock, agriculture, trade, handicrafts, contribution of migrants), especially since it contributes to the diversification of family activities and increases their resilience ability (Thébaud et al., 2017).

Talking about climate change, even transhumant farming is at risk. In response to dispersion of pastoral resources in time and space, an adaptation is necessary for herders who develop diversified pastoral practices based on mobility to have livestock feed (Abdoulaye, 2016; Kinzo and Djohy, 2016). The climatic crises coupled with demographic growth and expansion of crop areas threaten rural livelihoods and require new adaptation strategies to reduce the vulnerability of transhumant herders and of their livestock to climate change. Traditional transhumance is undergoing new changes because it is no longer able to respond effectively to animal feeding and watering problems (Kiema et al., 2014). The low regeneration capacity of forage species leads to the appearance of glacis, unpalatable and invasive species, a decrease in grazing areas, as well as difficulties in accessing water points for livestock watering, increased deforestation through tree cutting, etc. (Yameogo et al., 2014; Konare and Coulibaly, 2019).

A number of previous studies have been conducted to understand the perceptions of populations on climate change and their adaptation strategies (Bonnet and Guibert, 2014; Dovonou-Vinagbe, 2017; Amuzu et al., 2018; Fadina and Barjolle, 2018; Budhathoki and Zander, 2019). To reducing their vulnerability to climate change, transhumant herders developed related strategies such as amplitude of movements, modification of transhumance periods, use of crop residues, haymaking, treatment of straw with urea, transhumant pastoralism, agro-pastoralism, fodder storage and silage (Diouf et al., 2014; Totin et al., 2016).

In Benin, livestock herders used some strategies for adapting to climate change, including the creation of water dams and the installation of fodder reserves, the introduction of new breeds, the improvement of livestock performance through selection, the new sources of food, the constitution of food reserves for the dry season, the change of zones and transhumance routes (Katé et al., 2015; FAO, 2017). However, there is limited evidence in the literature on the factors that influence the adoption of different adaptation strategies developed by transhumant.

Several theories apprehended the determinants of adoption of a practice, innovation, or decision (Yazdanpanah et al., 2014; Mendling et al., 2018; Reddy, 2019; Clohessy et al., 2020; Pakmehr et al., 2021). The most recent theories are the theory of planned behavior (TPB) and the theory of cognitive stress (TCS) (Yazdanpanah et al., 2014; Pakmehr et al., 2021). According to the TPB, perceived environmental risks, attitudes, and subjective norms positively influence decision making to adopt a practice or technology (Yazdanpanah et al., 2014). According to the TCS theory, the threats and stresses perceived by a man from the environment determine the reactions or responses to counter the negative effects on self (Pakmehr et al., 2021). This theory echoes the TPB in that both theories address the place of risk or threat perceptions in a decision or adoption process. For example, strategies developed by individuals to respond to the adverse effects of climate change are associated with their perceived risks (Roy et al., 2021; Talwar, 2021). Thus, climate change adaptation, is a response process for reducing the adverse effects of climate change according to individual perceptions of climate change (Li et al., 2017; Mkonda et al., 2018; Hasan and Kumar, 2019; Budhathoki and Zander, 2019). Yang et al. (2021) argue that short-term and long-term perceptions of climate change drive different adaptation behaviors in China. Moreover, several studies have highlighted the importance of socioeconomic, demographic, and institutional factors in the decision-making process to choose an adaptation strategy (Reddy, 2019; Marie et al., 2020; Acevedo et al., 2020; Atube et al., 2021; Kuchimanchi et al., 2021). Both theories are therefore applicable in the context of climate change where populations perceive climate risks as threats. As a result, the choice of adaptation strategies by transhumant herders may depend on their socioeconomic and demographic characteristics and their perceptions of climate change. Against this backdrop, these factors were considered in this study to explain the adoption of an adaptation strategy by transhumant herders to climate change.

2 Materials and methods

2.1 Study area

The Northern region of Benin is known as one of the most frequented regions by transhumant herders because of the favorable agro-ecological conditions (Youssao et al., 2009). The transhumant herders siting in the region often come from the far north Nigeria and Niger. They practice an extensive and traditional mode of animal husbandry based on the exploitation of natural pasture (*ibid*). This study was conducted in the district of Sinende and Gogonou (Figure 1).

The district of Sinendé is located between 10°20′41" North latitude and 2°22′45″ East longitude, while that of Gogounou is at the southern entrance of the department of Alibori between 10°33′ and 10°57' North latitude and 2°15′ and 3°15′ East longitude. Both communes are characterized by a Sudanian-type climate entitling the population, a rainy season from April to October and a dry season from November to March. In this region, Boko et al. (2012) attested that the number of rainy days is decreased from 11 to 28% whereas the temperature is increased of 1°C over a period of more than

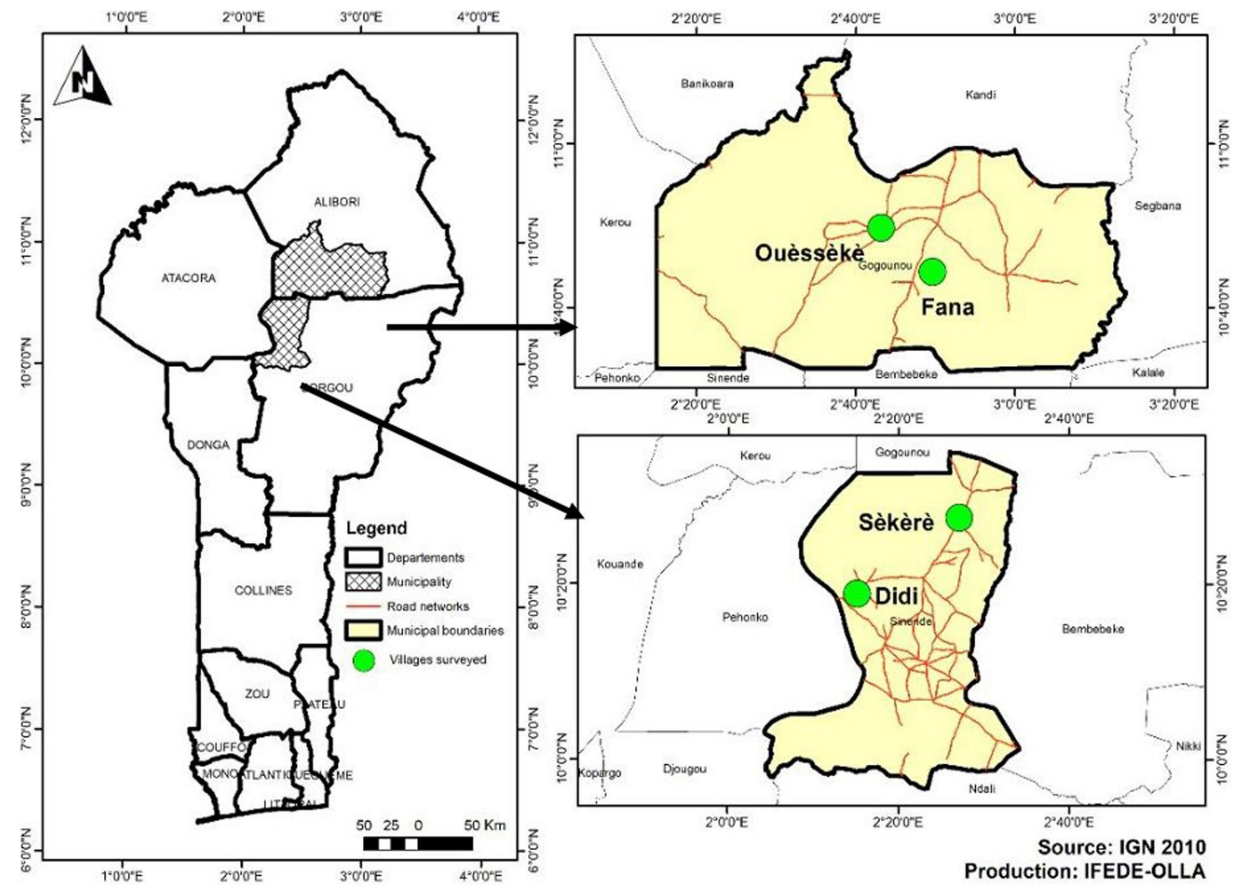

FIGURE 1
Location of study areas.

60 years. The spatio-temporal variability of rainfall in these environments makes the availability of food resources for transhumant animals uncertain, particularly in the dry season (Lesse et al., 2015).

Agriculture and livestock are the main activities of the population. The majority of the population of Sinendé is Bariba (60%) and Fulani (35%) who are engaged in agriculture and livestock raising, respectively. Gogounou homes a large herd of cattle and small ruminants due to the high proportion of the Fulfulde community and favorable climatic conditions (approximately 123,500 ha of pasture). The cattle livestock is concentrated more than 85% (Alkoiret et al., 2011). The livestock system used in this district is the traditional extensive type, characterized by transhumance in the dry season. The soils are of tropical ferruginous type and are suitable for the development of herbaceous forage resources.

2.2 Sampling and sample size

The target population was the transhumant herders. We used a multistage sampling technique:

- Stage 1: The districts were selected using a purposive sampling approach based on the importance of transhumance and the adaptation of transhumant herders to climate change in North Benin. The purposive selection involved officers from the national and regional professional organizations of cattle breeders [*Union Départementale des Organizations Professionnelles d'Eleveurs de Ruminants* (UDOPER) and *Association Nationale des Organizations Professionnelles d'Eleveurs de Ruminants* (ANOPER)].
- Stage 2: From each district, two villages were selected. These villages were Ouèssèkè and Fana in Gogonou district and Sèkèrè and Didi in Sinendé district.
- Stage 3: From each village, 25 transhumant herders were randomly selected. In total, 50 transhumant herders per district and 100 transhumant herders were selected in the study area.

2.3 Method of primary data collection

We collected primary data from the sample through a survey conducted in April 2020. Data collection was based on a questionnaire that covered key information such as: (i) sociodemographic and economic characteristics such age, size of household, marital status, religion, education, transhumance experience, access to extension services, transhumant herders group membership, secondary activity; (ii) perceptions on climate change and adaptation strategies to counter the climate change effects on their transhumance activities.

2.4 Data analysis

Data were analyzed using descriptive statistics such as means, standard deviations and frequencies.

The adoption theories used in this study postulate that the use of an adaptation strategy is based on perception of environmental risk and socioeconomic, demographic and institutional factors (Yazdanpanah et al., 2014; Marie et al., 2020; Pakmehr et al., 2021; Atube et al., 2021; Kuchimanchi et al., 2021) (Figure 2). The choice of each adaptation strategy by a transhumant is a binary decision and many adaptation strategies could be used by a transhumant. Binary logistic regression model was used to identify the decision factors which influenced the choice of each adaptation strategy (Ouédraogo et al., 2010; Kabore et al., 2019). The model was simultaneously applied of eight adaptation strategies used by transhumant herders in the study area. We used Stata software for the econometric analysis.

Q_k is binary dependent variable which is adaptation strategy k. Q_k can be written as Equation 1:

$$Q_k = \begin{cases} 1 \; if \; a \; given \; adaptation \; strategy \; k \; is \; used \\ 0 \; otherwise \end{cases} \quad (1)$$

Q is the dichotomous dependent variable and is 1 if the transhumant used the adaptation strategy k and 0 if not. Q is thus latent variable with probability p for $Q_k = 1$ while $Q_k = 0$ has a probability 1-p. Eight adaptation strategies by the transhumant herders were identified and are dichotomous choice variables considered in this study (Table 1). Thus, eight binary logistic models were simultaneously estimated using the X variables specified in Equation 2:

$$Q_k = \alpha + \beta X_i + \varepsilon_k \quad (2)$$

Where X_i is vector of explanatory variable influencing a given adaptation strategy. These variables are described in Table 1. α is the constant term, β is a vector of parameters estimated and ε_k is the error term. The conditional probability is estimated as Equation 3:

$$\Pr = \left(z_i = 1 | x\right) = F\left(x'_i \delta\right) \quad (3)$$

Where $F(.)$ is the cumulative logistic density function applied to the model. The correlation test was used to check multicollinearity among the explanatory variables. From regression model, we dropped the variables strongly correlated to each other variable with correlation coefficient superior or equal to 0.5. Moreover, all explanatory variable which did not influence any model were dropped. For this, household size, access to credit and income level were deleted in the model.

3 Results

3.1 Socioeconomic and demographic profile of transhumant herders

The transhumant herders surveyed had an average age of 44 years and 22 years of experience in transhumance. The average size of transhumant households was 11 persons. The most of them (78%) had not been at school. The majority of transhumant herders surveyed (72%) were Peulh. Approximately 94% of those surveyed were married. The religion practiced by the majority of transhumant respondents was Islam (68%). The majority of transhumant respondents (62%) did not belong to socio-professional organizations. Approximately 74% of respondents stated that they were not in contact with an extension service. In the end, most of the transhumant farmers surveyed were married Muslim men, about 44 years old, and did not belong to any organizations. Few of them were in contact with extension services (Table 2).

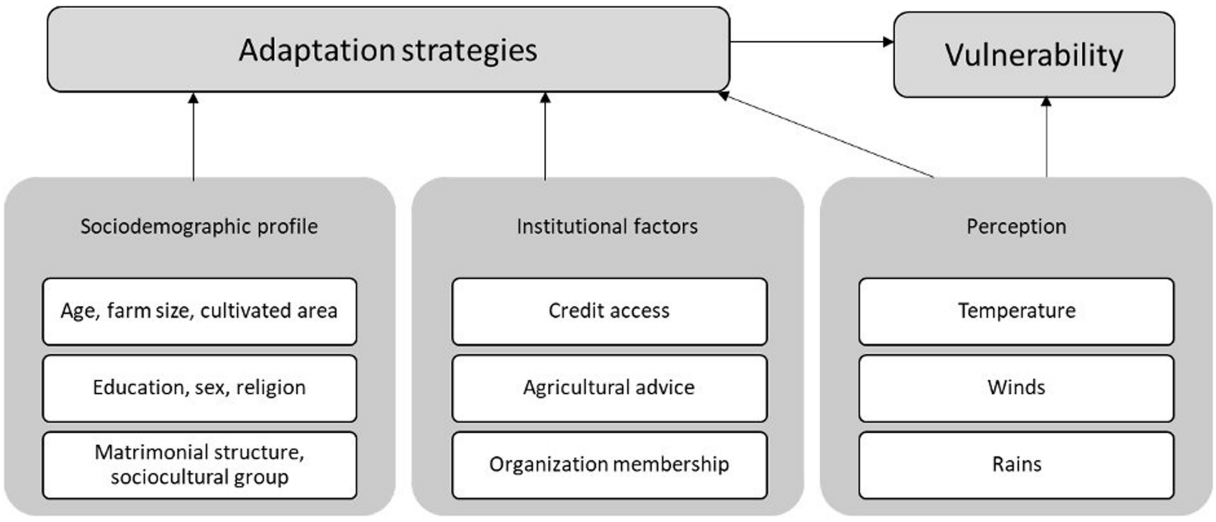

FIGURE 2
Theory of change framework.

TABLE 1 Description of variables used in the logistic regression.

Variables	Definition	Value and unit of measurement
Dependent variable		
Adaptation strategy	Adaptation option Adaptation strategies considered in this study are cattle genetic selection, introduction of new breeds, installation of fodder reserves, change of the transhumance period, sedentarization of animals, change in transhumance areas and routes, constitution of food reserves for the drought pocket and prayers and offerings to deities.	Dummy variable 1 = using adaptation strategy, 0 = Not using adaptation strategy

Independent variables				
Variable	**Definition**	**Value and unit of measurement**	**Expected sign**	**Citation**
Socioeconomic and demographic characteristics of transhumant herders				
Age	Age of transhumant	Continous variable	+	Menghistu et al. (2020)
Ethnic group				
Peulh	Transhumant belongs ethnic group peulh (modality of reference)	Dummy variable, 1 = Peulh, 0 = otherwise	+/−	−
Bariba	Transhumant belongs ethnic group Bariba	Dummy variable, 1 = Bariba, 0 = otherwise	+/−	−
Dendi	Transhumant belongs ethnic group Dendi	Dummy variable, 1 = Dendi, 0 = otherwise	+/−	−
Education level				
No education	Transhumant did not go to school (modality of reference)	Dummy variable, 1 = No education, 0 = Otherwise		
Primary level	Transhumant had a primary education	Dummy variable, 1 = primary education, 0 = Otherwise	+	Mahmood et al. (2021) Yang et al. (2021)
Secondary level	Transhumant had a secondary education	Dummy variable, 1 = Secondary education, 0 = Otherwise	+	
Literacy	The transhumant is alphabetized	Dummy variable, 1 = Alphabetized, 0 = Otherwise	+	
Marital status				
Not married	The transhumant was not married (modality of reference)	Dummy variable, 1 = Not married, 0 = Otherwise	−	
Married	The transhumant was married	Dummy variable, 1 = married, 0 = otherwise	+	
Divorcee	The transhumant was divorcee	Dummy variable, 1 = Divorcee, 0 = Otherwise	+	
Religion				
Animism	The transhumant practiced traditional religion (reference modality)	Dummy variable, 1 = yes, 0 = Otherwise		
Christian	The transhumant was Christian	Dummy variable, 1 = yes, 0 = Otherwise		
Muslim	The transhumant was Muslim	Dummy variable, 1 = yes, 0 = Otherwise		
Transhumance experience	Number of experiences years in transhumance	Continuous variable	+	Atube et al. (2021)
Agriculture (secondary activity)	The transhumant practiced agriculture as a secondary activity	Dummy variable, 1 = yes, 0 = Otherwise	+/−	
Access to extension service	Transhumant access to extension services	Dummy variable, 1 = yes, 0 = otherwise	+	Mahmood et al. (2021) and Menghistu et al. (2020)
Herder's group membership	The transhumant belongs to herder's organization	Dummy variable, 1 = yes, 0 = otherwise	+	Atube et al. (2021)

(Continued)

TABLE 1 (Continued)

Independent variables				
Variable	Definition	Value and unit of measurement	Expected sign	Citation
Perception on climate change				
Decrease in the number of rainy days	Transhumant perceived the climate change through a decrease in the number of rainy days	Dummy variable, 1 = yes, 0 = otherwise	+	Mahmood et al. (2021) Yang et al. (2021).
Increase in the number of rainy days	Transhumant perceived the climate change through an increase in the number of rainy days	Dummy variable, 1 = yes, 0 = otherwise	+/−	
High intensity of rainfall	Transhumant perceived the climate change through a high intensity of rainfall	Dummy variable, 1 = yes, 0 = otherwise	+/−	
Irregularity of rainfall	Transhumant perceived the climate change through an irregularity of rainfall	Dummy variable, 1 = yes, 0 = otherwise	+/−	
Late start of rains	Transhumant perceived the climate change through a late start of rains	Dummy variable, 1 = yes, 0 = otherwise	+	
Early cessation of rains	Transhumant perceived the climate change through an early cessation of rains	Dummy variable, 1 = yes, 0 = otherwise	+	
Drought pocket	Transhumant perceived the climate change through a drought pocket	Dummy variable, 1 = yes, 0 = otherwise	+	
Recurrence of flooding	Transhumant perceived the climate change through a recurrence of flooding	Dummy variable, 1 = yes, 0 = otherwise	+/−	
Incorrect distribution of rainfall	Transhumant perceived the climate change through an incorrect distribution of rainfall	Dummy variable, 1 = yes, 0 = otherwise	+	
Excessive heat during the day	Transhumant perceived the climate change through an excessive heat during the day	Dummy variable, 1 = yes, 0 = otherwise	+	
Excessive heat at night	Transhumant perceived the climate change through an excessive heat at night	Dummy variable, 1 = yes, 0 = otherwise	+	
Daytime coolness	Transhumant perceived the climate change through a daytime coolness	Dummy variable, 1 = yes, 0 = otherwise	+	
Coolness at night	Transhumant perceived the climate change through a coolness at night	Dummy variable, 1 = yes, 0 = otherwise	+	
Strong wind	Transhumant perceived the climate change through a strong wind	Dummy variable, 1 = yes, 0 = otherwise	+	
Whirlwinds	Transhumant perceived the climate change through a whirlwinds	Dummy variable, 1 = yes, 0 = otherwise	+	

3.2 Perceptions of transhumant herders on climate change and their adaptation strategies

The perceptions of the transhumant herders on climate change focused on climatic parameters (rain, temperature, and wind) (Table 3). Considering the rains, more than half of the respondents perceived the climate change through decreased rainfall, irregularity of rainfall, early cessation of rainfall, pockets of drought, incorrect distribution of rainfall, and late start of rains. About a temperature, more than half of the respondents perceived excessive heat during the day and night as climate change manifestations. Regarding the wind, less than half of the respondents declared that they had experienced strong winds. Thus, the transhumant herders surveyed felt the manifestations of climate change more in terms of rainfall and temperature than in terms of wind.

Adaptation strategies used by transhumant herders surveyed were based on genetic performance of cattle improving, feed research for cattle and water search strategies (Table 3).

Adaptation strategies used by the more than half of respondents to counter the negative effects of climate change were the change of the transhumance period, the sedentarization of animals, the change in transhumance areas and routes and constitution of food reserves for the drought pocket (Table 3). However, <25% of respondents used cattle genetic selection and prayers and offerings to deities to tackle climate change.

3.3 Determinants of adoption of climate change adaptation strategies

The models were globally significant with explanatory powers $R^2 > 50\%$ (Table 4). This indicate that 50% of variation of adoption of

TABLE 2 socioeconomic and demographic characteristics of transhumant herders.

	Variables	Mean	Standard deviation
Quantitative variables	Age (years)	44.38	12.44
	Experience in transhumance (years)	22.15	9.76
	Size of households	10.72	5.52

	Variables	Modality	Frequencies (%)
Qualitative variables	Education level	No education	78
		Primary	17
		Secondary	5
	Alphabetization	No	77
		Yes	23
	Ethnic group	Bariba	27
		Dendi	1
		Peulh	72
	Marital status	No married	3
		Divorcee	3
		Married	94
	Religion	Animism	23
		Christian	9
		Muslim	68
	Herder's group membership	No	62
		Yes	38
	Access to extension services	No	74
		Yes	26

each adaptation strategy to climate change were explained by the explanatory variables.

- *Installation of fodder reserves*: Christian and Muslim religion and ethnic group Dendi had a negative influence on the adoption of installation of fodder reserves in the face of climate change. The married and divorcee status positively influenced the adoption of this strategy. The perception of climate change through the drought pocket and whirlwinds negatively influenced the adoption of this strategy. On the other hand, when transhumant herders perceived climate change through daytime and nighttime coolness, they are more predisposed to install fodder reserves to cope the adverse effects of climate change.
- *Introduction of new breeds*: Age, the secondary education level, Bariba and Dendi sociocultural groups and christian and muslim religions negatively influenced the adoption of introduction of new. While the perception of climate change through the recurrence of floods positively influenced the adoption of this strategy.
- *Cattle genetic selection*: Bariba and Dendi sociocultural groups, christian and muslim religions negatively influenced the adoption of cattle genetic selection to climate change. While the married and divorcee status positively influenced the adoption of this strategy. The perception of climate change through the early cessation of rains, the daytime coolness and strong wind positively influenced the adoption of this strategy to improve the cattle performance in the face to climate change. Indeed, the early cessation of rains causes the early drying of pastures and the early start of the dry season. Thus, in order to make animals more resistant or tolerant to drought, transhumant herders select cattle breeds that can withstand the drought and survive the dry season.
- *Food stockpiling for the drought pocket*: No socio-demographic characteristics influenced the adoption of food stockpiling in the face of climate change. The early cessation of rains negatively influenced the adoption of this adaptation strategy. On the other hand, high rainfall intensity, pockets of drought and excessive heat at night were the perceptions of climate change which positively influenced the adoption of food stockpiling in the face of climate change.
- *Change in transhumance areas and routes*: Age and Muslim religion positively influenced the adoption of changing transhumance areas and routes in the face of climate change. In addition, the perception of recurrence of floods negatively influenced the adoption of this adaptation strategy.
- *Prayers and offerings to deities*: The secondary level of education, the number of years of transhumance experience and membership in an organization positively influenced the adoption of prayers and offerings to deities in the face to climate change. In contrast, contact with an extension service negatively influenced the adoption of this adaptation strategy. Increased rainfall, rainfall irregularities and whirlwinds had a negative influence on the adoption of prayers and offerings to deities in

TABLE 3 Perceptions on climate change and adaptation strategies used.

Climate parameters	Perceptions on climate change	Frequencies (%)
Rains	Decrease in the number of rainy days	79
	Irregularity of rainfall	76
	Early cessation of rains	75
	Drought pocket	73
	Late start of rains	61
	Incorrect distribution of rainfall	61
	High intensity of rainfall	37
	Recurrence of flooding	23
	Increase in the number of rainy days	20
Temperature	Excessive heat during the day	77
	Excessive heat at night	67
	Coolness at night	41
	Daytime coolness	20
Winds	Strong wind	38
	Whirlwinds	25

Types of adaptation strategies	Adaptation strategies	Frequencies (%)
Strategies for improving the genetic performance of cattle	Cattle genetic selection	24
	Introduction of new breeds	39
Strategies based on feed research for cattle	Installation of fodder reserves	44
	Change of the transhumance period	56
	Sedentarization of animals	64
	Change in transhumance areas and routes	76
	Food stockpiling for the drought pocket	86
Water search strategies	Prayers and offerings to deities	12

the face to climate change. In contrast, the high intensity of the rains and the excessive heat at night positively influenced the adoption of this adaptation strategy.

- *Sedentarization of animals*: Christian and muslim religion and the number of years of transhumance experiences positively influenced the adoption of animals sedentarization in the face to climate change. No perception influenced the adoption of animals sedentarization.
- *Change of the transhumance periods*: The practice of agriculture, Christian and Muslim religions positively influenced the adoption of change of the transhumance period. On the other hand, literacy had a negative effect on the adoption of change of the transhumance periods. The late onset of the rains, excessive heat during the day and whirlwinds positively influenced the adoption of change of transhumance periods. While, the early cessation of rains, cool nights and strong winds negatively influenced the adoption of this adaptation strategy to climate change.

In sum, adoption of adaptation strategies to climate change depends mainly to sociodemographic profile of herders, institutional environment (access to credit, organization membership, access to extension service) and their perception on climate change (Figure 3).

4 Discussion

4.1 Perceptions, response stimuli to climate change

The perceptions of transhumant herders on climate change through rainfall and temperature variability in North Benin found in this study are consistent with the results of Adifon et al. (2020) and Egah et al. (2019) who demonstrated an increasing trend in temperature in North Benin. They are consistent with temperature trends in the Lake Chad Basin where temperature and precipitation will increase by 0.65–1.6°C and decrease by 11–13% in precipitation, respectively, over the periods 2016–2035 (Mahmood et al., 2019). Bolatova et al. (2024) also revealed an increased temperature in Kazakhstan. The same perceptions were observed in Cameroon, south-eastern Botswana and north-western Bangladesh where transhumant herders and farmers reported not only changes in start and stop times, distribution, number of days and amount of rainfall but also temperature variability in terms of heat, number of hot days, etc. and fogs on the other (Kgosikoma et al., 2018; Roy et al., 2021; Ngute et al., 2021). The high rainfall intensity perceived by transhumant farmers should not be neglected because Kpanou et al. (2021) demonstrated an increase in the number of extreme rainfall events in the southern parts of Côte d'Ivoire and Togo/Benin, resulting

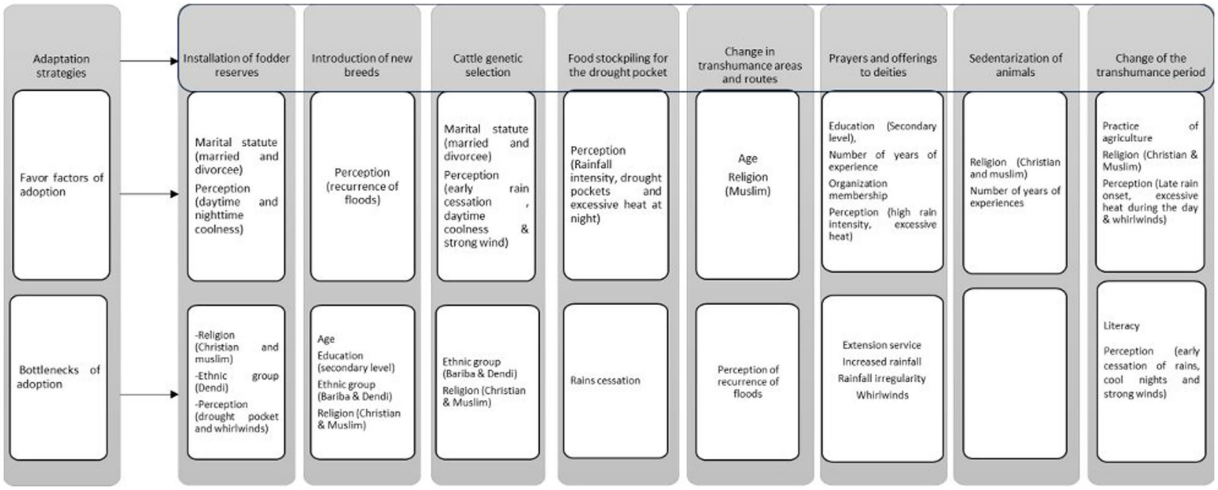

FIGURE 3
Favor factors and bottlenecks of adaptation adoption.

in an increase in total rainfall. Unlike, at Kazakhstan, farmers noticed the decreased rainfall which affect leguminous crops yield (Bolatova et al., 2024). Perceptions of these climate risks are forcing transhumant herders to develop strategies to adapt to climate change (Zagaria et al., 2021; Egah et al., 2024).

Several adaptation strategies to climate change were based on feed and water research for cattle. These strategies are similar to those revealed by Faisal et al. (2021) who show the adaptation strategies adopted by livestock herders aim the accessibility and availability resources. In this study, most of adaptation strategies were oriented to improved feeding, to improved/stress tolerant breed/species, etc. (Faisal et al., 2021). The adaptation strategies developed by transhumant herders to reduce the adverse effects of climate change on their livelihoods and subsistence in North Benin integrate the adaptation mechanisms of agropastoralists in Cameroon, Southeast Botswana and China (Kgosikoma et al., 2018; Ngute et al., 2021; Yang et al., 2021). These authors add adaptive strategies that are not developed by transhumant herders in North Benin but that converge on new food sources and changes in transhumance areas and routes practiced in the study area. These include the use of trees for fodder or fodder supplementation, vaccination of animals, fencing and use of shelters, long-distance migration, and the search for employment. This difference can be explained by the fact that transhumant herders in northern Benin did not observe the appearance of new diseases due to climate change.

Climate risk perceptions are correlated with the adoption of climate change adaptation strategies. This finding fits well with the premise of Mahmood et al. (2021) and Yang et al. (2021). These authors showed that adoption of adaptation strategies is based on perceived climate risks. However, the results of this study suggest the relativization of this assertion because certain perceptions, notably the decrease in the number of rainy days and the incorrect distribution of rainfall are not associated with the adoption of any climate change adaptation strategy. Also, certain adaptation strategies, notably the sedentarization of animals, are not correlated with any perception of climate change. In addition, some perceptions of climate risks stimulated the adoption of adaptation strategies, while others inhibited their adoption. As an illustration, transhumant farmers who perceived the late onset of rains adjusted the transhumance period, agreeing with the results of Kgosikoma et al. (2018) who showed the shift in crop planting date according to the onset of rains in Bostwana. On the other hand, increased rainfall and irregularity of rainfall inhibits the adoption of prayers and offerings to deities by transhumant people because these climate risks are not a threat of lack of rainfall to elicit supplications to deities. However, the perception of these risks encourages the adoption of fodder supplementation (Yang et al., 2021). The introduction of new breeds of cattle among transhumant herders is consistent with that observed among farmers who adopt drought-resistant crop varieties in the face of climate change (Marie et al., 2020). The positive influence of excessive heat at night on the adoption of food stockpiling and prayers and offerings to deities is explained by the fact that this perception is a warning sign of the scarcity of rainfall, which would compel them to build up food reserves to cope with it (Yang et al., 2021). All this shows that certain adaptation strategies can be stimulated or inhibited by certain perceptions of climate change by transhumant herders.

In sum, the results of this study support theories of planned behavior (TPB) and cognitive stress (TCS) (Yazdanpanah et al., 2014; Pakmehr et al., 2021). However, they relativize by showing that all climate perceptions are not stimuli for adoption of climate change responses by transhumant herders. Moreover, the adoption of adaptation strategies in the face of climate change does not only emanate from climate risk perceptions but also depends on socio-demographic characteristics (Mahmood et al., 2021).

4.2 Socio-demographic and institutional characteristics: evidence in the process of transhumant adaptation to climate change

The results of this study confirm the importance of socio-demographic characteristics in the adoption of adaptation strategies by transhumant herders in the face of climate change (Ali et al., 2021).

TABLE 4 Determinants of adoption of climate change adaptation strategies.

Variables	Installation of fodder reserves		Introduction of new breeds		Cattle genetic selection		Constitution of food reserves for the drought pocket		Change in transhumance areas and routes		Prayers and offerings to deities		Sedentarization of animals		Change of the transhumance period	
	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef.	*t*	Coef.	*t*
Age	0.002	0.3	−0.014**	−2.0	−0.003	−0.5	0.003	0.5	0.013*	1.94	−0.003	−0.5	−0.009	−1.2	0.011	1.5
Education level																
Primary level	−0.029	−0.2	0.097	0.7	0.137	1.1	0.024	0.2	−0.024	−0.2	−0.099	−0.9	−0.030	−0.2	0.038	0.3
Secondary level	−0.185	−0.8	−0.431*	−1.7	−0.122	−0.5	0.202	0.9	0.347	1.5	0.473**	2.4	0.195	0.8	0.369	1.4
Literacy	0.142	1.3	−0.055	−0.5	−0.072	−0.7	0.011	0.1	−0.192*	−1.7	0.008	0.1	−0.132	−1.1	−0.265**	−2.0
Ethnic groups																
Bariba	−0.613	−1.4	−0.900*	−1.9	−0.905**	−2.1	0.443	1.1	0.311	0.7	−0.590	−1.6	0.480	1.0	0.688	1.3
Dendi	−0.771*	−1.7	−0.901*	−1.8	−0.879*	−1.9	0.217	0.5	0.119	0.2	−0.487	−1.2	0.542	1.1	0.608	1.1
Marital status																
Married	0.499*	1.7	0.596*	1.9	0.701**	2.4	−0.190	−0.7	−0.169	−0.5	0.313	1.2	0.469	1.4	−0.519	−1.5
Divorcee	0.770*	1.9	0.770	1.7	0.733*	1.7	0.159	0.4	0.232	0.5	0.160	0.4	0.064	0.1	−0.574	−1.1
Agriculture (secondary activity)	−0.236	−1.5	−0.231	−1.4	−0.155	−0.9	0.149	1.1	−0.073	−0.4	0.013	0.1	0.274	1.6	0.389**	2.1
Religion																
Christian	−0.420**	−2.3	−0.584***	−2.8	−0.326*	−1.7	0.203	1.2	0.238	1.2	0.036	0.2	0.438**	2.1	0.406*	1.8
Muslim	−0.280**	−2.0	−0.603***	−3.9	−0.267*	−1.9	0.125	1.0	0.376**	2.5	0.023	0.2	0.359**	2.3	0.414**	2.5
Transhumance experience	0.002	0.3	0.011	1.3	−0.001	−0.2	0.000	−0.1	−0.005	−0.6	0.013*	2.0	0.015*	1.8	−0.005	−0.5
Herder's group membership	0.017	0.1	0.110	0.7	0.172	1.1	−0.028	−0.2	0.200	1.2	0.261*	1.9	0.147	0.8	0.157	0.9
Access to extension service	−0.223	−1.4	−0.132	−0.7	−0.196	−1.2	−0.041	−0.3	−0.221	−1.3	−0.289**	−2.0	−0.033	−0.2	−0.005	−0.0
Perceptions on climate change																
Decrease in the number of rainy days	0.161	1.6	0.142	1.2	0.019	0.2	0.083	0.9	−0.047	−0.4	0.032	0.3	−0.016	−0.1	0.015	0.1
Increase in the number of rainy days	0.071	0.6	0.060	0.5	0.109	0.9	−0.101	−0.9	0.018	0.1	−0.296***	−2.8	0.173	1.3	−0.123	−0.9
High intensity of rainfall	−0.015	−0.2	0.049	0.5	0.072	0.8	0.184**	2.2	0.065	0.7	0.215***	2.7	0.011	0.1	−0.018	−0.2
Irregularity of rainfall	0.016	0.2	0.026	0.2	−0.098	−0.9	−0.037	−0.4	−0.082	−0.7	−0.160*	−1.8	0.013	0.1	0.094	0.8
Late start of rains	0.037	0.4	−0.057	−0.5	−0.077	−0.8	−0.098	−1.2	0.030	0.3	0.028	0.3	−0.090	−0.9	0.192*	1.7
Early cessation of rains	0.158	1.5	−0.085	−0.7	0.191*	1.8	−0.165*	−1.7	0.007	0.1	0.049	0.5	0.146	1.2	−0.217*	−1.7
Drought pocket	−0.238**	−2.4	−0.052	−0.5	−0.139	−1.4	0.167*	1.9	0.154	1.5	0.006	0.1	0.158	1.4	0.121	1.0
Recurrence of flooding	0.055	0.4	0.242*	1.7	0.072	0.5	−0.148	−1.3	−0.253*	−1.8	−0.030	−0.3	−0.223	−1.5	−0.172	−1.1

(Continued)

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TABLE 4 (Continued)

Variables	Installation of fodder reserves		Introduction of new breeds		Cattle genetic selection		Constitution of food reserves for the drought pocket		Change in transhumance areas and routes		Prayers and offerings to deities		Sedentarization of animals		Change of the transhumance period	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Incorrect distribution of rainfall	−0.018	−0.2	−0.019*	−0.2	−0.092	−0.9	0.081	0.9	0.029	0.3	0.062	0.7	−0.065	−0.6	0.040	0.3
Excessive heat during the day	−0.131	−1.3	−0.137	−1.2	−0.004	−0.0	−0.126	−1.3	−0.040	−0.4	−0.118	−1.3	0.031	0.3	0.291**	2.3
Excessive heat at night	−0.019	−0.2	0.133	1.1	−0.042	−0.4	0.374***	3.7	0.092	0.8	0.217**	2.2	0.163	1.3	−0.075	−0.6
Daytime coolness	0.304**	2.6	0.090	0.7	0.324**	2.7	−0.158	−1.5	−0.035	−0.3	−0.119	−1.1	0.028	0.2	0.000	0.0
Coolness at night	0.411***	3.7	−0.138	−1.1	−0.047	−0.4	−0.052	−0.5	−0.153	−1.3	0.067	0.7	−0.126	−1.0	−0.239*	−1.8
Strong wind	−0.046	−0.4	0.198	1.6	0.199*	1.7	−0.017	−0.7	−0.189	−1.5	−0.050	−0.5	0.073	0.6	−0.255*	−1.8
Whirlwinds	−0.229*	−1.9	0.114	0.9	0.052	0.4	0.022	0.2	0.107	0.9	−0.228**	−2.2	0.084	0.6	0.299**	2.1
_cons	0.791	1.6	1.637***	2.9	0.894*	1.7	0.181	0.4	0.064	0.1	0.162	0.4	−1.047*	−1.8	−0.816	−1.3
Logistic regression	RMSE = 0.337; R-sq = 0.679; F = 5.033; p = 0.000		RMSE = 0.374; R-sq = 0.592; F = 3.448; p = 0.000		RMSE = 0.349; R-sq = 0.538; F = 2.774; p = 0.0003		RMSE = 0.3074; R-sq = 0.457; F = 2.006; p = 0.009		RMSE = 0.361; R-sq = 0.507; F = 2.443; p = 0.001		RMSE = 0.2979; R-sq = 0.419; F = 1.718; p = 0.035		RMSE = 0.385; R-sq = 0.555; F = 2.964; p = 0.0001		RMSE = 0.4.105; R-sq = 0.5.242; F = 2.6216; p = 0.0006	

The increase of age favors the adoption of changes in transhumance areas and routes because it offers the possibility for transhumant herders to have a greater knowledge of transhumance areas and routes than younger people (Menghistu et al., 2020). However, it also inhibits the adoption of new cattle breeds in the face of climate change. The younger age group is more open to external worlds and more aggressive in obtaining new breeds (Kgosikoma et al., 2018).

The positive influence of education level on the adoption of prayers and offerings to deities is explained by the fact that education plays a determining role in the adoption of adaptation strategies such as fodder supplementation in the face of climate change (Mahmood et al., 2021; Yang et al., 2021). Muddassir and Alotaibi (2023) show that education plays important role in adoption process of the farmers in Pakistan. However, literacy does not favorite the adoption of change of transhumance areas and routes unlike Reddy (2019) showed with fertilizer using.

The number of years of experience in transhumance and membership in organizations are also assets for the adoption of prayers and offerings to deities and the sedentarization of animals. These results confirm the work of Atube et al. (2021) who show that producers' experiences positively influence the adoption of an adaptation strategy.

Contact with an extension service inhibits prayers and offerings to deities. Unlike Menghistu et al. (2020) in sub-Saharan Africa, Mahmood et al. (2021) in the Lake Chad basin (Africa) and Muddassir and Alotaibi (2023) in Pakistan, this study points out that extension services do not always promote the development of climate change adaptation practices because it considers scientific reasoning which did not meet transhumant faith or belief.

The sociocultural groups Bariba and Dendi were less predisposed to adopt the cattle genetic selection, the installation of fodder reserves and the introduction of new breeds than Peulh. Indeed, the Peulh are more experimented than other ethnic groups in pastoralism because his main activity was a cattle breeding which they inherit from their parents (Dickin et al., 2021). The others ethnic groups are the farmers before becoming the cattle breeders.

In sum, all of socioeconomic and demographic characteristics do not positively influence the adoption of adaptation strategies by transhumant herders to climate change. However, they play an important role in the adoption of climate change adaptation strategies (Marie et al., 2020; Atube et al., 2021). This study confirm that the adoption process of adaptation strategies is complex and involves several factors which are the perceived changes, the livelihood capital, etc. (Kuchimanchi et al., 2021).

5 Conclusion

Transhumant perceptions of climate change reflect the variability of rainfall, temperature and wind. The majority of these perceptions constitute stimuli for the adoption of adaptation strategies by transhumant herders to climate change. Adaptation strategies based on cattle feed search, water search and cattle genetic performance. The strategies aimed at food search include the constitution of fodder reserves, the use of new sources of food, the change of areas, routes and period of transhumance. The introduction of new breeds of cattle and genetic selection of cattle according to their performance constitute the strategies for genetic improvement of animals in the face of climate

change. Strategies based on water search are prayers and offerings to deities and the creation of micro water tanks. The adoption of these coping strategies depends on certain perceptions and socio-demographic characteristics of transhumant herders, thus confirming the hypothesis. However, the results of the study relativize that all climate risks perceptions and socio-demographic characteristics are not stimuli for responses to climate change by the transhumant herders.

In sum, the results of the study suggest that policies should strengthen transhumant people's access to information on climate change to better contribute to their resilience and capacity to adapt to climate change.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MD: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. JE: Formal analysis, Funding acquisition, Methodology, Writing – review & editing. PD: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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