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Research article

Small ruminant farmers' feeding strategies to cope with climate change across five agroecological zones of Benin, West Africa

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ABSTRACT

This study aimed to understand feeding strategies used by small ruminant farmers to cope with climatic change in the five contrasting agroecological zones (AEZ) of the Benin Republic and to identify the determinants of adopting these strategies. A semi-structured questionnaire was used to conduct interviews with 400 smallholder farmers in the rural areas of Benin. Data was collected on production system characteristics, farmers' perception of climatic changes' impacts on livestock production, and their coping strategies. Cross tabulations with Chi^2 statistic and the non-parametric Kruskal Wallis test were used to compare farmers' perceptions and coping strategies between the five AEZ. Then, the binomial logistic regression was used to identify determinants of using a particular adaptive feeding strategy. The farmers perceived climatic changes as rainfall delays, increasing rainfall, less frequent drought periods during the rainy season, no change in sunshine duration, and no change in temperature. These changes negatively affected grassland biomass production (86.3 %, 86.3 % and 77.5 % of farmers in South Borgou, Plateau, Atacora chain AEZ, respectively) and water availability (100 %, 93.7 %, and 85 % of farmers in Oueme Valley, Plateau and Mekrou-penjari AEZ, respectively). Consequently, farmers mentioned decreased animal growth (58.8 % and 45 % of farmers in Plateau and South Borgou AEZ, respectively) and increased animal mortalities (43.8 % in Plateau AEZ). Farmers' current and future coping strategies varied significantly ($p<0.05$) among AEZ. These strategies included more diversification of feed resources used, more free wandering of animals, feeding intensification with supplements as current strategies, and new feed resource exploration and forage cultivation as future strategies. Logistic regression results showed that gender, education level, main activity, and the climatic and agroecological zones where the farm is located influenced the strategies used. The study showed that farmers understood climate change and its impact on production systems. In response, the common climate-smart feeding strategies adopted were mainly diversifying feed resources. Feed resources use strategies, and limitations to adopting these strategies, could be assessed in future studies.

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1. Introduction

In 2016, the Sub-Saharan Africa (SSA) region accounted for 950 million people, approximately 13 % of the global population, and this share is projected to increase to almost 22 % or 2.1 billion in 2050 [1,2]. Livestock keeping employs more than half of the total labor force and, within the rural population, provides a livelihood for many small-scale producers [3]. Smallholder farms constitute approximately 80 % of all farms in SSA and employ about 175 million people directly [1].

In the Republic of Benin, the agricultural population accounts for 54.8 % of the total population, and livestock farming is practiced by 65.42 % of agricultural households. Livestock farming mainly concerns cattle (22.4 %), sheep (44.9 %), and goats (50.3 %) [4]. Small ruminants are produced nationwide, with about 950,000 heads of sheep and 2,000,000 heads of goats. The national herds support the livelihoods of about 600,000 rural people, mainly low-income people [4]. Indeed, small ruminants represent a significant production for ensuring food, financial (savings, household needs in off-farm periods, medical costs), and socio-cultural (baptism, wedding, Aïd) security [5–7] for farmers.

In 2021, Benin's national demand for meat at Benin was estimated at around 250,000 tons, while the national production met only 37.2 % of this demand, with cattle contributing 49.1 %, goats at 12.5 %, sheep at 12.1 %, pigs at 12.8 %, and poultry at 13.5 % [4]. However, these statistics did not take household production into account. Like in other West African countries, small ruminant meat comes mainly from small-scale farms with a traditional, extensive, and natural grazing-based system [8,9]. Feeding constraints are the major limitation to small ruminant production [6,9–11]. This is due to the farmers' low training capacity to feed their animals efficiently, the forage scarcity during dry seasons, and the high cost of supplements that can be used to improve the animals' nutritional status. Even though recent studies have emphasized alternative feeds and innovative feeding strategies, it has been observed that poor rural farmers are slow to adopt these technological innovations [12].

These constraints are enhanced by ongoing climatic changes [13] with direct and indirect effects on ruminant breeding, including heat stress, limited and low-quality pasture availability, and emerging infectious diseases [14–16]. Therefore, productive and reproductive performances decrease, and mortality increases. Indeed, Diallo et al. [17] revealed that a one-degree rise could cause a drop in milk yield of 23 % and 8 % in sheep and goats, respectively. Dimon et al. [18] showed that feeding practices influence reproductive and mortality parameters in small ruminants. Furthermore, exposure of animals to heat stress compromises growth, milk, and meat production and reproduction [16]. Smallholder poor farmers in developing countries constitute one of the most vulnerable groups to climate change, being exposed to strong climate signals with a limited adaptive capacity [19] due to the lack of training and information. As a result, climate change poses a more significant threat to food security in these countries [1–3,20]. So, identifying strategies for improving smallholder farmers' adaptive capacity is essential to enhance animal productivity and increase farmers' incomes [19].

Benin has been experiencing climatic changes since the 1960s [21,22]. Several studies in West African regions, particularly in the Republic of Benin, have examined how small ruminant and cattle farmers perceive and adapt to climate change in various

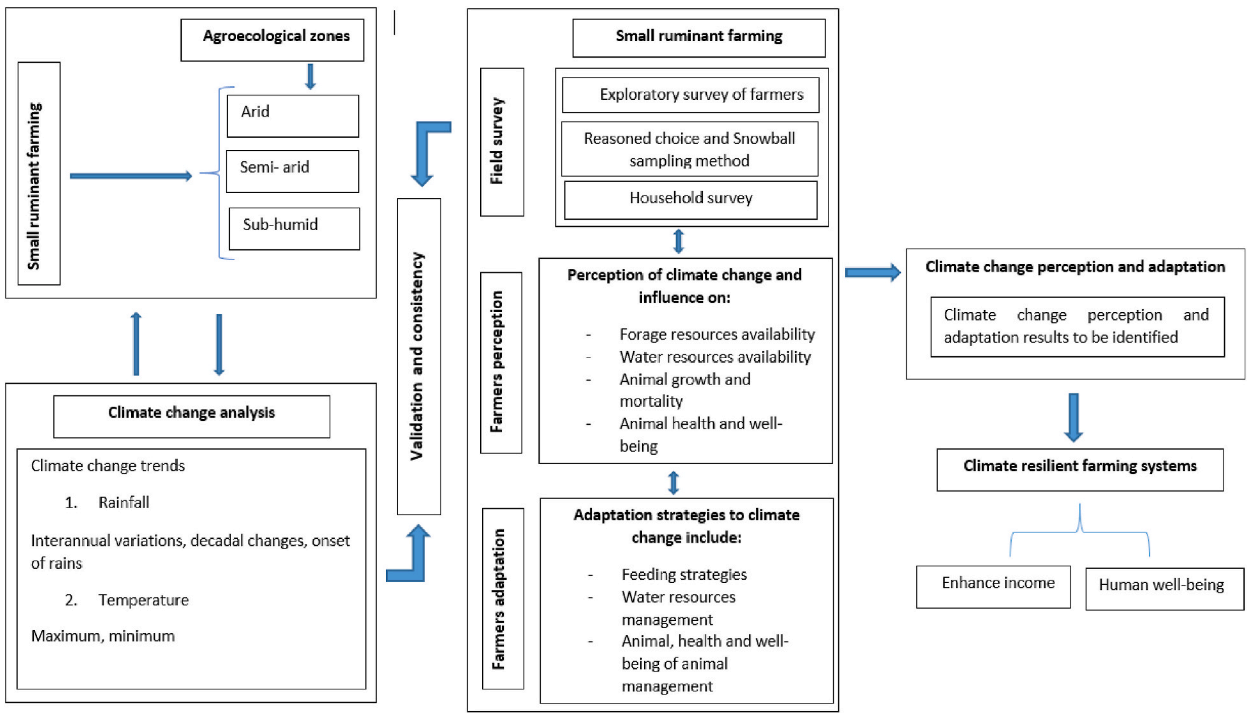

Fig. 1. Conceptual framework of the study.

environments [23–26]. The common adaptive measures documented were the increased use of agro-industrial by-products, crop residues or tree fodders, the better integration of crop and livestock, and transhumance [27,28]. However, these studies were mainly concerned with cattle farms. Recently, some studies have addressed the perception and adaptation practices in small ruminant farms in

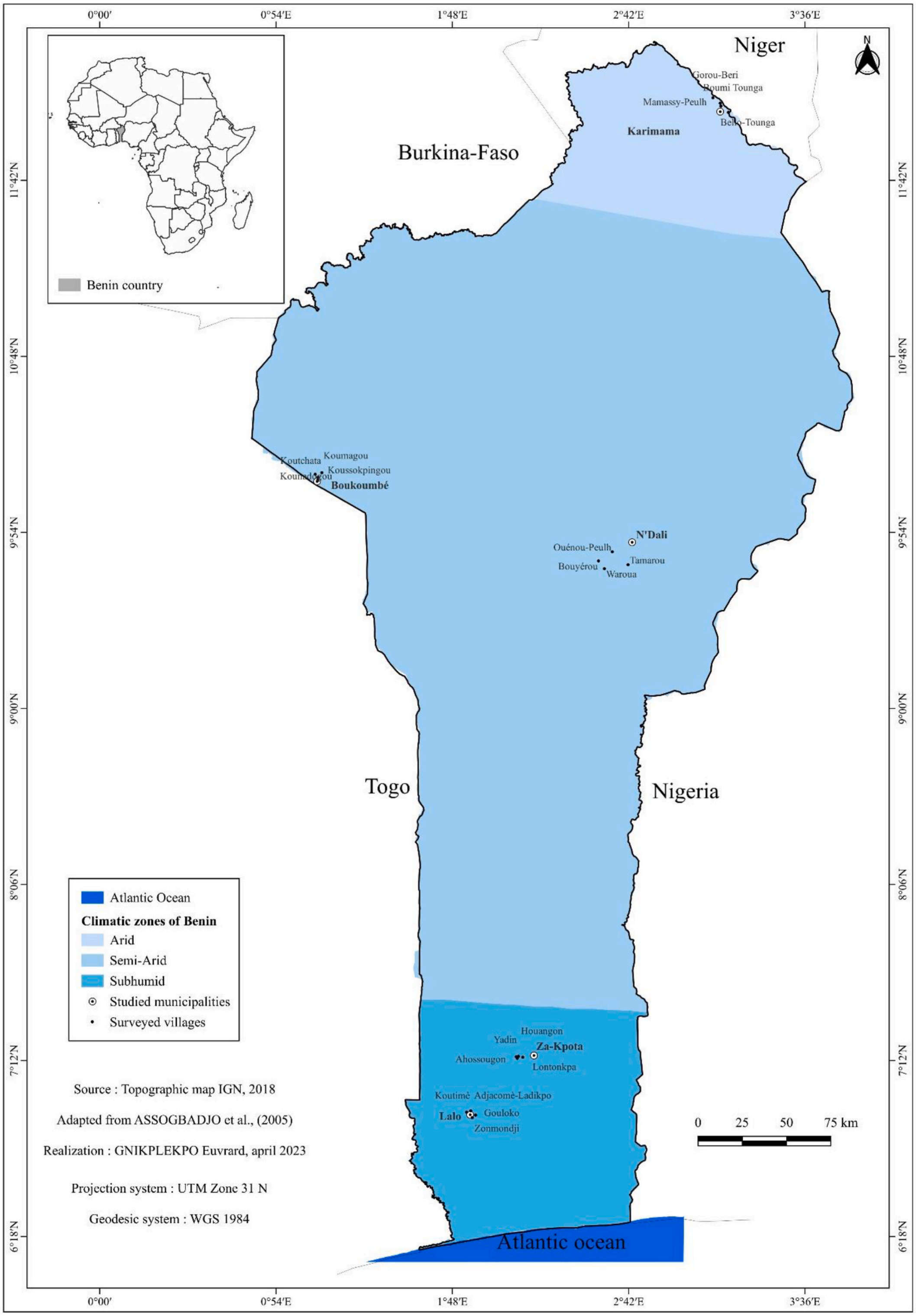

Fig. 2. Map of the study area showing the surveyed municipalities in the agroecological zones.

Nigeria, Ghana, Burkina-Faso, and Cameroun [29–33]. In Benin, only the works of Dimon et al. [27] and Ariom et al. [34] have addressed small ruminant farmers' adaptative strategies to climate change.

Meanwhile, there is scarce information about herder coping strategies for feeding practices in West Africa in various agroecological zones (AEZ). Indeed, climate changes may be perceived differently, and farmers can develop various adaptive strategies to the climatic characteristics of the region where the farm is located [35]. Therefore, this study aimed to assess the small ruminant small-scale farmers' perception of climate change impacts on their environment and production, report their coping strategies across different AEZ and identify determinants of adopting some coping strategies. This study assumed that smallholder farmers of small ruminants, with little capacity to embrace technical innovations, perceive climate change impact differently. In response to the changing climate, these farmers could have developed innovative feeding strategies adapted to their AEZ. This study addressed the following research questions: How do small ruminant farmers perceive climate change across AEZ? What kind of feeding strategies are developed by farmers to face climate change? Is there a variation in strategies developed by farmers according to the AEZ?

2. Materials and methods

The analytical framework of the study is shown in Fig. 1. This study focused on understanding the perceptions of small ruminant farmers of climate change and its impacts on production systems and adaptation strategies. It also connected the socio-economic status of farms and farmers' adaptation strategies in the face of climate change. The study started with the observation that the adaptation strategies of small ruminant farmers were linked to their perception of the impacts of climate change and how they had to deal with it. Several studies have indicated that perception is influenced by the socio-economic characteristics of farmers' households [36,37] and adaptation measures [38,39]. The physical and institutional environment of agricultural producers also matters [40]. The relationship between the different variables was done using descriptive statistics and binary logistic regression methods, making it possible to analyze the determinants of adopting adaptation strategies.

2.1. Study area

The study was conducted from February to June 2019 in five municipalities (Lalo, Za-kpota, N'dali, Boukombe, and Karimama), corresponding to five different AEZ (Plateau, Oueme Valley, South Borgou, Atacora chain, and Mekrou-penjari) in the Republic of Benin. These AEZ were located in three different climatic zones (arid, semi-arid, and sub-humid) (Fig. 2) as described in Table 1, where biophysical factors were defined according to the works of Adamou et al. [41] and Akoegninou et al. [42]. The municipalities (commune) were selected according to two criteria: i) hold a high number of small ruminants and ii) be a municipality with a high proportion of food unsecured households according to the Comprehensive Food Security and Vulnerability Analysis [43]. Food insecurity is when people do not have regular access to safe, nutritious food for normal growth and development and an active, healthy life [1]. These food-insecure households were selected to make small ruminant keeping a tool against poverty and to improve access to animal protein. Four villages were selected in each municipality (n = 20 villages) following the criteria mentioned above. As there is no exhaustive and reliable database of small ruminant farmers in the studied areas, the local official from the Ministry responsible for animal production was contacted and asked to help select municipalities and villages to be surveyed.

2.2. Survey data collection

For this study, a survey was conducted to collect data on farmers' characteristics and perceptions, as made in previous studies [11,44,45]. A primary list of some farmers was obtained from the locals responsible for animal production for the interview. Then, the snowball sampling method [46] was used to extend this list to the number required by our study. As also used in previous studies [11,44,47], an equal number of farmers to interview per village (n = 20 farmers per village) was fixed, corresponding to 80 farmers per municipality. The interviews were conducted using a semi-structured questionnaire in the local language, and translators were used when required. The data collection strategy and research method allowed interviewees to freely express their opinions and thoughts [48,49]. The questionnaire included, among other things, the socio-economic characteristics of households, management practices and constraints to production, breeding objectives, perception of climate change (trends in rainfall, temperature, over at least the last 30 years), impacts on production resources (animal welfare, feed and water resources, and animal health) and animal performance, and farmer coping strategies.

2.3. Climatic data collection

Climatic data (from 1990 to 2020) was assessed from the agro-climatic database of the National American Security Agency [50] (Figs. 3–5). The mean annual rainfall, relative humidity, and the mean temperatures of the three warmest and coldest months were calculated for each municipality. The three warmest months were January to March for the two Southern municipalities and February to April for the three others. The three coldest months were July to September for the two Southern municipalities and October to December for the three others from the North.

2.4. Data processing and statistical analysis

All the statistical analysis was performed using SPSS version 23.0 software. As in previous studies, qualitative and quantitative

Table 1
description of the study areas.

Climatic zones	Agroecological zones	Surveyed municipality	Characteristics					
			Climat	T (°C)	Rainfall (mm/year)	Altitude (m)	Soil type	Vegetation
Arid	Mekrou-penjari	Karimama	Tropical (one rainy season and one dry season)	25 to 42	700 to 900	164	Ferruginous Very fertile alluvial deposits of the Niger River	Sparse shrubby to thorny savannah (*Acacia sieberiana*)
Semi-arid	South Borgou	N'dali	Tropical (one rainy season and one dry season)	25 to 40	1000 to 1.400	393	Tropical ferruginous	Shrubby, tree-dominated savannah dominated by *Vitelaria paradoxa* (Shea)
	Atacora chain	Boukombé	Tropical (one rainy season and one dry season)	25 to 31	800 to1.500	223	Ferruginous	Gallery forest, Wooded/arboreal savannah with *Vitelaria paradoxa and Parkia biglobosa*
Sub-humid	Oueme Valley	Za-kpota	Sub-equatorial (two rainy seasons and two dry seasons of unequal durations)	24 to 34	1000 to 1.600	121	Ferralitic soil	Shrubby thicket dominated by oil palms and grasses
	Plateau	Lalo	Sub-equatorial (two rainy seasons and two dry seasons of unequal durations)	22 to 32	1.000 to 1.500	80	Vertisol, ferralitic	Semi-deciduous dense forest with large trees

T: Temperature; adapted from Refs. [41,42].

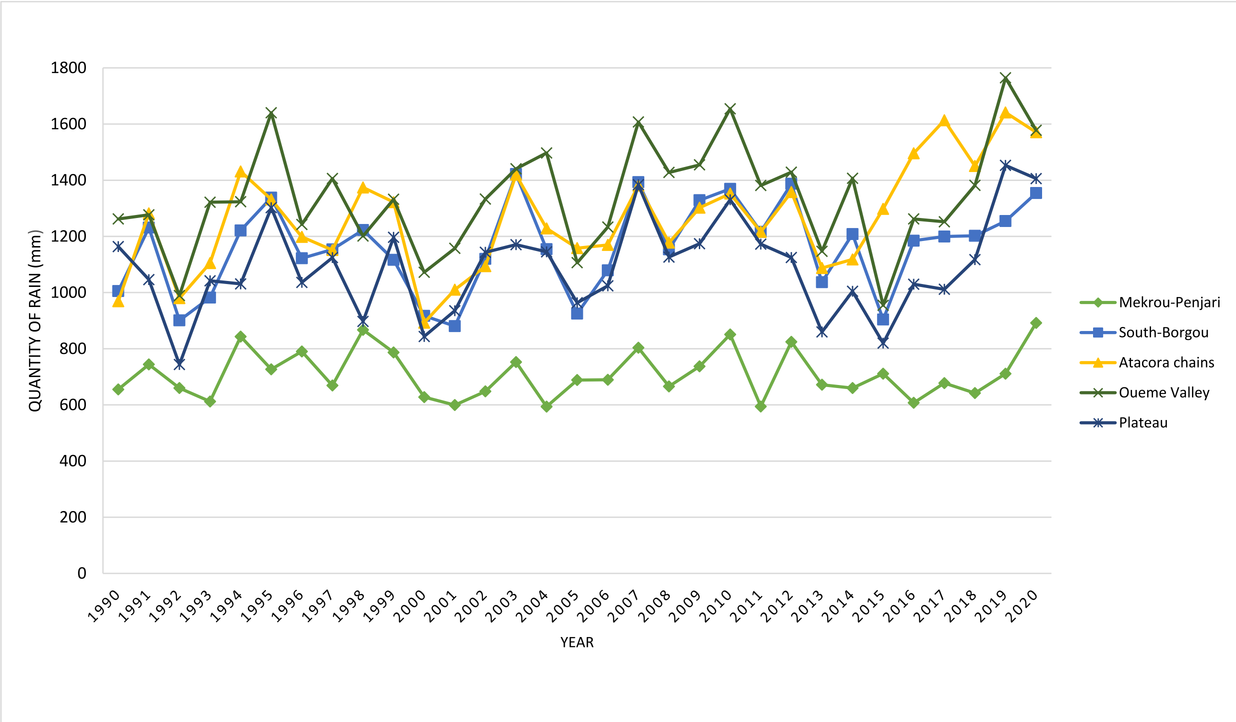

Fig. 3. Mean annual rainfall in five agroecological zones in Benin from 1990 to 2020 [50].

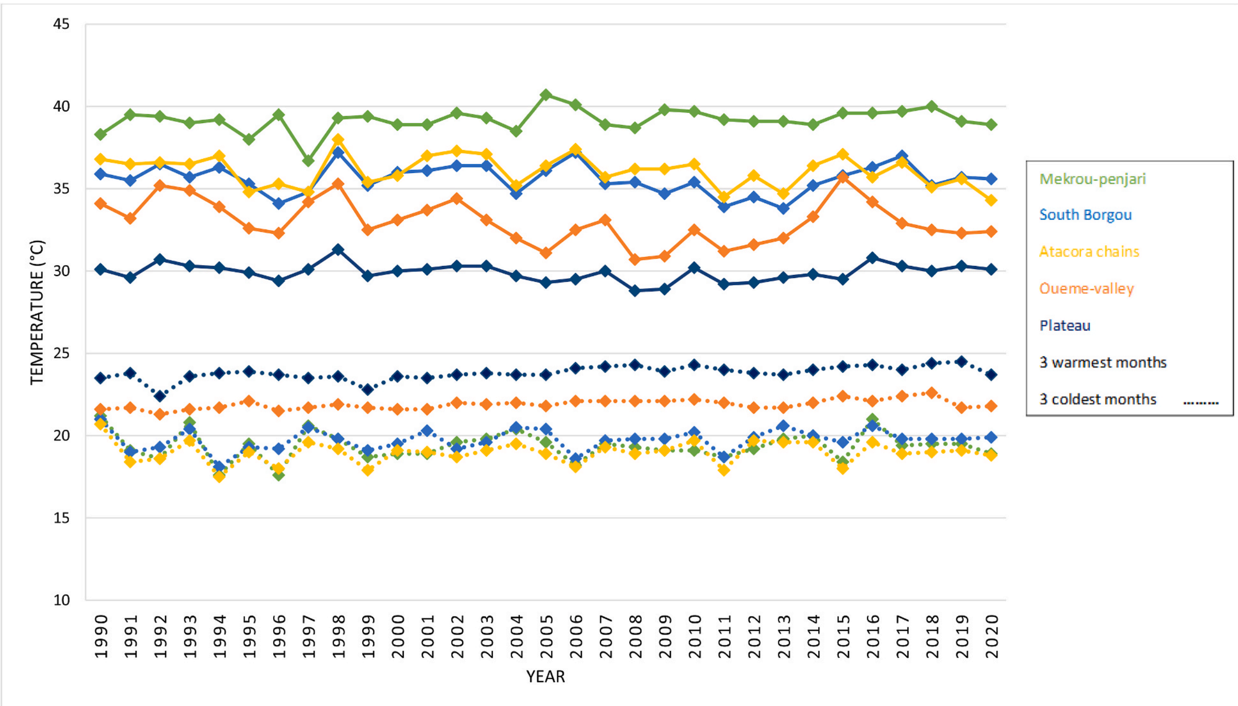

Fig. 4. Mean temperature of the three warmest months and the three coldest months per year in five agroecological zones in Benin from 1990 to 2020 [50].

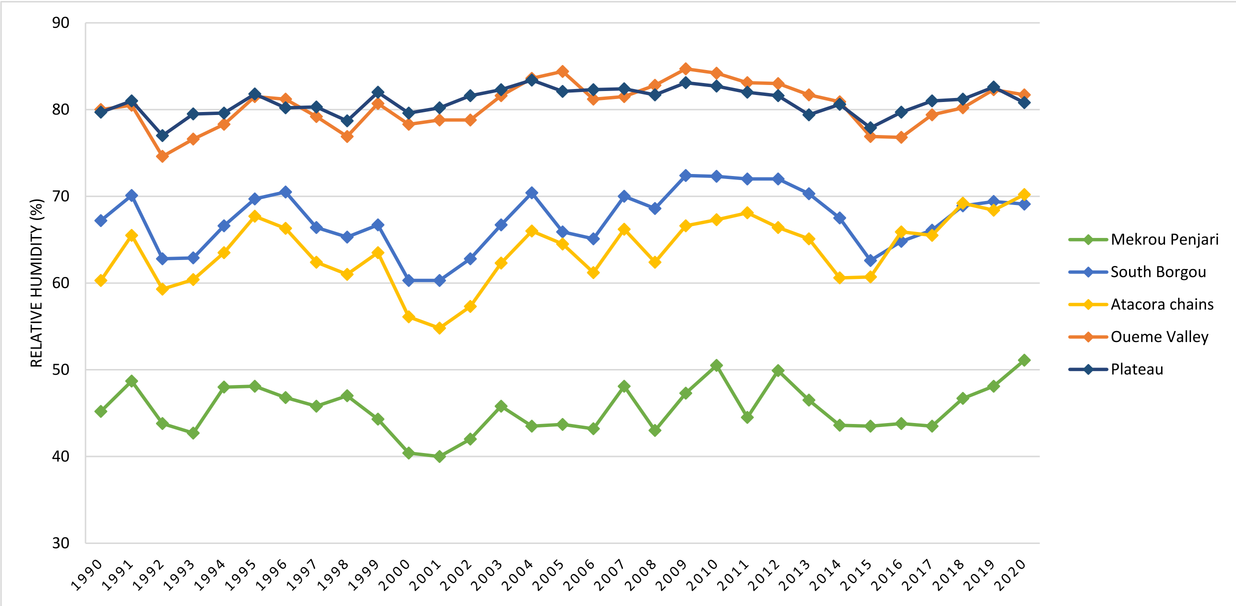

Fig. 5. Mean annual relative humidity trend across the five agroecological zones (1990–2020) [50].

methods were used to analyze the data [44,51]. Cross tabulation with the Pearson chi^2 statistic assessed the differences between relative frequencies according to the agroecological areas for the categorical variables. For the quantitative variables, means and standard error were calculated. The non-parametric Kruskall-Wallis test was used to explore the differences between these means according to the agroecological areas.

The binary logistic regression was then used to determine the factors influencing farmers' decisions for a particular coping strategy against climate change [52]. The probability that a farmer uses separately each of the following strategies: diversification of feed resources (1: yes or 0: no), feeding intensification (1: yes or 0: no), new feed resources exploring (1: yes or 0: no), forage cultivation (1: yes or 0: no); as an individual strategy was predicted.

As for the choice of explanatory variables in the model, the approach consisted of a systematic search for all variables statistically linked to the dependent variable. Thus, the socio-economic determinants of the farmers that could influence the choice of future adaptation measures were predicted. Prior to each regression analysis, the Pearson correlation test was applied to identify and omit independent variables that are strongly correlated to each other. The predictor variables were the climatic and AEZ where the farm is located, the farmer's gender, age, educational level, main activity, type of farming, household size, experience in small ruminant breeding, and membership in farmers' organizations. Four logistic regressions were implemented, each of them aiming to predict one of the following strategies: "more diversification of feed resources" or "feeding intensification with supplements" as the current strategy, and "new feed resources exploration" or "forage cultivation" as a future strategy.

The binary logistic regression model makes it possible to predict the membership of a predefined class from the series of predictors. As a general rule, the dependent variable is binary or dichotomous. It can be 1 (group member) with a probability of success of P or 0 (non-member) with a failure probability of 1-P. The relationship between the dependent and independent variables is not a linear function. Instead, the logistic regression function is used, which is the logit transformation of y:

$$Logit\,[y(x)] = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_i x_i$$

Where α = the constant of the equation and β = the coefficient of the independent variables.

The model considers the relationship between a binary dependent variable (Y) and a set of independent variables (X_i). In the logistic regression procedure, the analysis begins with a complete model, including all variables. Then, variables that are not useful for predicting the dependent variable are eliminated from the model. The analysis is completed when no variables can be eliminated from the model. The signs of the coefficients indicate the direction of the relationship between the independent variables and the dependent variable.

The Hosmer and likelihood ratio tests allowed us to assess the model's overall fit. In the logit model, the signs of the coefficients (β_j) reported in the resulting regression informed about the plausibility of the relationship between the strategy variable of interest and the explanatory variables introduced in the model. The degree of dependence between the variables was measured using the odds ratio (OR). The latter was defined as the ratio of probabilities that measured the link between characteristic X and the occurrence of event Y. Consequently, if OR = 1, event Y and variable X were independent; if OR > 1, the link between Y and X was positive, and negative, if OR<1.

3. Results and discussion

3.1. Climate data variation in the agroecological zones

Figs. 3–5 showed the evolution of rainfall, temperature, and relative humidity from 1990 to 2020 in the studied AEZ; as expected, these parameters varied across the zones. Rainfall was higher in Atacora chain and Oueme Valley, and lowest in Mekrou-penjari (extreme North). In this AEZ, rainfall hardly reached 900 mm/year, and the lowest values observed were about 600 mm/year (1993, 2001, 2004, 2011, 2016). Rainfalls above 1500 mm/year were frequently observed in Oueme Valley and, in recent years, in the Atacora chain. The Northern climatic zones (arid and semi-arid) presented the highest mean temperatures of the three warmest months, ranging from 36 °C to 41 °C, with the topmost values in 1998, 2006, and 2015. The same AEZ presented the lowest mean temperatures of the three coldest months. Relative humidity increased from the North (arid zone) to the South (sub-humid zone) of Benin. Our findings about variation in climatic data across different AEZ zones of Benin were confirmed by previous studies' authors [53–55] and attested to the reality of climate change, confirming the climate change.

3.2. Socio-demographic characteristics of the small ruminant farmers

Except for age, all socio-demographic parameters shown in Table 2 were significantly different (P<0.05) across the AEZ. Most farmers in all AEZ were men; women were the most represented in Plateau AEZ (40 %). Women were more involved in small ruminant keeping in Southern Benin, mainly in Plateau AEZ, which agrees with previous findings in South Benin [6].

Dendi and Peulh ethnic groups were present in the Northeastern part of Benin, Ditamari in the northwestern part (mountainous

Table 2
Socio-demographic characteristics of small ruminant farmers in five different agroecological zones of Benin.

Variables	Modalities	Agroecological zones					Chi2	P
		Mekrou-penjari (n = 80)	South-Borgou (n = 80)	Chain Atacora (n = 80)	Oueme Valley (n = 80)	Plateau (n = 80)		
Nominal variable (Frequency, %)								
Gender	Man	97.5	83.8	85.0	83.8	60.0	861.48	0.001
	Woman	2.5	16.2	15.0	16.2	40.0		
Ethnic	Adja	0.0	0.0	0.0	0.0	92.5	2523.75	0.001
	Fon	0.0	0.0	0.0	100.0	7.5		
	Dendi	75.0	45.0	0.0	0.0	0.0		
	Ditamari	0.0	1.3	100.0	0.0	0.0		
	Peulh	25.0	51.2	0.0	0.0	0.0		
	Others (Sahoue, Yoruba, Betamaribe)	0.0	2.5	0.0	0.0	0.0		
Religion	Christian	0.0	12.5	7.5	25.0	16.3	1300.2	0.001
	Islam	100.0	86.3	0.0	0.0	7.5		
	Local religion (i.e. animism)	0.0	1.3	92.5	75.0	76.2		
Education	Primary	2.5	8.8	6.3	0.0	52.5	916.9	0.001
	Secondary	1.3	2.5	2.5	0.0	15.0		
	Others (university, religious, etc.)	0.0	0.0	0.0	0.0	1.3		
	None	96.3	88.8	91.3	100.0	31.2		
Main activity of the breeder	Agriculture	47.5	41.3	83.8	43.8	25.0	866.62	<0.001
	Agriculture and livestock farming	8.8	17.5	2.5	17.5	17.5		
	Livestock farming	25.0	31.3	1.3	5.0	2.5		
	Trading	8.8	7.5	5.0	23.8	26.3		
	Other activities (crafting, fishing, transport, transformation)	10.0	2.5	7.5	10.0	28.7		
Membership in farmer association	Yes	5.0	0.0	2.5	0.0	0.0	10.83	0.029
	No	95.0	100.0	97.5	100.0	100.0		
Numeric variables (Mean and Standard Error)								
Age of the breeder (year)		45.8 ± 11.4	48.2 ± 14.5	45.3 ± 11.7	47.1 ± 11.5	47.7 ± 13.5		0.71
Experience in small ruminants' breeding (year)		17.2^{a}±1.0	18.2^{a}±1.3	13.0^{b} ± 0.9	10.4^{c}±0.9	14.3^{b} ± 0.9		0.001
Household size		9.3^{ab} ± 0.6	10.2^{a}±0.6	8.4^{ab} ± 0.4	8.3^{b} ± 0.5	8.9^{ab} ± 0.5		0.029

P: probability; $^{a, b, c}$: values with the same letter in a row significantly differed at 5 % (Kruskall Wallis test).

region), and Fon and Adja in the Southern part. Consequently, as the religion varies according to the ethnic groups, Islam was mainly represented in the Northeastern part of the country and the local religion in the other regions. Farmers were generally uneducated except in the Plateau AEZ, where 52.5 % of the farmers had attended primary school. Farmers in Southern Benin and Atacora chain AEZ were animists; as expected, they were involved in goat farming. Therefore, our results followed the multifunctional roles of small ruminant keeping, including the use for cultural ceremonies [56].

Agriculture was the main activity of farmers, with differences according to the AEZ. In the Mekrou-penjari and Sud Borgou AEZ, at least one in four herders were breeders, which was the main profession, and they had the longest breeding experience and household size. Agriculture is the primary activity for most farmers. As confirmed by findings in other African countries [11,57–59], livestock farmers practiced other activities like trading for income diversification. However, most farmers interviewed in our study areas did not belong to a farmer's association.

3.3. *Small ruminant production characteristics*

Goat farmers (n = 213; 53.3 %) were the most represented, followed by mixed goat-sheep farmers (n = 148; 37.0 %) and sheep farmers (n = 39; 9.8 %). All the production characteristics of small ruminants varied significantly ($p<0.05$) according to the AEZ (Table 3). The Sahelian sheep and goat breeds were almost exclusively kept in the arid area (Mekrou-penjari AEZ), while the Djallonke sheep and goat breeds were present in the four other AEZ. In the Northeastern AEZ, mixed herds (sheep and goats) represented the highest proportion of farming (76 % in Mekrou-penjari and 60 % in South Borgou). In the three other AEZ, goat herds were common. Sheep, goat, and mixed (sheep-goat) flock sizes varied significantly according to AEZ, with the highest values of Tropical Livestock

Table 3
Small ruminant production characteristics in five different agroecological zones of Benin.

Variables	Modalities	Agroecological zones					Chi2	P value
		Mekrou-penjari (n = 80)	South-Borgou (n = 80)	Atacora Chain (n = 80)	Oueme Valley (n = 80)	Plateau (n = 80)		
Nominal variable (Frequency, %)								
Small ruminants farming								
Sheep breeds	Djallonke	0.0	91.2	98.7	100	100	491.74	<0.001
	Sahelian	97.5	6.3	1.3	0.0	0.0		
	Both	2.5	2.5	0.0	0.0	0.0		
Goat breeds	Djallonke	2.5	97.4	95.0	100.0	100.0	379.22	<0.001
	Sahelian	95.0	1.3	5.0	0.0	0.0		
	Both	2.5	1.3	0.0	0.0	0.0		
Farm type	Goat farming	11.3	7.5	66.3	96.3	85.0	245.59	0.001
	Sheep farming	12.5	32.5	2.5	0.0	1.3		
	Mixed sheep and goat farming	76.3	60.0	31.3	3.8	13.8		
Other animals kept	Poultry	67.5	58.8	83.8	61.3	60.0	665.54	<0.001
	Pig	0.0	3.8	68.8	10.0	7.5	925.61	<0.001
	Cattle	63.7	60.0	20.0	0.0	0.0	887.03	<0.001
Feeding strategy								
Feeding pattern of small ruminant	Natural pasture only	0.0	20.0	27.5	31.3	17.5	689.35	<0.001
	Natural pasture and supplements	100.0	80.0	72.5	68.8	82.5		
Supplementary feed in the dry season	By-products	0.0	27.5	3.8	45.0	80.0	271.41	<0.001
	Crop residues	28.7	5.0	30.0	7.5	0.0		
	Both	71.3	41.3	38.8	5.0	2.5		
	None	0.0	26.3	27.5	42.5	17.5		
Supplementary feed in the rainy season	By products	15.0	32.5	7.5	55.0	77.5	140.73	<0.001
	Crop residues	5.0	15.0	1.3	3.8	0.0		
	Both	3.8	5.0	8.8	5.0	0.0		
	None	76.3	47.5	82.5	36.3	22.5		
Healthcare pattern of small ruminant	Breeder	23.8	23.8	25.0	96.3	28.7	1072.56	<0.001
	Veterinary	6.3	46.3	28.7	2.5	22.5		
	Breeder and veterinary	68.8	30.0	18.8	0.0	47.5		
	None	1.3	0.0	27.5	1.3	1.3		
Numeric variables (Mean and Standard Error)								
Goat flock size (TLU)		0.7bc±0.6	1.5a±0.4	0.7b ± 0.1	0.6c±0.0	0.7bc±0.1		0.001
Sheep flock size (TLU)		1.0 ± 0.2	1.8 ± 0.2	1.1 ± 0.0	0.0 ± 0.0	0.8 ± 0.0		0.077
Mixed flock size (TLU)		1.6b ± 0.2	2.8a±0.2	2.1b ± 0.6	2.0 ab ± 0.4	1.1b ± 0.2		0.001
Global flock size (TLU)		1.4b ± 0.2	2.4a±0.2	1.2b ± 0.2	0.6d ± 0.0	0.7c±0.1		0.001
Cultivation surface area (Ha)		5.9^{a}±0.3 n = 80	7.0^{a}±0.6 n = 76	3.9^{b} ± 0.2 n = 78	3.4^{c}±0.4 n = 57	1.1^{d} ± 0.1 n = 60		0.001

TLU: Tropical Livestock Unit corresponding to an animal of 250 Kg, P: probability; 1 goat/sheep: 0.1 TLU; [a, b, c]: values with the same letter in a row significantly differed at 5 % (Kruskall Wallis test).

Unit (TLU - corresponding to an animal of 250 Kg) (1.5 TLU, 1.8 TLU, 2.8 TLU) found in South Borgou AEZ. In Northeastern Benin (Mekrou-penjari and South-Borgou AEZ), livestock keeping was a primary activity for more than 33 % of the farmers who were from the Muslim religion. This confirms the livestock breeding orientation of Muslims in semi-arid and arid areas in Benin, as noticed in other West African countries [11]. However, more traders were reported in Southern regions (Oueme Valley and Plateau AEZ). Previous studies [6,11] confirmed this finding, arguing that few goat numbers are kept as savings in traditional farms.

In Northeast Benin, mixed (sheep-goat) herds were kept. Indeed, Muslim farmers preferred sheep in addition to their goat herd, as mentioned by Yusuf et al. [59]. This is due to its higher price in the market and the possible use for Muslim feasts. Djallonke and Shaelian breeds were kept in the various AEZ, confirming previous findings in West Africa [10,60]. Sahelian sheep were preferred in Northeast areas, as these areas have characteristics similar to those of the Sahelian zone. Also, there was frequent mobility of transhumant herds from Niger and Burkina-Faso in these areas, from which this breed was introduced. Poultry was present in 67 % of farms in all AEZ, while pigs were encountered almost exclusively in the Atacora chain AEZ and cattle in the three Northern AEZ.

All small ruminants had access to natural pasture resources for at least one part of the year in all AEZ. Except in the Arid AEZ, about 75 % of farms in other AEZ are used to supplement the animals during the dry and/or rainy seasons with agro-industrial by-products and crop residues in single-use or combination. Almost all farmers in the Oueme Valley AEZ managed animal health care themselves. In the four other AEZ, 75 % of farmers used veterinary agents, exclusively or not, for health care.

Regarding herd size and cultivated crop area, the arid and semi-arid areas in the North presented the most crowded herds. In contrast, the lowest cultivation surface areas were found in Plateau AEZ (1.1 ha) and the highest (7.0 ha) in South Borgou AEZ. These characteristics are similar to findings by several authors [45,51].

3.4. Small ruminant farmers' perception of climate change and its causes

Table 4 showed small ruminant farmers' perceptions of climate change; all parameters differed significantly ($p<0.01$). At least 90 % of farmers in all AEZ acknowledged an ongoing change in the climate in their environment. About 50 % of those farmers experienced rain delays, except in the Atacora chain AEZ, where 33 % of farmers mentioned earlier rains. In the AEZ from arid and semi-arid zones (Mekrou-penjari, South-Borgou, and Atacora chain), about 40 % of farmers perceived a decreasing trend in rainfalls. Few farmers

Table 4

Perceptions and causes of climate change according to small ruminant farmers in five different agroecological zones of Benin.

Variables		Agroecological zones					Chi2	P value
		Mekrou-penjari	South-Borgou	ChainAtacora	Oueme Valley	Plateau		
Nominal variable (Frequency, %)								
n		80	80	80	80	80		
Perception of climate change	Yes	93.8	98.8	98.8	90.0	98.8	13.28	0.010
	No	6.2	1.2	1.2	10.0	1.2		
n		75	79	79	72	79		
Onset of rains	Delayed	52.5	78.8	41.3	72.5	67.5	52.47	<0.001
	Earlier	11.2	10.0	32.4	6.2	17.5		
	No change	36.3	11.2	26.3	21.3	15.0		
Rainfall	Increasing	51.2	63.7	60.0	83.7	88.6	57.62	<0.001
	Decreasing	42.5	35.0	38.7	6.3	11.4		
	No change	6.3	1.3	1.3	10.0	0.0		
Stormy rain	More frequent	0.0	0.0	7.5	0.0	2.5	30.19	<0.001
	Less frequent	93.7	98.7	91.2	90.0	96.2		
	No change	6.3	1.3	1.3	10.0	1.3		
Flood frequency	Increasing	93.8	98.8	98.8	81.3	93.8	33.10	<0.001
	Decreasing	0.0	0.0	0.0	8.7	5.0		
	No change	6.2	1.2	1.2	10.0	1.2		
Drought periods during rainy seasons	More frequent	28.7	36.3	25.0	16.3	65.0	57.24	<0.001
	Less frequent	65.0	62.5	73.8	73.8	33.8		
	No change	6.3	1.3	1.3	10.0	1.3		
Sunshine duration	Increasing	20.0	32.5	21.3	21.3	40.0	21.56	0.006
	Decreasing	0.0	0.0	0.0	0.0	2.5		
	No change	80.0	67.5	78.7	78.7	57.5		
Temperature	Increasing	0.0	0.0	0.0	10.0	61.3	185.69	<0.001
	Decreasing	0.0	0.0	0.0	0.0	0.0		
	No change	100.0	100.0	100	90.0	38.8		
Causes of climate change	Anthropogenic actions	20.0	55.0	38.8	8.8	3.8	213.85	0.001
	Social laws transgression and God's anger	47.6	18.8	25.1	50.1	56.3		
	Anthropogenic actions and God's anger	7.5	3.8	1.3	13.8	30.0		
	Unknown causes	25.1	22.6	35.1	27.5	10.1		

P: probability.

mentioned more frequent stormy rains in the last 30 years, mainly in the Atacora chain and Plateau AEZ.

Farmers had different ways of understanding the changes occurring in the climate of their areas, as shown in previous studies [61–63]. Most of the farmers accurately described the climate in their AEZ, as increased rainfalls and no change in temperature were mentioned by most of the farmers, which was in agreement with meteorological data. The temperature variation was also less perceived by the farmers. This is consistent with findings in other rural communities [64–66]; farmers could understand rainfall patterns.

The farmers accurately described the climate in Northern Benin AEZ as climatic data confirmed low rainfalls; in recent years, rains increased in the Atacora chain and Southern Borgou. As stated by farmers, lower rainfalls were found in Mekrou-penjari, but this did not mean a decreasing trend. Indeed, farmers may not have enough experience describing the trend in this climate parameter, but they could explain how they think these parameters are in their areas [67]. Farmers think there are no temperature changes in the arid and semi-arid zones, which is confirmed by meteorological data. Previous studies have demonstrated the capacity of farmers to understand and predict the weather in their area [62]. However, some farmers in Plateau AEZ were less good at understanding changes occurring in their areas. Indeed, they recognized an increase in temperature that did not match the meteorological data.

Our results emphasize other components of these climatic parameters, which revealed stormy rains, floods, and drought frequency. Except in the Plateau AEZ, at least 60 % of farmers mentioned less drought periods during the rainy seasons. Indeed, drought periods could be a significant source of animal stress affecting their physiology [3]. These less frequent drought periods in the rainy season are good because they could positively affect pasture development and increase biomass availability [13], thus improving animal productivity in most farms. Some Farmers in the sub-humid area, i.e., Oueme Valley and Plateau AEZ, perceived more flood occurrences that could reduce accessibility to grazing lands, as found by Koura et al. [13]. An increase in sunshine duration was acknowledged, more in the South Borgou and Plateau AEZ. Only farmers in Plateau (60 %) and Oueme Valley (10 %) thought the temperature had increased over the last 30 years.

According to the farmers in semi-arid zones, these changes were mainly due to anthropogenic actions, while the other zones mainly related climate change to God's anger due to human misconduct or no respect for social/natural rules. This is consistent with previous studies in West African countries [68] stating that farmers in Benin related climate changes to anthropogenic actions or God's wrath. The recognition by farmers of climate change as a consequence of their actions (deforestation and social rules transgression) is also well documented [68] and could be a factor for changes in their practices.

3.5. Small ruminant farmers' perception of the impacts of climate change on their production

The main impacts (Table 5) of climate change reported by herders were decreased natural grazing and water availability. Consequently, some negative effects on animal growth, mortality, health, and well-being were reported. This perception varied between AEZ. In Oueme Valley, all the farmers reported a lower water availability against only 40 % for the low pasture availability,

Table 5
Impacts perceived by the small ruminant farmers of climate change in five different agroecological zones of Benin.

Variables		Agroecological zones					Chi2	P
		Mekrou-penjari (n = 75)	South Borgou (n = 79)	Chain Atacora (n = 79)	Oueme Valley (n = 72)	Plateau (n = 79)		
Nominal variable (Frequency, %)								
Natural grazing availability	Positive effects	5.0	1.3	12.5	3.8	1.3	106.03	<0.001
	Negative effects	62.5	86.3	77.5	40.0	86.3		
	No effects	32.5	12.5	10.0	56.2	12.5		
Animal growth	Positive effects	2.5	0.0	13.8	0.0	0.0	69.38	<0.001
	Negative effects	27.5	45.0	35.0	18.8	58.8		
	No effects	70.0	55.0	51.2	81.2	41.2		
Animal mortality	Positive effects	0.0	0.0	1.3	0.0	1.3	35.91	<0.001
	Negative effects	8.8	15.0	22.5	21.3	43.8		
	No effects	91.3	85.0	76.2	78.8	55.0		
Animal health and well-being	Positive effects	1.3	0.0	16.3	0.0	0.0	74.76	<0.001
	Negative effects	56.3	31.3	18.8	25.0	41.3		
	No effects	42.4	68.7	64.9	75.0	58.7		
Water availability	Positive effects	0.0	0.0	0.0	0.0	1.3	80.09	<0.001
	Negative effects	85.0	66.3	53.8	100	93.7		
	No effects	15.0	33.7	46.3	0.0	5.0		

while only 54 % of farmers from the Atacora chain reported a negative impact on water availability.

According to the farmers interviewed, climate change negatively impacts grasslands and water availability, decreasing pasture production and forage quality, as mentioned also in the literature [69,70]. As grazing in the natural pasture is the primary feeding strategy in West African countries [9,11], animals were affected by its low availability and quality due to climatic stress. Indeed, lower forage quality means that animals may not fulfill the energy required to maintain their body weight [3]. In particular, the negative effect on daily weight gain and feed conversion is acknowledged [71–73].

Water and land resources are key inputs in livestock production systems [74,75]. In particular, more drought periods during the rainy season and rain delays in most AEZ, coupled with land degradation [76], could enhance the impact of climatic changes. In the worst case, this could lead to the disappearance of plant resources that are less resilient to water stress, as reported in Southern Benin [13]. Moreover, the nutritional imbalance of small ruminants increases disease frequency, affects animal immunity, and possibly leads to higher mortality.

According to the majority of farmers, the duration of sunshine has not changed, which is favorable to the proper functioning of the animal organism there is less heat stress [76,77].

Animals in the Northern Benin areas (Mekrou-penjari, South Borgou, and Atacora chain AEZ) experienced the hottest in the dry season and the coldest temperature in the rainy season. Heat stress alters sheep and goats' physiology, making them susceptible to disease and stress [78]. Reproductive performance, such as decreased fertility, conception rate, longevity, and meat quality, may be affected [79]. Heat stress could be considered the most detrimental factor for the economy of small ruminant production [80], affecting the livelihood of the poor farmers in West Africa.

3.6. *Small ruminant farmers' current coping strategies to climate change*

Adaptation refers to adjustments in environmental systems in response to observed or expected changes in climatic stimuli [81]. Table 6 summarizes adaptation strategies to climate change currently used or to be used in the future by farmers. The diversification of feed resources was the most popular current solution to cope with the perceived impacts of climate change. Its implementation varied from one AEZ to another, from 88 % to about 43 % and 36 % of farmers in the Plateau, the Oueme Valley, and the Atacora chain, respectively. The two more frequently reported current adaptation measures encountered in the three Northern AEZ were increasing free wandering (28.4 % for all three AEZ) and feeding intensification (average 25.4 % for all three AEZ). Most farmers did not cite herd size reduction (average 4.3 % across all AEZ), forage conservation (average 3.1 % across all AEZ, except in Mekrou-penjari AEZ (20 %)), veterinary care (highest value was 10 % in Oueme Valley AEZ), and frequent watering (highest value was 15 % in Atacora chain AEZ) as present-day solutions.

Diversification of feed resources is a good option and the most used strategy. Using a mix of fodders, agro-processing by-products, crop residues, and cereal grain, as also suggested by other authors [18,82], may allow the animals to have a diversity of nutrients, enhancing the chance to cover their nutritional requirements. Tree and shrub leaves provide some phytochemical components that

Table 6
Current and future adaptation measures cited by small ruminant farmers against climate change in the five agroecological zones.

Variables		Agroecological zones					Chi2	P
		Mekrou-penjari (n = 75)	South Borgou (n = 72)	Atacora chain (n = 79)	Oueme Valley (n = 72)	Plateau (n = 79)		
Nominal variable (Frequency, %)								
More free wandering	Currently	26.3	20.0	38.8	13.8	35.0	17.43	0.002
	In the future	11.3	3.8	5.0	8.8	0.0	11.35	0.023
More diversification of feed resources	Currently	63.7	57.5	36.3	42.5	87.5	52.89	<0.001
	In the future	12.5	22.5	20.0	17.5	6.3	10.10	0.039
Feeding intensification with supplements	Currently	27.5	35.0	13.8	5.0	2.5	45.83	<0.001
	In the future	12.5	7.5	8.8	5.0	12.5	3.46	0.485
Herd size reduction	Currently	1.3	5.0	8.8	2.5	3.8	6.51	0.164
	In the future	5.0	2.5	7.5	1.3	13.2	13.92	0.008
Forage conservation	Currently	20.0	2.5	3.8	2.5	3.8	30.20	<0.001
	In the future	12.5	0.0	0.0	0.0	5.0	28.42	0.062
More veterinary care	Currently	1.3	2.5	7.5	10.0	3.8	8.95	0.007
More frequent watering	Currently	3.8	6.3	15.0	6.3	1.2	14.15	<0.001
New feed resources exploration	In the future	13.8	5.0	12.5	2.5	33.8	41.40	<0.001
Forage cultivation	In the future	2.5	10.0	6.3	0.0	7.4	10.25	0.036

P: probability.

could improve the digestibility of poor grass grazed [82]. However, over-utilization of range fodder plants like *Afzelia africana, Pterocarpus erinaceus, and Khaya senegalensis* has decreased the plants population number [83,84]; thus, farmers should be advised to use the existing population of fodder trees sustainably. Increasing agro-processing by-products (corn bran, soybean bran, cotton cake, cassava peelings) utilization is a well-known strategy [82,85] that could sustain production by smallholders and participate in a circular economy. Crop residues (cereal straw, cowpea haulm, peanut haulm) are well-utilized in semi-arid and arid areas [9,85], and this strategy allows nutrient cycling in farms.

The free grazing of small ruminants is the least demanding measure regarding resource allocation (material, human, and financial) and allows animals to access forage resources independently. However, the downside of this measure is also significant as animals are more exposed to disease, predation, and theft, and conflicts with crop farmers frequently happen. In addition, the continuous degradation of natural pastures and soils due to cattle overgrazing, soil compaction, and erosion will no longer guarantee the provision of animals with sufficient and quality feed [76].

Moreover, some farmers tried intensifying their production through systematic supplementation with agro-processing by-products or concentrate. Many previous studies have shown farmers' resistance to this strategy [82] due to the high cost of supplements. Few farmers practice forage conservation, though this is a major strategy reported in semi-arid and arid areas to cope with climatic change [86]. It seemed transportation issues might have limited this strategy. Moreover, farmers should be aware of the nutritional characteristics of all these feed resources and trained to optimize their use in animal nutrition [87].

3.7. Small ruminant farmers' future coping strategies to climate change

In the future, if climate change aggravation occurs, some farmers will adopt or expand mitigation measures. The most cited strategies were either more diversification of feed resources (6 %–22.5 % of farmers, according to the AEZ) or feeding intensification with supplements (5 %–12.5 % of farmers, according to the AEZ). Other strategies were herd size reduction (2.5 %–13 % of farmers according to the AEZ) and exploration of new feed resources (2.5 %–34 % of farmers according to the AEZ). Farmers even mentioned forage cultivation as an adaptive strategy to feed scarcity due to climatic change.

Farmers were aware that the different commonly used feed resources were being reduced and that it was important to adopt other strategies, such as looking for new feed resources or forage cultivation in the future. Farmers in Oueme Valley, an area with higher humidity and rainfall than the other areas, likely will adopt both strategies. However, forage cropping was often constrained by limited financial means and land availability, arguing the need for financial support or credit [88] to help those farmers adapt further to climate change. Indeed, farmers with higher income sources were about to adopt forage cultivation [89]. In addition, farmers need to be trained in the production, conservation, and rational use of different fodder resources cultivated.

Farmers acknowledged the need to look for new feedstuffs in animal nutrition, consistent with findings in the literature [89]. New feed resource exploration, like least-known or underutilized feeds or forage, is essential to limit the pressure on conventional feeds. However, this issue should be supported by scientific data on the nutritional value of new feedstuff available in various areas. Furthermore, actions should increase farmers' access to climate information and adaptive options. Currently, most farmers lack a network for sharing information and various experiences for adapting to climate change. However, such networks are crucial for increasing the adoption of coping strategies [90].

Moreover, local and tolerant breeds were utilized by farmers in the different AEZ of Benin and have been acknowledged to have better adaptive capability in extreme environmental conditions (high temperature, feed scarcity, water scarcity) [16,91]. Indeed, indigenous sheep and goat breeds display higher thermos-tolerance to extreme temperatures [92,93]. Therefore, farmers could be trained in good feeding and watering practices to improve feed intake and animal utilization under heat stress [94].

Table 7
Binary logistic regression results on predicting "diversification of feed resources" as a current adaptive strategy.

Diversification of feed resources	β	S.E. of β	Wald	df	P value	Exp(β)
Constant	1.295	0.510	6.444	1	0.011	3.650
Education level			20.75	3	0.000	
Education level (primary)	−0.922	0.673	1.873	1	0.171	0.398
Education level (secondary)	−22.73	40192	0.000	1	1.000	0.000
Education level (other)	−1.837	0.419	19.27	1	0.000	0.159
Climatic zones			10.636	2	0.005	
Climati zones (arid)	−0.855	0.293	8.547	1	0.003	0.425
Climatic zones (semi-arid)	−0.247	0.306	0.652	1	0.420	0.781
Household size	0.120	0.028	17.812	1	0.000	1.128
Overall model evaluation (modèle x2)	57.51			6	0.000	
Goodness of fit test (Hosner and Lemeshow)	19.49			8	0.012	
−2 log likelihood	487.98					
-Cox and Snell R2	0.13					
Nagelkerke R2	0.18					

3.8. Determinants of farmers adoption of coping strategies

The backward logistic regression was used to predict factors influencing the use of a particular current strategy as an individual, such as diversification of feed resources and feeding intensification (Tables 7 and 8). Future strategies like new feed resource exploration or forage cropping (Tables 9 and 10) were also predicted. Adaptation measure "Diversification of feed resources" referred to using different forage resources and supplements randomly from one day to another, according to their availability in the farm and surrounding areas. ''Feeding intensification" consisted of the compulsory use of supplements (by-products or concentrate) in animal diets. "New feed resources exploring" reflected the search by livestock farmers for non-conventional or little-known feed resources for feeding small ruminants. In contrast, ''Forage cultivation'' reflected livestock farmers' desire to use forage cropping to feed their animals.

All four prediction full model Tables 7–10 were statistically significant, indicating that the predictors as a whole reliably distinguish farmers that adopted or not a current or future measure face the effects of climate change. The Nagelkerke R^2 values and Hosmer and Lemeshow's test's non-significance confirmed the regression models' validity.

Results showed that the farmer's education level, the climatic zone where the farm is located, and the household size were the key factors influencing the adoption of diversification of feed resources as a current strategy. The probability of adoption of feed diversification was positively influenced by the household size ($\beta = 0.120$, $Exp(\beta) = 1.128$, $p < 0.001$) and negatively influenced by the climatic zone other than the arid zone ($\beta = -0.855$, $Exp(\beta) = 425$, $p < 0.001$). It was higher when the farmer had no formal education ($\beta = -1.837$, $Exp(\beta) = 159$, $p < 0.001$).

On the other hand, being a woman farmer or practicing agriculture and other activities ($\beta = 1.392$, $Exp(\beta) = 4.025$, $p < 0.001$), and owning goat farms ($\beta = 0.976$, $Exp(\beta) = 2.655$, $p < 0.01$), had a positive influence in the adoption of feeding intensification as a strategy. These women had multiple sources of income (agriculture, trading, and livestock breeding) and could reinvest their money in livestock keeping by buying high-quality feeds. Some authors point out the importance of the farmer's income level in adopting technologies, particularly in the choice of a coping strategy for climate change [76,82,87]. However, our study showed that only goat farmers were more interested in this strategy. Indeed, goats farming is more common, and these animals have lower nutritional requirements [95], which could be covered with fewer supplements.

Regarding farmers' future strategy, the adoption of exploration of new feed resources was determined by the farmer's gender and the AEZ. The probability of adopting this strategy was 0.997 greater when the farmer was a woman ($\beta = -0.997$, $Exp(\beta) = 0.369$, $p < 0.05$) and when the farms were located in the Oueme Valley AEZ ($\beta = 1.502$, $Exp(\beta) = 4.489$, $p < 0.001$).

The agroecological location ($\beta = 2.632$, $Exp(\beta) = 13.908$, $p < 0.01$) and farmers' main activity ($\beta = 1.983$, $Exp(\beta) = 7.262$, $p < 0.01$) were factors that positively affected farmers' willingness to adopt forage cultivation. A farmer was more likely to adopt forage cultivation if their farm was located in Oueme Valley and they practiced agriculture and other activities as their main occupations.

4. Limitations

This study has a few limitations. A lot of qualitative data was used in the study, which could be subjective. This study relied on the farmers' memory of their perception of changes in climatic parameters over 30 years, which could introduce biases in the quality of data collected. In addition, meteorological data were collected from the agro-climatic database of the National American Security Agency (http://power.larc.nasa.gov). On-station data collected in the studied areas could be more reliable, but they are unavailable for all the areas.

5. Conclusion

This study aimed to understand small ruminant farmers' feeding strategies to cope with climatic change and the determinants of

Table 8
Binary logistic regression results on predicting "feeding intensification with supplements" as a current adaptive strategy.

Feeding intensification	β	S.E. of β	Wald	df	P value	Exp(β)
Constant	−1.988	0.313	40.38	1	0.000	0.137
Main activity of breeder			21.91	4	0.000	
Main activity of breeder (agriculture)	−1.210	0.762	2.522	1	0.112	0.298
Main activity of breeder (other)	0.693	0.591	1.371	1	0.242	1.999
Main activity of breeder (trade)	−0.468	0.528	0.786	1	0.375	0.626
Main activity of breeder (agriculture and other)	1.392	0.370	14.15	1	0.000	4.025
Gender of farmer (man)	−1.440	0.566	6.481	1	0.011	0.237
Type of farming			11.63	2	0.003	
Type of farming (goat)	0.976	0.346	7.972	1	0.005	2.655
Type of farming (goat-sheep)	−0.568	0.688	0.683	1	0.409	0.567
Overall model evaluation (modèle x2)	67.66			7	0.000	
Goodness of fit test (Hosner and Lemeshow)	8.24			7	0.31	
−2 log likelihood	293.86					
-Cox and Snell R2	0.16					
Nagelkerke R2	0.26					

Table 9
Binary logistic regression results on predicting "new feed resources exploration" as a future adaptive strategy.

New feed resources exploring	β	S.E. of β	Wald	df	P value	Exp(β)
Constant	−1.819	0.325	31.33	1	0.000	0.162
Gender of farmer (Man)	−0.997	0.444	5.047	1	0.025	0.369
Agroecological zones			34.40	4	0.000	
Agroecological zones (Mekrou-penjari)	−1.014	0.609	2.776	1	0.096	0.363
Agroecological zones (South-Borgou)	−0.019	0.471	0.002	1	0.967	0.981
Agroecological zones (Atacora chains)	−1.151	0.830	1.925	1	0.165	0.316
Agroecological zones (Oueme Valley)	1.502	0.427	12.37	1	0.000	4.489
Overall model evaluation (modèle x2)	45.06			5	0.000	
Goodness of fit test (Hosner and Lemeshow)	0.12			5	1.0	
−2 log likelihood	271.56					
-Cox and Snell R2	0.11					
Nagelkerke R2	0.20					

Table 10
Binary logistic regression results on predicting "forage cultivation" as a future adaptive strategy.

Forage cultivation	β	S.E. of β	Wald	df	P value	Exp(β)
Constant	−4.493	0.894	25.27	1	0.000	0.011
Main activity of breeder			12.02	4	0.017	
Main activity of breeder (agriculture)	−18.66	5503	0.000	1	0.997	0.000
Main activity of breeder (other)	−1.325	1.133	1.366	1	0.243	0.266
Main activity of breeder (trade)	−0.327	0.874	0.140	1	0.708	0.721
Main activity of breeder (agriculture and other)	1.983	0.686	8.347	1	0.004	7.262
Agroecological zones			7.447	4	0.114	
Agroecological zones (Mekrou-penjari)	1.378	0.829	2.762	1	0.097	3.967
Agroecological zones (South-Borgou)	1.858	0.987	3.541	1	0.060	6.412
Agroecological zones (Atacora chains)	−16.58	4233	0.000	1	0.997	0.000
Agroecological zones (Oueme Valley)	2.632	0.968	7.389	1	0.007	13.91
Overall model evaluation (modèle x2)	33.95			8	0.000	
Goodness of fit test (Hosner and Lemeshow)	1.31			7	0.98	
−2 log likelihood	130.70					
-Cox and Snell R2	0.08					
Nagelkerke R2	0.24					

adopting these strategies. Farmers perceived climate changes differently in their agroecological zones, which could be summarized as rain delays, increasing rainfall and floods, and drought pockets during the rainy season. These changes negatively affected grassland biomass production and water availability. Many farmers adapted their feeding systems through diversification of feed resources, free wandering, and feeding intensification. New feed resource exploration and forage cropping are the strategies expected to be used if climate change increases. Several factors, like the gender of farmers, their education level, their main activity, their farm location (climatic and agroecological zone), and the small ruminant farming type, affected the choice of a particular coping strategy. Policymakers could use this study to make decisions to improve small ruminant production and farmers' livelihoods in West African countries. Further studies could assess the limitations of adopting the different adaptive strategies and participatory identification of ways for their alleviation.

6. Implications of the study

This study allowed to identify particular strategies or approaches to improve adaptation to climate change according to the AEZ or the farmers' characteristics, i.e., their gender and main activities. This study highlighted the need to inform farmers about temperature-related variations, which seemed to be less well perceived, and their potential impact on production systems. Indeed, heat stress remains a major constraint on animal welfare and productivity in hot climates [96]. In the Plateau AEZ, where farmers have recognized an increase in temperature, they can be educated on the need to provide animals with adequate buildings (well-ventilated, trees planted around buildings) to optimize their well-being and production. Indeed, smaller animals' improved surface area/live weight ratio enables them to dissipate heat more efficiently [97].

Based on the regression results, the strategy of diversifying feed resources was implemented by farmers without any level of education and in households with a large number. This raises the issue of farmers' abusive and uncontrolled exploitation of feed resources and implies actions to educate and raise awareness among farmers to ensure the rational use of forage/fodder resources, as suggested by Ayantundé et al. [93]. Furthermore, feeding intensification has proved to be preferred by women goat farmers who are practicing farming and other activities such as agricultural processing. Goats represent a vital capital asset for these women from poor households [6,10], justifying farmers' attitude to incorporate high quantities of agro-food processing by-products in diets to foster their growth. Therefore, goat and sheep farmers (men especially) need to be made aware of and oriented towards supplementing practice, which aligns with the Beninese government's policy of sedentary herding.

The abundance of plant resources in the Oueme Valley AEZ, one of the wettest places in Benin [98], has justified the prospective adoption of a measure involving farmers' exploration of new feed resources. However, exploring new feed resources would fit in effectively with the small ruminant nutrition plan if the choice of these new resources has scientific support through availability, animal preference, digestibility, and animal growth evaluation [82]. Likewise, the forage cropping strategy put forward by livestock farmers in the Oueme Valley AEZ is motivated by the excellent distribution of production factors (fertile land, available water) in this region. In contrast, although good, this measure seems inappropriate for farmers from arid and semi-arid zones, where space is more available, but water is less during the dry seasons [76,99]. Thus, policymakers could develop programs for the large-scale production of forage resources in Oueme Valley AEZ to be exported to other AEZ.

CRediT authorship contribution statement

Euvrard Landry Romaric Gninkplékpo: Writing – original draft, Methodology, Investigation, Formal analysis. **Bossima Ivan Koura:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis. **Paolo Lesse:** Writing – review & editing, Investigation, Conceptualization. **Ismael Toko:** Writing – review & editing, Investigation, Conceptualization. **Dominique Demblon:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization. **Marcel R.B. Houinato:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization. **Jean-François Cabaraux:** Writing – review & editing, Validation, Supervision, Investigation, Funding acquisition, Conceptualization.

Ethics approval and consent to participate

Before data collection, the participants gave oral consent to participate in the study. Verbal consent was collected because many of the participants were illiterate. Then, written informed consent was obtained from the village chief to publish the survey data on behalf of all the farmers.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e39834.

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Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

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