frontiers | Frontiers in Environmental Economics

TYPE Original Research
PUBLISHED 04 April 2023
DOI 10.3389/frevc.2023.1134864

OPEN ACCESS

EDITED BY
Nelson Chanza,
University of Johannesburg, South Africa

REVIEWED BY
Md. Shakhawat Hossain,
Northwest A&F University, China
Albert Manyani,
Bindura University of Science Education, Zimbabwe

*CORRESPONDENCE
Janvier Egah
✉ egahjanvier@gmail.com;
✉ janvier.egah@fa-up.bj

†Deceased

SPECIALTY SECTION
This article was submitted to Economics of Climate Change, a section of the journal Frontiers in Environmental Economics

RECEIVED 31 December 2022
ACCEPTED 13 March 2023
PUBLISHED 04 April 2023

CITATION
Egah J, Yegbemey RN, Idrissou FA and Baco MN (2023) Eliciting indigenous knowledge to predict climate events for the food security of agro-pastoral households in North Benin. *Front. Environ. Econ.* 2:1134864. doi: 10.3389/frevc.2023.1134864

Eliciting indigenous knowledge to predict climate events for the food security of agro-pastoral households in North Benin

Janvier Egah[1]*, Rosaine N. Yegbemey[2†], Fadilath Abikè Idrissou[1] and Mohamed Nasser Baco[1]

[1]Laboratoire Société Environnement (LaSEn), Faculté d'Agronomie, Université de Parakou, Parakou, Benin, [2]Laboratoire d'Analyses et de Recherches sur les Dynamiques Economiques et Sociales, Faculté d'Agronomie, Université de Parakou, Parakou, Benin

Populations are subjected to climatic uncertainties, the predictions of which are major challenges for the scientific community. This study analyzes indigenous climate event prediction and adaptation based on indigenous knowledge in North Benin. A sample of 80 holders of indigenous knowledge of prediction of climate events was selected using snowball sampling in the district of Gogonou. Data were collected during semi-structured interviews with the indigenous knowledge holders. Data included the profile of the knowledge holders, climate events and their prediction signs, and the planned responses in the face of climate events. Data were analyzed using discourse analysis and descriptive statistics. The results showed that the holders of indigenous knowledge of prediction of climate events are agropastoralists and some of their wives. They are over 60 years old and rooted in traditional religion. Climate events predicted were floods, pockets of drought, early cessation of rains, and invasion of fields by caterpillars. These climate events are predicted from animal, vegetable, and nature behaviors. The responses developed in the face of climate events are mainly the relocation of fields to firm land, the use of drought-tolerant varieties, the relocation of planting periods, and the planning of the suspension of children's schooling for spreading and planting operations. These findings demonstrate the necessity for policymakers to consider the value of indigenous knowledge to reduce the effects of climate change.

KEYWORDS

indigenous knowledge, climate events, agropastoralism, West Africa, prediction

1. Introduction

Providing climate service to rural communities is a challenge for the scientific community in the face of climate change. Climate services facilitate the decision-making process to strengthen the resilience and adaptation of production systems to climate shocks (Leal Filho et al., 2022). This contributes to reducing weather-related crop losses and improving food security in rural communities (Varah and Varah, 2022). Droughts and the subsequent low availability of water are major challenges for crop production (Rabbany et al., 2021). Temperature rises could improve crop income in Bangladesh when adequate irrigation facilities are provided (Hossain et al., 2019). Unfortunately, these modern climate services are not very accessible to rural communities because the channels and languages of dissemination of climate information are not adequate to the socio-economic and cultural realities of rural populations (Yegbemey and Egah, 2021). Faced with this, rural populations have developed indigenous knowledge to prevent climatic events. This indigenous knowledge, which is the basis of

the adaptation and resilience mechanisms of rural populations, remains little studied by the scientific community. The present study aims to analyze indigenous knowledge for predicting climatic events and adaptation based on indigenous knowledge in Benin in West Africa.

Climate change is one of the major threats affecting the livelihoods and food security of a large share of the population in Sub-Saharan Africa (Chimi et al., 2022). Indeed, in most Sub-Saharan African countries, agriculture is the major source of livelihood of the population and a key driver of food security (Kijazi et al., 2013; Leal Filho et al., 2022). Agriculture is highly dependent on rainfall, making it very vulnerable to the adverse effects of climate change. These climatic changes are manifested by the scarcity of rainfall, the recurrence of pockets of drought, the early or late cessation of rainfall, the early or late onset of rains, violent winds, heat waves, and temperature increases (Dambeebo et al., 2022). In Benin, studies have shown an increasing temperature trend of $1.0 \pm 0.1°C$ and decreasing rainfall between 1950 and 2005 (Akponikpè et al., 2019). These values will be higher by 2050. These events have adverse effects on the means and modes of subsistence. According to the IPCC (2022), millions of people are exposed to food insecurity because of the climatic events which reduce water security, cause low food production, decrease the diet diversity, and increase the malnutrition in the population, specifically the indigenous people in Africa and other areas of world. Animal diseases also increase in frequency and emergence due to these climatic changes (IPCC, 2022). In Benin, a country in West Africa, adverse climate change effects cause a decrease in crop yields. By 2050, it is predicted that maize and cotton production will decrease by 30% and 20%, respectively (Akponikpè et al., 2019). This in turn exposes populations to food insecurity. In Benin, 9.6% of households are in food insecurity (Institut national de la statistique et de l'analyse économique (INSAE) and Programme Alimentaire Mondial (PAM), 2017). Beyond crop production, many people rely on rain-fed agro-pastoralism systems with limited adaptation capacities (Daoudi et al., 2013). Increasing climate variability due to climate change puts agro-pastoralists at risk of losing their livestock. According to the Intergovernmental panel on climate change (IPCC) (2022), climate change negatively affects the rate of animal growth and the productivity of the pastoral system. Indeed, climate change is subjecting populations, especially rural populations, to climatic hazards. While much of the attention seems to be on crop production, climate change and variability are key challenges for policymakers, scientists, and agro-pastoralists. The adverse effects of climate change will be more severe in developing countries (Hossain et al., 2018).

The prediction of climatic events is one method to strengthen the adaptive capacities and resilience of populations in general and agropastoralists in particular (IPCC, 2022). Weather and climate forecasts broadcast through television channels, the Internet, etc. do not reach rural populations who do not have access to broadcasting channels and do not understand the languages in which the information is broadcast (Yegbemey and Egah, 2021). The rural population develops indigenous knowledge to predict climate events and reduce their vulnerability through the adjustment of their adaptation strategies (Kijazi et al., 2013; Leal Filho et al., 2022; Varah and Varah, 2022).

Indigenous knowledge in this study means knowledge accumulated over many years through experiences, including daily practices, learning, and lessons during the interaction of human societies with their environments for forecasting the climatic events (Dambeebo et al., 2022). In the climatic events forecasted, four pillars of indigenous knowledge could be taken account (Leal Filho et al., 2022). These pillars are the type, application context, adaptation value, and effects in responses to climate change in Africa (Leal Filho et al., 2022). Some studies have been carried out on indigenous knowledge for predicting climate events. These studies have revealed that people rely on the behavior of animals, plants, and nature to predict climate events (Chimi et al., 2022; Dambeebo et al., 2022; Varah and Varah, 2022). These studies show that adaptation and resilience strategies are based on the indigenous knowledge that plays an important role in local communities (Kijazi et al., 2013; Leal Filho et al., 2022). But few studies have addressed the indigenous knowledge of agropastoralist communities to forecast climatic events and their ability to cope with the adverse effects of climate events in West Africa. The understandings of climatic events' arrival allow to build the resilience and are a key determinant of adaptation capacity (Varah and Varah, 2022).

The present study aims to analyze the indigenous knowledge of agropastoralists to predict climatic events and discuss how this knowledge influences their adaptation strategies in North Benin. To achieve these goals, a mixed method combining qualitative and quantitative methods is used to collect and analyze the data.

2. Materials and methods

2.1. Choice and justification of the study area

The study was conducted in the commune of Gogounou in North Benin. The choice of the study area was based on the criterion of the presence of agropastoralism in this agro-ecological zone. The commune of Gogounou belongs to the cotton zone of northern Benin, which has been identified as one of the most vulnerable agro-ecological zones to climate variations in Benin (Ministère de l'Environnement et de la Protection de la Nature, 2008). It is located between 10°33′ and 10°57′ North latitude and 2°15′ and 3°15′ East longitude (Figure 1).

The physical and climatic vulnerability of this zone is very particular due to its geographical location in the country. Indeed, it is a zone with a Sudanian type of climate with rainfall between 800 and 1300 mm and an average annual rainfall of 1,058.61 mm.

The relief is essentially made up of plains and plateaus topped in places by hills whose maximum height is around 300 m. The climate is Sudano-Guinean, with a rainy season from May to October and a dry season from November to April, with a harmattan period from November to February. The soils are those of the granite-gneissic basement, mostly ferruginous and generally suitable for agriculture. In the alluvial plains, alluvial soils dominate, and the clay-sand soils are quite rich due to the contribution of organic matter by the annual high water of the rivers. The cultivable area is estimated at 1,705 km², i.e., about 35% of the total area (4,910 km²).

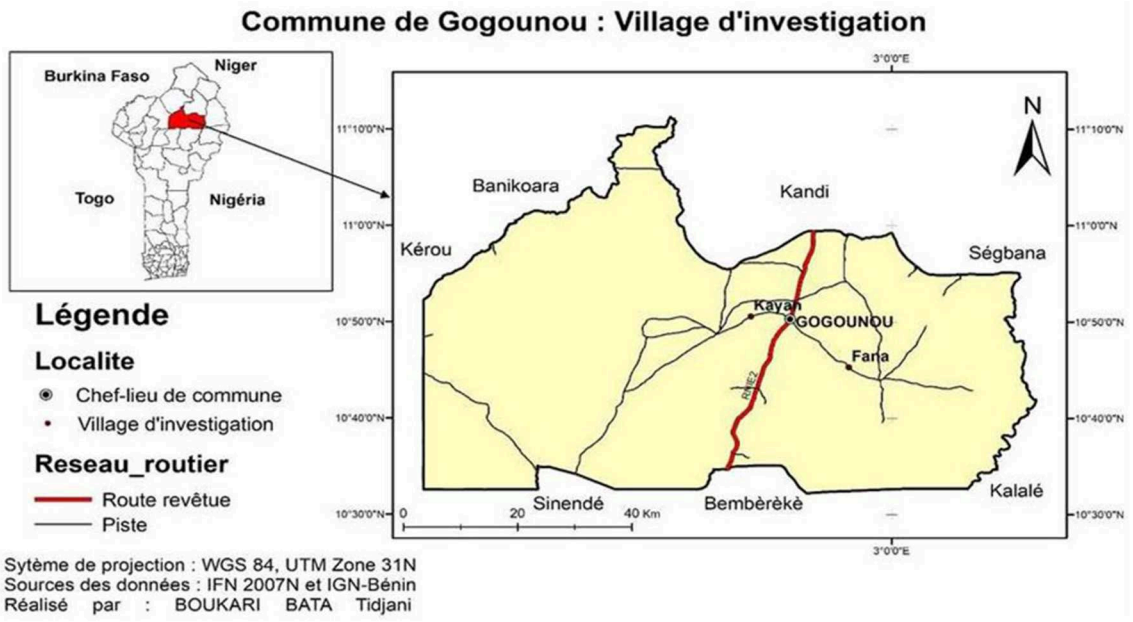

FIGURE 1
Study area.

Agriculture is marked by food crops including cereals (corn, sorghum, millet, rice, soybeans etc.), tubers (yams, cassava, and sweet potatoes), and industrial crops (cotton and groundnuts) which constitute the main sources of income for agricultural workers. The commune ranks fourth nationally after Kalalé, Banikoara, and Kandi. At the communal level, livestock production is the second most common activity after agriculture. In 2010, there were 70,000 head of cattle; however, in 2016, this number dropped to 55,000. This drastic decrease in five years was seen in the communes of Borgou, Atacora, Donga, and Zou-Collines, which receive more rainfall, thus having enough pasture and where rural activities are less intense. Livestock is the primary economic source for Fulbe households, which account for 43.50% of the population, and secondary for other households. The importance of this livestock has favored the creation of two important regional and international livestock markets, namely the self-managed livestock market of Gogounou Centre and the traditional livestock market of Petit-Paris. In addition to these two markets, there are the small ruminant markets of Borodarou and Diadia. The livestock market in Gogounou Centre is built of permanent materials and offers fairly comfortable housing and working conditions. The existence of this market promotes agropastoralism. There are also warrantage stores in the commune that facilitate the trade of corn. We also note the well-structured organization of livestock breeders from the grassroots to the apex: the Groupements Professionnels Eleveuses de Ruminants (GPER), the Groupements Professionnel de Femmes Éleveuses de Ruminants (GPFER), the Union d'Arrondissement des Groupements Professionnels d'Eleveurs de Ruminants (UAGPER), the Union Communale des Organisations Professionnelles d'Eleveurs de Ruminants (UCOPER), the Union Départementale des Organisations Professionnelles d'Eleveurs de Ruminants (UDOPER), and the Association Nationale des Organisations Professionnelles d'Eleveurs de Ruminants (ANOPER).

Two villages were selected on a rational basis. These are villages in which agropastoralism is developed and the populations have the capacity to predict climatic events according to the people we met. The villages were chosen using a grid for the selection of study villages in the commune of Gogounou, which was filled out in advance thanks to input from stakeholders (Communal Unit, Producers' Association, Town Hall, ANOPER, etc.). Also, these are accessible villages. These villages are Fana and Kayan.

2.2. Choice of investigation units and sampling technique

The investigation unit is represented by the agropastoralist households. The agropastoralists were selected using the snowball sampling technique. This technique made it possible to start with one agropastoralist who predicted climatic events to identify the others. Village leaders facilitated the identification of the first agropastoralist in their village. The sample size was obtained when the information collected was saturated, i.e., did not vary during the data collection. A total of 80 agropastoralists (so 40 households per village) were surveyed.

2.3. Data collection and analysis

Data collection was done in two stages: individual interviews and focus group interviews.

- Concerning the individual interview addressed to agropastoralists predictors, data collected were predicted climate events, socioeconomic characteristics (age, sex, number of years of experience in agropastoralism, number of agricultural workers, household size, education level, sociocultural group, marital status, main activity, secondary activity, and status in the village) of predictors of these climate events, signs of prediction and manifestations of these signs, and adaptation and predisposition strategies developed to reduce the risk of surprise from these climate events. These data were collected during semi-structured individual interviews using an interview guide and a questionnaire. The questionnaire focused on socioeconomic characteristics while the interview guide collected data on climate events, predictors, and coping and predisposition strategies. Both tools (questionnaire and interview guide) were administrated to the agropastoralist predictors of climate events.
- The focus group interviews took place after the individual interviews in each village. A focus group discussion allowed to validate the information collected individually on climatic events and prediction signs. The available agropastoralists individually surveyed had participated in the focus groups. In total, two focus groups of 10 to 12 participants were organized according to the availability of agropastoralists in the public place of each village.

The triangulation technique was used to ensure the validity of the data from the individual and group interviews and observations. Information on climate events, predictive signs, and developed adaptation strategies were analyzed using stakeholder discourse analysis. Descriptive statistics was used to calculate the frequencies of respondents according to the religion, the marital status, per climate events, indigenous knowledge signs, and adaptation strategies. The means and standard deviation were calculated for age, household size, number of years of experience in agropastoralism, and number of agricultural workers. The socioeconomic characteristics allowed to highlight the profile of predictors of climate events.

3. Results

3.1. Profile of holders of indigenous knowledge of prediction of climate events

Most of the holders (96%) were male and had no education level at Gogonou (Table 1). They belonged to the sociocultural group Peulh and were married (Table 1). The main activity of most of them (62%) was crop production while the secondary activity of 58% of respondents was breeding (Table 1). The majority of the holders (89%) of indigenous knowledge were aboriginal. All of the holders were Muslim. The mean age of the holders was 53 years (Table 1). The holders had about 29 years of experience in agropastoralism. Each holder's household had an average of seven farm workers (Table 1). The average household size was nine people.

3.2. Indigenous knowledge of prediction of climatic events by agropastoralists

According to the respondents' statements at Gogonou, the predicted climatic events were the start of the rainy season, the pockets of drought, the stopping of rains, the start of harmattan, flooding, and wind violence (Table 2). The early start of rains and the occurrence of pockets of drought were predicted by more agropastoralists (96% and 73% respectively) than other climatic events. On the other hand, the cessation of rains (44%), flooding (40%), and violent winds (20%) were predicted by fewer agropastoralists than other climatic events. In conclusion, the start of rains and the occurrence of pockets of drought were more predicted than other climatic events at Gogonou in North Benin.

The signs of prediction of climatic events vary according to the climatic events at Gogonou.

Concerning the events related to the occurrence or cessation of rainfall, the agropastoralists predicted these events by the clouds to the East with heat, the circulation of the wind from the West to the East, the song of birds moving from south to north, the call of certain birds and insects, the laying of guinea fowl, the flowering of certain trees, the appearance of new leaves on certain trees, the ripening of the fruits of some trees, and the appearance of lightning "*badjalè*" (in local language) accompanied by the rumble of thunder.

- **Clouds to the east accompanied by heat**: Cloud formation was an indicator of the arrival of rain in the rainy season according to the respondents. Indeed, the agropastoralists noted that the darkening of the sky announces the presence of clouds. This cloud would only be a sign of the arrival of the rains if it was formed in the east, according to the respondents. Also, it must be accompanied by heat before producing rain. One respondent said: "*when the cloud is close to the ground and is in the east, I am certain that the rain will come. But when the cloud is far from the ground and the cool wind is blowing, I can still be confident that there will be rain*."
- **Wind flow from west to east**: Wind leaving the west to the east in the rainy season was a predictor of rain onset according to the respondents.
- **Bird song moving from south to north**: The movement of some birds from south to north was a sign of predicting the start of rains. These were birds such as swallows. These birds, as they move about, give songs that announce the start of the rainy season. Thus, one of those respondents said that "*when we hear the song of these birds, we are certain that it will rain in a few days and we begin to get ready for work in the fields and other activities*."
- **Call of certain birds**: Some birds or insects announce the rains through their song "*koukou*". This was the case of brown hawks and the insect called ≪*tchédoulè*≫ in the local language.
- **Laying of guinea fowl**: The laying of guinea fowl was a sign of the start of the rains for the respondents. One of the respondents said: "*When we see that the guinea fowl starts laying eggs, it means that the rains will start soon*."

10.3389/frevc.2023.1134864

TABLE 1 Socioeconomic profile of holders of indigenous knowledge of climatic events' prediction.

Socioeconomic characteristics	Modalities	Frequency (%)
Sex	Female	4.4
	Male	95.6
Education level	No education	95.6
	Primary	2.2
	Secondary	2.2
Sociocultural group	Peulh	95.6
	Bariba	4.4
Marital status	Single	2.2
	Married	95.6
	Widowed	2.2
Main activity	Breeding	35.6
	Crop production	62.2
Secondary activity	Breeding	57.8
	Crop production	35.6
Status in the village	Aboriginal	88.9
	Allochtone	11.1

Socioeconomic characteristics	Minimum	Mean	Standard deviation	Maximum
Age	30.00	52.87	16.89	88.00
Number of years of experience in agropastoralism	8.00	29.07	13.26	60.00
Number of agricultural workers	0.00	5.07	5.19	19.00
Household size	1.00	8.62	5.48	24.00

Source: Survey August–September 2021.

- **The flowering of certain trees**: The appearance of flowers on certain trees announced the start of the rain. These include the shea tree, néré, Kapokier, and mango. Thus, some respondents affirmed that "*when we go to the pasture with the beefs and we see the flowering of certain trees, we are certain that the rainy season is coming.*"
- **The appearance of new leaves on certain trees**: New leaves appearing on certain trees is a sign that announces the rainy season. These are trees such as *goungounmi, bodi, banoui, ganki, wagnanyin, wangnin*, etc.
- **The maturity of the fruits of certain trees**: The maturity of the fruits of certain trees such as *tchégnéley*, mango, and néré was a sign that announced the rainy season.
- **Appearance of lightning "*badjalè*" accompanied by the rumble of thunder**: The appearance of lightning in the sky followed by the rumble of thunder was a sign that announced the rainy season.

In conclusion, rainfall prediction signs could be categorized into three types: natural, animal, and plant. The animal signs occupy a predominant place in the indicators of prediction of climatic events. Specifically, the movement of birds and the flowering of certain trees were signs that predict rainfall. Natural signs were used by fewer respondents to predict rainfall (Table 3).

TABLE 2 Climatic events predicted by the agropastoralists.

Climatic events predicted	Frequency (%)
Start of the rains	95.6
End of the rainy season and start of dry season	68.9
Occurrence of pockets of drought	73.3
Stopping of rains	44.4
Start of harmattan	68.9
Flooding	40.0
Wind violence	20.0

Source: Survey August–September 2021.

Concerning the predictive signs of the start of the dry season, they were the appearance of six stars, the loss of the leaves of some trees, the appearance of new leaves on some trees [shea (*Vitellaria paradoxa*) and nere (*Parkia Biglobosa*)], the flowering of some trees (*Detarium senegalense*, called ≪*konkéyil*≫ in the local

10.3389/frevc.2023.1134864

TABLE 3 Signs of prediction of climatic events.

Climate events	Plant signs	Animal signs	Natural signs
Start of the rainy season	Appearance of the leaves of "boboli" (*Sterculia stegera*)	Song cou cou cou of the bird "*koukouwél* in Peuhl"/*Bosoussookou* (in Bariba) between 4 and 5 am at one month before the first rains. Its English name is gray cuckoo (*Cuculus canorus*)	Appearance of 3 stars in the west called "*natchondé*" in Fulani
	Appearance of the leaves of "*kourou*i" (*Bombax costatum*)	Collective movement from North to South of the bird "*Gnalègnalè*" (*Bubulcus ibis*)	–
	Appearance of young leaves of kayin (*kaya senegalensis*)	Collective movement from South to North of the dark blue bird "*Tchankoli*"	–
	Appearance of young leaves of konkey	Appearance of the African ostrich called ≪ *walial* ≫ in peuhl	–
	Appearance of young leaves of *wagnin in fulani*	The laying of eggs by guinea fowl heralds the rainy season	–
	Maturity of the wild yam called *Dikarè* in Peuhl and *Diga* in Bariba	–	–
	Appearance of the wheel flowers of Flamboyant (*Delonix regia*)	–	–
Pockets of drought	–	Appearance of caterpillars called "*guili tèréna*" in fulani	–
Recovery of the rains after a pocket of drought	–	Appearance of the African ostrich called "*walial*" in Fulani Appearance of the white eggs of ants (*métélis* in peuhl)	–
End of the rainy season and announcement of the dry season	Drying and loss of leaves of "boboli" (*Sterculia stegera*)	–	Appearance of a rainbow means the end of the rainy season
	Appearance of the fruits of the Shea tree (*Vitellaria paradoxa*)	–	–
	Cashew flowering	–	–
	Flowering of the Angel Hair (*Cajanus cajan*)	–	–
Harmattan	Appearance of the flowers and fruits of "*kourou*i" (*Bombax costatum*)	–	Wind direction: from east to west announces the arrival of harmattan
	Appearance of the flowers of néré (*Parkia biglobosa*), mango trees (*Mangifera indica*)	–	–
Dry season	Appearance of the flowers and fruits of "*kourou*i" (*Bombax costatum*)	Collective movement from South to North of the "*Gnalègnalè*" bird (*Bubulcus ibis*) Collective movement from North to South of the bird "*Tchankoli*" of a dark blue color	–
	Fall of the seeds of Nimes	–	–
	Sorghum flowering	–	–
	Maturity and fall of the fruits of the tree *Akakagni* (in Nago)	–	–
Rain coming in the next few hours	–	Cricket "*tchédourè*" cries (after 24 h at most) Song of Aloutoutou in Nago (after 72 h at most)	Blazing sun followed by strong heat and no wind during the rainy season is a signal that rain should fall within 24 h Cloud formation is a preparatory sign for rain within hours
Announcement of heavy rains	–	Presence and the untimely song of the Toobakou bird in June	–

Source: Survey August–September 2021.

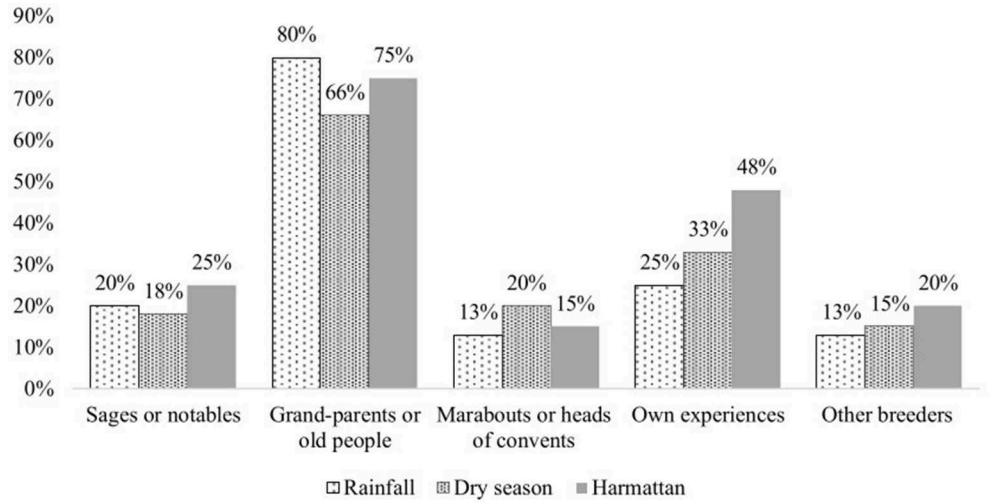

FIGURE 2
Sources of knowledge of the warning signs of climate events.

language), the maturity of some fruits of nere (*Parkia Biglobosa*), the cry ≪ *tchiiiiiii tchiiiiii* ≫ of the insect (*Cicada cymbalization* called ≪ *tchédourè* ≫in the local language) and the song of cricket ≪ *Gryllidae*≫, the disappearance of clouds and the cracking of some trees according to the respondents at Gogonou. Stars aligned three (3) to three (3) perpendicularly moving toward the sunset (westward) is a predictor of the arrival of the dry season. However, this astral sign is often spotted only by very knowledgeable or initiated people who are able to interpret it. The start of leaf fall on certain trees is an indicator that helped the agropastoralists surveyed to predict the start of the dry season. When large trees such as Boboli begin to lose their leaves, this indicated to agropastoralists that the dry season is approaching. According to respondents, *Detarium senegalense* only flowers at the beginning of the dry season. In sum, the prediction of the start of the dry season can be made from natural, animal, and plant signs. Plant signs predominated in the prediction of the onset of the rains at Gogonou (Table 3).

In relation to the harmattan, the signs of prediction are the dew, the flowering of certain trees, the call and movement of certain birds, the appearance of insects (*piti piti dji pèrèna dji*) and of ants (*pirodji* and *gnalèdjè*), cotton harvest, the nest of certain birds, change in wind direction from east to west, and humidity. Indeed, the fog leaves dew on the plant leaves in the early morning. The water droplets generate the dew deposit on the leaves. When agropastoralists noticed these droplet deposits, they assume that the harmattan will come soon. The call and movement of certain birds such as *gnalègnalè* (in local language) leaving the south for the north, *tchancoli* leaving the north to the south, and *toutouwa* and *touroubiidji* singing were signs announcing the start of the harmattan. The appearance of insects (*piti piti dji pèrèna dji*) and of ants (Ephemeral ant) at night after a rainfall is a sign announcing the harmattan. The period when cotton is harvested is a sign that announces the arrival of the harmattan. The nest of certain birds such as *Mata-cofiri* (red bird) and wild pigeon observed almost everywhere on the trees is a sign of the start of the harmattan. The wind changing direction from east to west and becoming drier is a sign of predicting the arrival of harmattan. In conclusion, the harmattan was more predicted by animal signs than other signs (Table 3).

3.3. Sources of knowledge of the warning signs of climate events

Agropastoralists acquired knowledge about predicting climatic events through talking, stories, and tales with their grandparents, sages and notables, marabouts, fellow herders, and their own experiences. Most of the interviewees acquired their knowledge from their grandparents regardless of the climatic event at Gogonou (Figure 2).

3.4. Adaptation strategies used by agropastoralists

Adaptation strategies were organized according to climate events.

3.4.1. Adaptation strategies based on rainfall prediction

Coping strategies and predispositions depend on the prediction sign.

For short-term rainfall prediction signs such as the appearance of clouds in the east and wind flow from west to east, agropastoralists have developed two types of strategies: strategies to preserve animals from rain and strategies to prepare for spot cropping operations. The strategies for preserving the animals were for keeping the animals under shelter, collecting hay or dried fodder, and cleaning rainwater collection troughs. Strategies for

preparing cultivation operations included mobilizing seeds during the sowing period, mobilizing inputs during the spreading period, and mobilizing labor for sowing or spreading fertilizer. In the case of the onset of rains or the resumption of rains after a pocket of drought, the appearance of signs (bird song moving from south to north, call of certain birds, laying of guinea fowl, etc.) led agropastoralists to bring their herds close to their residence and to define strategies for the mobilization of production factors (land, labor, and capital). They defined the plots to be cultivated during the season and the crops to be grown on each plot. According to the crops, they sorted and reserved seeds from past harvests. They prepared the field work by clearing the new wasteland and plowing the old wasteland. For some agropastoralists who do not own land, they began negotiating with farmers for the land or reminding their former landowners that they will cultivate on the land. From a labor perspective, some agropastoralists negotiated with farm workers for the clearing and plowing of their crop fields. They would check that the tools of the trade, such as plows and oxen, were in good shape for the agricultural season. This would allow them to acquire new tools or repair existing and failing ones to keep them up to date. In terms of capital, the strategies were: (i) to negotiate loans from microfinance institutions, traders, or colleagues and (ii) to sell agricultural products. These strategies allowed them to have financial resources when they resumed agricultural activities to meet their expenses.

They contacted the agricultural advisors to find out about the availability of inputs, costs, and possible supply locations. In order to do this, they defined the quantity of inputs they would need, based on the crops and areas to be planted, and communicated this to the agricultural advisors. When it came to the resumption of rains after a pocket of drought, they mobilized chemical fertilizers and weeded the fields to prepare them for spreading when the rains arrived.

3.4.2. Adaptation strategies based on the prediction of the end of the rains

The appearance of signs of the end of the rains led agropastoralists to make arrangements for the next season, managing the crops and their herds. Agropastoralists began to clear fields and make mounds for yams. The mounds are designed while the soils are wet. The appearance of signs of the end of the rains caused backward agropastoralists to hurry to finish ridging before the rains stopped. This was especially true for agropastoralists growing yam. Groundnut and voandzou producers mobilized labor to harvest these crops before the rains stopped.

Agropastoralists who had cassava, soybean, etc. on their fields began to dig it up to prepare the soil for the next season because in the dry season, the soil becomes hard, the soybean pods burst, and the seeds sink into the soil so that harvesting becomes difficult and could cause vegetation fires. Storage facilities are cleaned and prepared for the storage of agricultural products.

Agropastoralists collected crop residues or negotiated with farmers to park their herds on harvested fields. Agropastoralists store water in tanks to water their animals.

Livestock producers enter into negotiations with farmers for the parking of animals on the fields after the harvest. They define the parking arrangements. Farmers required the participation of herders in the harvest of agricultural products before accepting the parking of animals on their fields. Herders who agree with the condition mobilize to support farmers during harvesting.

Farmers preferred to park their own animals on their crop fields. They make hay to feed their animals during the dry season. The agro-pastoralists entrust their animals to Fulani herders for transhumance. The Fulani feed and milk the herds during the transhumance and. The milk constitutes the profit of the herders. As the end of the dry season approaches, they return the animals to the agropastoralists at Gogonou.

4. Discussion

Agropastoralists rely on signs mobilized through their experiences to predict certain climatic events. These climatic events are mostly the start of the rainy season, the appearance of a pocket of drought, the end of the rainy season, or the start of the dry season and the harmattan. These climatic events are similar to those found by Zvobgo et al. (2022) in Zimbabwe and by Son et al. (2019) in Vietnam. According to Zvobgo et al. (2022), the people arrive to forecast the rainy day, growing season quality, rainy cessation, the droughts, weather events, the rain onset, etc. In Vietnam, the indigenous people forecast drought, rain, floods, and cold spells (Son et al., 2019).

Indigenous knowledge is accumulated from past or succeeding climate events to build indigenous knowledge of prediction of climate events. The indigenous knowledge relates to the behaviors of animals, plants, and nature or the environment to anticipate the occurrence of each climate event. These results have been found by some authors who have proven the appearance of certain signs before the arrival of climatic events. Chimi et al. (2022) showed that change of the color of the clouds to pinkish-red and the fear of animals, specifically birds, precede the arrival of strong winds. This statement corroborates with the results of this study which have proven the song of the birds is an indicator of rain arrival. Varah and Varah (2022) have shown that the formation of plant leaves, flowering, and fruiting like in this study indicate the arrival of a new season. The end of the rain season or the start of the dry season were predicted by flowering, the new leaves of plants, etc. in this study. The appearance of migration birds, of the termites or the guinea fowl, and the song of crickets such as the cicadas indicate the climate events arrival in Ghana (Sullo et al., 2020). Son et al. (2019) indicated that indigenous knowledge guides the local decision making for several communities. McKemey et al. (2020) indicated that biotic and abiotic signs guide the activities calendar and are used to forecast seasonal change. Indeed, people combine experiences and informal experiments to forecast climatic events (Leal Filho et al., 2022). These authors showed that this indigenous knowledge is transmitted using the oral and practice channel from one generation to the next. Varah and Varah (2022) indicated that the transmission channels are through the songs, dances, adages, myths, folklore, stories, rituals, and agricultural activities. This shows the importance of culture and history in the construction and conservation of indigenous knowledge. In

addition, agropastoralists use the interactions between humans, animals, and the environment to build their indigenous knowledge. This observation was also made by Varah and Varah (2022) who asserted that indigenous knowledge results from interactions between skills, ideas, and philosophies developed by people during the long interaction process with their natural environment. That is why Dambeebo et al. (2022) declared that indigenous knowledge is manifested through people's practices which are guided by the cultures, norms, beliefs, and values which characterize a community. Leal Filho et al. (2022) showed four dimensions of indigenous knowledge, namely the application context, the type, the adaptation value, and the response effects to climate change in Africa. Adaptation capacity based on the indigenous knowledge in this study allows to prepare the field activities for reducing adverse effects of climatic events. The agropastoralists mobilize human capital by preparing agricultural labor which will be important to reduce the adverse effects of climatic events, physical capital such as seeds, work tool, agricultural inputs, etc., and social capital to get more information about the supply source of inputs and of seeds, the credit source, etc. These results corroborates those of Varah and Varah (2022) and Zvobgo et al. (2022). Varah and Varah (2022) showed that farmers cultivate crop diversity and tolerant varieties to drought whereas Zvobgo et al. (2022) revealed the decisions related to crop varieties' selection, the agricultural calendar, land preparation, seed preparation, cultivation area to be allocated to each crop, dry planting, drought tolerant crops to be grown, and zero tillage. Adaptation strategies used by the agropastoralists in this study are similar to adaptation strategies used in Pakistan (Usman et al., 2023). According to these authors, water mobilization strategies through harvesting, irrigation, land leveling to store water, etc. are the adaptation strategies used by farmers in Pakistan.

This way of preparing before the occurrence of climatic events reduces the shock of climatic events and strengthens the resilience and adaptive capacity of agropastoralists (Leal Filho et al., 2022). For these authors, traditional knowledge is used to enhance the capacity of farmers and their livelihood options. But the effectiveness of adaptation capacities depends on knowledge management which connects indigenous knowledge with the skill and available resources to cope with the adverse effects of climatic events (Leal Filho et al., 2022). The adaptation process is a long-term process that learns from previous experiences and adjusts from these experiences to reduce the shock of climatic events (Son et al., 2019). Decision-making that relies on indigenous knowledge is fundamental to improving the livelihoods and living conditions of agropastoralists (Leal Filho et al., 2022). In Vietnam, the farmers who predict the climatic events use animal breeds and native crop varieties facing the climatic events (Son et al., 2019). In Pakistan, the adaptation strategies reduce the negative effects of climate change, showing the importance to raise awareness about the different adaptation strategies in the face of climate change (Usman et al., 2023).

Indigenous knowledge allows the agropastoralists to predict climatic event arrival and to cope with their adverse effects. But this effectiveness of indigenous knowledge depends on the ability to make better decisions by developing more appropriate adaptation strategies (Yaro and Hesselberg, 2016; Chimi et al., 2022).

5. Conclusion

Vulnerability and inaccessibility to weather information have forced agropastoralists to develop indigenous knowledge to predict climate events. These climatic events include the start and end of rainy seasons, dry seasons, the appearance of pockets of drought, the harmattan, etc. These climatic events are predicted from animal behavior, plant phenology, and nature. The appearance of these predictive signs alerts agropastoralists to the probable arrival of a climatic event, leading them to develop adaptation and resilience strategies to reduce climatic shocks. The adaptation and resilience strategies developed from indigenous knowledge are related to the preparation of agriculture activities, the search for seeds and other inputs, the search for labor, etc. These adaptation and resilience strategies are based on the mobilization of human, social, financial, and physical capital to improve their living conditions and livelihoods. However, one limitation of the study is the self-reported data. Therefore, direct observations are needed to adjust adaptive capacities and influence policies for the development of agropastoralism in the face of climate change. The indigenous knowledge of climate event prediction could be incorporated into climate change adaptation policy documents by policymakers to ensure household food security.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JE designed the proposal, collected and analyzed the data, and wrote the paper. RY contributed to design the proposal. FI contributed to data collection. MB read the paper. All authors contributed to the article and approved the submitted version.

Funding

The research of this article was supported by DAAD within the framework of the climapAfrica programme with funds from the Federal Ministry of Education and Research.

In memoriam

After submitting this paper, colleague Rosaine N. Yegbemey, co-author of this paper, died tragically in a horrible and

unprecedented accident on January 29, 2023. Through this paper, I am grateful to him for having known, worked with and collaborated with him. He was a very committed personal friend, sincere and honest in his relationships. May his soul rest in peace and his good works accompany him.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Akponikpè, P. B. I., Tovihoudji, P., Lokonon, B., Kpadonou, E., Amegnaglo J., Segnon A. C., et al. (2019). *Etude de Vulnérabilité aux changements climatiques du Secteur Agriculture au Bénin. Report produced under the project "Projet d'Appui Scientifique aux processus de Plans Nationaux d'Adaptation dans les pays francophones les moins avancés d'Afrique subsaharienne"*. Berlin: Climate Analytics gGmbH. p. 101.

Chimi, P. M., Mala, W. A., Fobane, J. L., Essouma, F. M., Ii, J. A. M., Funwi, F. P., et al. (2022). Climate change perception and local adaptation of natural resource management in a farming community of Cameroon: a case study. *Environ. Challenge* 8, 100539. doi: 10.1016/j.envc.2022.100539

Dambeebo, D., Dakyaga, F., and Derbile, E. K. (2022). Navigating complexities towards sustainable food crops production: local practices for climate change adaptation in rural Ghana. *Discover Sustain.* 3, 11. doi: 10.1007/s43621-022-00078-7

Daoudi, A., Terranti, S., Hammouda, R. F., and Bédrani, S. (2013). Adaptation à la sécheresse en steppe algérienne: le cas des stratégies productives des agropasteurs de Hadj Mechri. *Cahiers Agricultures.* 22, 303–310.

Hossain, M. S., Arshad, M., Qian, L., Zhao, M., Mehmood, Y., and Kächele, H. (2019). Economic impact of climate change on crop farming in Bangladesh: an application of Ricardian method. *Ecol. Econ.* 164, 106354. doi: 10.1016/j.ecolecon.2019.106354

Hossain, M. S., Qian, L., Arshad, M., Shahid, S., Fahad, S., and Akhter, J. (2018). Climate change and crop farming in Bangladesh: an analysis of economic impacts. *Int. J. Clim. Change Strateg. Manage.* 11, 424–440. doi: 10.1108/IJCCSM-04-2018-0030

Institut national de la statistique et de l'analyse économique (INSAE) and Programme Alimentaire Mondial (PAM) (2017). *Analyse Globale de la Vulnérabilité, de la Sécurité Alimentaire et Nutritionnelle (AGVSA)*. Benin: INSAE and PAM.

IPCC (2022). "Climate change 2022: impacts, adaptation and vulnerability," in *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, eds H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, et al. (Cambridge, UK and New York, NY: Cambridge University Press), 3056. doi: 10.1017/9781009325844

Kijazi, A. L., Chang'a, L. B., Liwenga, E. T., Kanemba, A., and Nindi, S. J. (2013). The use of indigenous knowledge in weather and climate prediction in Mahenge and Ismani wards, Tanzania. *J. Geogr. Reg. Plan.* 6, 274–279. doi: 10.5897/JGRP2013.0386

Leal Filho, W., Barbir, J., Gwenzi, J., Ayal, D., Simpson, N. P., Adeleke, L., et al. (2022). The role of indigenous knowledge in climate change adaptation in Africa. *Environ. Sci. Policy* 136, 250–260. doi: 10.1016/j.envsci.2022.06.004

McKemey, M., Ens, E., Rangers, Y. M., Costello, O., and Reid, N. (2020). Indigenous knowledge and seasonal calendar inform adaptive savanna burning in northern Australia. *Sustainability.* 12, 1–18.

Ministère de l'Environnement et de la Protection de la Nature. (2008). *Plan d'Action National pour l'Adaptation aux Changements Climatiques (PANA)*. Ministère de l'Environnement et de la protection de la Nature, Cotonou, Bénin. p. 81.

Rabbany, M. G., Mehmood, Y., Hoque, F., Sarker, T., Khan, A. A., Hossain, K. Z., et al. (2021). Effects of partial quantity rationing of credit on technical efficiency of Boro rice growers in Bangladesh: application of the stochastic frontier model. *Emirates J. Food Agric.* 33, 501–509. doi: 10.9755/ejfa.2021.v33.i6.2714

Son, H. N., Chi, D. T. L., and Kingsbury, A. (2019). Indigenous knowledge and climate change adaptation of ethnic minorities in the mountainous regions of Vietnam: a case study of the Yao people in Bac Kan Province. *Agric. Syst.* 176, 102683. doi: 10.1016/j.agsy.2019.102683

Sullo, C., King, R. S., Yiridomoh, G. Y., and Doghle, K. (2020). Indigenous knowledge indicators in determining climate variability in rural Ghana. *Rural Soc.* 29, 59–74.

Usman, M., Ali, A., Bashir, M. K., Baig, S. A., Mushtaq, K., Abbas, A., et al. (2023). Modelling wellbeing of farmers by using nexus of climate change risk perception, adaptation strategies, and their drivers on irrigation water in Pakistan. *Environ. Sci. Pollut. Res.* 1–18. doi: 10.1007/s11356-023-25883-z

Varah, F., and Varah, S. K. (2022). Indigenous knowledge and seasonal change: insights from the Tangkhul Naga in Northeast India. *GeoJournal* 87, 5149–5163. doi: 10.1007/s10708-021-10559-3

Yaro, J. A., and Hesselberg, J. (eds) (2016). *Adaptation to Climate Change and Variability in Rural West Africa*. Berlin: Springer International Publishing. doi: 10.1007/978-3-319-31499-0

Yegbemey, R. N., and Egah, J. (2021). Reaching out to smallholder farmers in developing countries with climate services: a literature review of current information delivery channels. *Clim. Serv.* 23, 100253. doi: 10.1016/j.cliser.2021.100253

Zvobgo, L., Johnston, P., Olagbegi, O. M., and Simpson, N. P. (2022). *Preparedness: A case study of Smallholder Farmers in Chiredzi, Zimbabwe.*