Farmers' Perception of Indigenous Seasonal Forecast Indicators in North Central Burkina Faso

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Abstract

West African Sahel is one of the most exposed areas to the adverse effects of climate variability in the world. All agricultural production systems are affected. However, farmers use indigenous knowledge that enable them to make short, medium, and long-term seasonal predictions in order to adapt their agricultural calendar to these climatic risks. In the North Central region of Burkina Faso, this knowledge is not well documented. Therefore, this study aimed to identify the indigenous indicators of seasonal forecasts and analyze factors affecting their reliability. Surveys were carried out in focus group discussions with 204 farmers in 10 localities across the region. Results showed that farmers use meteorological (cold, heat, wind, clouds, rainfall distribution), biological (food plants phenology, migratory bird behaviour, occurrence of insects), astronomical (sun, moon, stars), religious or magical indicators to predict the coming rainy season. The intensity and duration of the cold period, heat intensity and the formation of dark clouds (April-May) are signs of an early start of the rainy season (or a wet season). Likewise, the abundant leafing, flowering and fruiting of *Vitellaria paradoxa*, *Lannea microcarpa*, *Lannea acida*, *Adansonia digitata* and *Tamarindus indica* (April-May) predict a wet rainy season, while abundant fruiting of *Sclerocarya birrea* indicates a drought. The arrival period (May-June) of migratory birds heralds a start of the season. Nowadays, climate change, the degradation of plant resources and increasing human pressure are affecting the reliability of these indigenous seasonal forecast indicators in the North Central region of Burkina Faso.

Keywords: adaptation, indigenous knowledge, seasonal forecasts, semi-arid environment

1. Introduction

In recent decades, global warming has become a fact of life for the whole Africa. This warming is due to anthropogenic climate change in particular, with serious repercussions for climate sensitive sectors (IPCC, 2014), including agriculture. Indeed, the agricultural sector in the West African Sahel is the most vulnerable to the negative effects of climate change (Roudier et al., 2011; Traoré et al., 2011). This vulnerability is linked to low agricultural production and the limited capacity of rural populations to adapt to climate change (Bryan et al., 2013).

West African agriculture is facing climatic risks that have become more recurrent these last decades (Sultan et al., 2020). All production systems are exposed to rainfall extremes, the most recurrent of which in the Sahelian zone are "false starts of rainy seasons", long dry spells, torrential rains and early season cessation, all of which increase the risk of food insecurity (Salack et al., 2020) and growing poverty. Indeed, rainy seasons during the dry years of the 1970-2013 period were characterized by low rainfall, late onset and early cessation, and a high frequency of dry spells (> 7 days) (Ibrahim et al., 2022). Cumulative rainfall, intra-seasonal rainfall distribution and start and cessation dates influence rainfed crops yields and determine the agricultural calendar (Marteau et al., 2011).

Declined and irregular rainfall considerably alters cropping seasons, forcing farmers to restructure their agricultural calendar, based on local knowledge (Agbodan et al., 2020). Indeed, African farmers use several local seasonal climate forecast indicators to adapt to climate variability and change (Jiri et al., 2015). In East Africa (Ethiopia, Tanzania, Uganda), farmers and herders combine meteorological, biological and astronomical indicators to make important agricultural and livestock decisions (Radeny et al., 2019). The main indicators are environmental (clouds, wind), biological (animals, plants), magical and religious (Chang et al., 2010).

In West Africa, farmers also use indigenous knowledge of seasonal forecasts (Ingram et al., 2002, Roncoli et al., 2008; Zongo et al., 2015; Ouédraogo et al., 2018; Nyadzi et al., 2021). They contribute to reducing the impact of climate on agricultural production (Nyong et al., 2007). The use of these forecasts helps farmers to guide their decision in the choice of crop plots, varieties, rotation, sowing dates and precautions for good agricultural production (Roudier et al., 2014). Hence, the main categories of indigenous seasonal climate forecast indicators are environmental, biological, magical and religious, and are transmitted from one generation to the following through oral tradition (Zongo et al., 2022). In Benin, indigenous seasonal climate forecasts are based on the observation of abiotic (moon, sun, stars, sky) and biotic (plants phenology, bird and insect behaviour) indicators with the observations largely undertaken by local elders and professional traditional forecasters (Amegnaglo et al., 2022). For people living in the savannah zones of northern Ivory Coast, the rainy season starts with the dry season leaf renewal of trees species such as *Adansonia digitata* and *Ceiba pentandra* (Brou and Chaléard, 2007).

In Burkina Faso, seasonal forecasts are based on biophysical, religious or magical signs (Yaka et al., 2012). According to these authors, they include environmental observations (behaviour of some birds and insects, phenology of some plant species, wind direction, moon and star cycles), traditional divination and interpretation of Christian or Islamic scriptures. For example, the Fulani of the northern region (Yatenga province) of the country use a variety of indicators to predict the quality of the coming season. These include observations of the wind, sun, stars and constellations, the phenology of some species (*Sclerocarya birrea*, *Lannea acida*, *Lannea microcarpa*), and some herbaceous plants (such as *Blepharis lineariifolia* and *Blepharis maderaspatensis*) (Bergeret, 2002).

In North Central of Burkina Faso, farmers rely on their indigenous knowledge to predict rainy seasons, in the absence of weather forecasts. Indeed, few farmers have little access to scientific climate information, provided by national radio (Zongo et al., 2015). Indigenous knowledge of seasonal climate forecasts is not well known or documented. This knowledge often varies according to locality, tradition and culture. Improving of indigenous knowledge could help farmers strengthen their adaptation strategies in the face of climatic risks. This requires, above all, some knowledge of these skills. Therefore, this study aimed to apprehend the perception of indigenous seasonal forecast indicators by farmers in the North Central Burkina Faso. Specifically, it sought to: (i) identify the indigenous indicators on which farmers rely to know beforehand the nature of the rainy season, and (ii) analyze the factors that reduce the reliability of these indicators. The study was based on the following assumptions: (i) Farmers in North Central region combine several categories of indigenous seasonal forecast indicators to predict rainy seasons; (ii) There are factors affecting the reliability of indigenous seasonal forecast indicators in this area.

2. Materials and Methods

2.1 Study Area

The North Central region of Burkina Faso covers three administrative provinces: Bam, Namentenga and Sanmatenga. Climatically, this region lies between the Sahelian and Sudano-Sahelian zones of Burkina Faso (Figure 1). Sahelian zone is characterized by average annual rainfall of 300 and 600 mm, and the Sudano-Sahelian zone, with an average rainfall of 600 and 900 mm. The climate is Sahelo-Sudanian, present two distinct seasons: a long dry season from November to May, and a short rainy season from June to October. Rainfall is lower in the north than in the south of the region (Zombré, 2006). The average annual temperature is 29 ℃ for the Sahelian zone, and 28 ℃ for the Sudano-Sahelian zone. Average annual potential of evapotranspiration (PTE) ranges from 3200 to 3500 mm in the Sahelian zone, and between 2600 and 2900 mm in the Sudano-Sahelian zone.

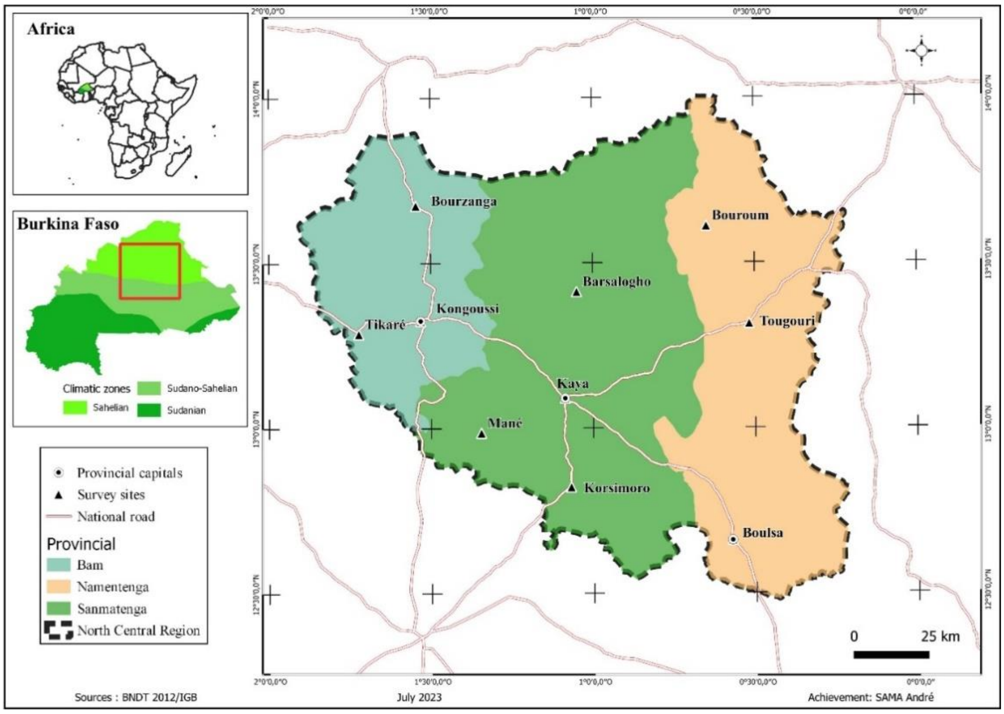

Figure 1. Location of Survey sites in the North Central region of Burkina Faso

According to the National Meteorological Agency (NMA) of Burkina Faso, the rainy season starts on average on June 4 in the south and June 19 in the north of this region (1981-2010 period). In 80 % of cases, the rains stop after October 6 in the south and after September 18 in the north. The length of the season varies on average from 110 to 120 days in the south and 75 to 85 days in the north. Harmattan and monsoon are the two main types of wind blowing in the region.

The overall natural vegetation is dominated by steppes and shrub to tree savannahs (Fontès and Guinko, 1995), with gallery forests bordering water bodies and wetlands. The northern part of the region is the shrub and tree steppe zone. The main tree and shrub savannah species encountered in Dem and Korsimoro localities (Sanmatenga province) are: *Vitellaria paradoxa*, *Parkia biglobosa*, *Tamarindus indica*, *Bombax costatum*, *Khaya senegalensis*, *Faidherbia albida*, *Diospyros mespiliformis*, *Sclerocarya birrea*, *Lannea microcarpa*, *Balanites aegytiaca* and *Piliostigma reticulatum* (Belem et al., 2008). According to the Ministry of Agriculture, agriculture is the main economic activity of households. Indeed, over 80 % of the region's inhabitants depend on this activity, which accounts for 41 % of their main source of household income (MAHRH, 2008).

2.2 Theoretical Framework

The purpose of this study is to identify the indigenous climate seasonal forecasting indicators used by farmers to predict the quality of rainy seasons, and analyze the factors reducing the reliability of these indicators. The studies showed that Africa farmers use several categories of indigenous knowledge for seasonal forecasts. These are meteorological, biological, astronomical (Radeney et al., 2019), biophysical, religious or magical (Yaka et al., 2012; Zongo et al., 2022). The identification of indigenous indicators of seasonal forecasts was based on surveys carried out in farming areas. Analysis of the factors reducing the effectiveness of these indicators was based on the limitations to their use, that could lead to their disappearance. Several studies showed that there are factors challenging and reducing the reliability of indigenous knowledge of seasonal climate forecasts. Therefore, these factors increase their vulnerability to disappearance (Mafongoya et al., 2021). Climate variability and change are among these factors (Ingram et al., 2002; Roncoli et al., 2008). Environmental degradation, ecosystem disturbance and changing climate have seen important traditional predictor indicators disappear or lost completely from the environment (Murgor, 2022). Analysis of these factors was therefore based on the relevant scientific literature.

2.3 Data Collection and Analysis

Surveys were carried out in 10 departments in the region (Figure 1). The selection of sites took into account criteria such as rainfall variability and climatic aridity (Kaboré et al., 2017). Indeed, the Barsalogho, Bouroum, Bourzanga and Tougouri sites are located in the semi-arid zone of the country. This zone is characterized by mean annual rainfall between 350 and 600 mm (Sarr et al., 2015). The other sites (Boulsa, Kaya, Kongoussi, Korsimoro, Mané, Tikaré) are located in the humid zone of this region. Interviewees were selected at random from a list of people fulfilling well-defined criteria such as: be experienced farmers, at least 45 years old and have lived long time ago in the study area. Older people are assumed to hold local knowledge. Indeed, sound knowledge are held by experienced farmers (usually the elderly) (Ogallo et al., 2000). Knowledge is transmitted from generations to other ones through oral tradition. Information have been collected through focus group discussions (Roncoli et al., 2008; Jiri et al., 2015) and key informant interviews, due to budget constraints. Two hundred and four (204) farmers, made up of men (153) and women (51), were surveyed using 25 focus groups with 8 people each. A questionnaire has been used, focused on indigenous indicators for predicting the nature of the rainy season (wet or dry), the start of the season (early or late) and the cessation of the season (early or late). An indicator is defined as a biological, abiotic, biophysical or meteorological parameter whose occurrence, presence, abundance or evolution at a given time of year makes it possible to predict the nature of the rainy season. The interview also focused on the cropping practices adopted by farmers to mitigate the climatic risks. These practices include crop sowing dates, rotation, varieties used, and off-season irrigation. The data have been collected between April and June in the years 2015 and 2016. Indeed, it is during this period that some indicators can be observed. Data analysis consisted in identifying the main indigenous seasonal climate forecast indicators in the various localities of the study area. These different indicators have been categorized. In the discussion section, survey results have been compared with those obtained by other authors in our area, and in other parts of Africa, to see how similar they are.

3. Results

Farmers have identified several indicators for predicting the nature and distribution of the rainy season. They are meteorological, biological, astronomical, religious or magical in nature.

3.1 Meteorological Indicators

Farmers in the North Central region use several meteorological indicators to predict the quality of the rainy season. Indigenous indicators for predicting the nature of rainy seasons, onset and cessation periods of the season are presented in Tables 1, 2 and 3. The intensity and duration of cold period (over three months) indicate an early start of the coming rainy season, a late cessation or a wet rainy season. On the other hand, the short duration of the cold period (two months) is indicative of a deficient rainy season, marked by a late start and an early cessation of the rains. Similarly, an interruption of the cold period by heat waves is a sign of a deficient season, with dry spells.

Furthermore, heat intensity during the warm period (March, April, May) is a sign of an early start of the rainy season. The formation of dark cloud in April-May towards the south and the frequent movement of winds from west to east predict a wet rainy season. In addition, farmers predict deficient seasons based on the frequency and intensity of winds blowing from east to west (May-June) at the start of the rainy season. The other indicators are "the first good rain that fall at night or early morning", "the heavy rain that fall in the second decade of June, and the "first rain with hail". They advertise an early start and a wet rainy season. However, the intense and irregular rains that sometimes occur in May, the late start to the season (around mid-July) which causes late crop sowing, the uneven distribution of rain over the rainy season and the frequency of rains falling during the day are perceived by farmers as indicators of an early cessation or a dry season. In the localities of Kongoussi and Tikaré, few farmers also predict the coming rainy seasons related to alternating dry and wet years, observed since many decades.

3.2 Biological Indicators

3.2.1 Plants Indicators

Farmers rely on the phenological phases (leaf renewal, flowering, fruiting) of some plant species to predict the nature of the rainy season and rainfall distribution. They identified seven (07) plant species that enable them to predict the quality of the season in their zone. The high leaf renewal, flowering and fruiting of *Vitellaria paradoxa*, *Lannea microcarpa*, *Lannea acida*, *Tamarindus indica* and *Adansonia digitata* before the onset of rainy season are indicators of an early start or a wet season in their locality. According to some farmers, rainy season will start early if *Adansonia digitata* foliage allows two or three harvests. However, late (or low) fruiting of *Vitellaria paradoxa*, *Lannea microcarpa*, accompanied by fruit dropping before full maturity, heralds a late start of the rainy season. In particular, the abundant fruiting of *Sclerocarya birrea* reflects a deficient rainy season, with long dry spells. Farmers also have observed that many fruit trees (For example *Mangifera indica*) produce at the same time during wet seasons, whereas in dry years, fruiting occurs at different times. This study shows that farmers in the North Central region rely mainly on the phenology of some food plants species to predict the quality of the rainy season.

3.2.2 Animal Indicators

Farmers also rely on the behaviour of some animals to predict the course of the rainy season. These include migratory birds, myriapods (millipedes) and insects such as black ants (Magnant) (*Dorylus sp*.), red ants (*Oecophylla sp*.) and termites (*Macrotermes sp*.). For instance, the passage in April-May of some migratory bird species (commonly known as ‘‘*Sigr-Wali*’’ or ‘‘*Teng-Luila*’’ in the national *Mooré* language) from the south to the north, or their presence, is seen as a harbinger of an early start of the season or a wet season. If the "*Teng-Luila*" build their nests with and east-facing opening, this is seen by farmers as a sign of a sudden end to the rains. On the other hand, if the opening is facing west, it means a late end of the season (or a good season). The movement of "*Kilonkoré*" birds from south to north announces the start of the rainy season. The strong presence of "*Leigdenga*" birds heralds an early start of the season. The presence of "*Luilgoamdga*" birds heralds a good rainy season.

Similarly, the rapid movement of red ants (*Oecophylla sp*.) from waterholes to slopes with their eggs and food reserves (cereals) announces the approach of a heavy rain. Moreover, the construction of termite mounds near waterholes is a sign of a deficient rainy season. The presence or abundance of black ants at the height of the season is a sign of a cessation of the rains. The abundance of red millipedes in fields and fallows during the season indicates a late cessation of the rains, while those of black millipedes (iules) heralds an early end of the season.

3.3 Astronomic Indicators

Astronomic indicators are based on farmers' observations of the movements of celestial bodies (sun, moon, stars) during May, June and August. The appearance of the sun and the constellation of stars allow some people to make predictions about the early or late start of the rainy season, duration, and its early or late cessation. For example, the appearance in early May of a large star "*Sagbonssa*" (in the national *Mooré* language), and its positioning in the middle of the sky in June, indicates that the rainy season will be surplus to requirement. Similarly, the constellation of certain stars ("*Gobé*" in the national *Mooré* language) heralds a late start of the rainy season. Furthermore, the moon's southern position in August is perceived by farmers as a late end of rains (a long rainy season). On the other hand, the moon's easterly position in August indicates an early end of the rainy season.

3.4 Religious or Magical Indicators

Annual festivals or customary rites, and dreams (or musings) of certain resource people are religious (traditional) or magical indicators. These rites are practiced in Korsimoro and Tikaré. Chicken sacrifices during festivals enable farmers to predict the quality of the coming season. The position in which the rooster is slaughtered is an indicator of the coming season. At Korsimoro, if the rooster slaughtered during the "*Kiougou*" feast struggles and falls on its back, this indicates a wet season. But, if it falls on its right or left side, this is interpreted as a late start of the season. This analysis shows that farmers rely on a variety of indigenous indicators to predict rainy seasons.

3.5 Farmers' Adaptation Practices Response to Climate Risks

The indigenous knowledge helps farmers to guide their decision-making when choosing plots and crop varieties, crop rotation and sowing dates. Short-cycle crops varieties (sorghum, millet, maize, cowpea, sesame, etc.) are used when a late onset of the rainy season is forecast. Seeds of improved varieties are also used to intensify crop production. Adaptation practices such as peanut-cowpea, cowpea-sesame rotation, and changing the sowing data, have been adopted by farmers. Some farmers refer to lunar cycles of the year to determine when to sow maize because of its sensibility to climate risks. Similarly, declining rainfall, late onset and early cessation of rains are climatic risks that can affect crop yields. To mitigate these risks, farmers whose plots are located in lowlands or in developed perimeters use off-season irrigation. The main crops are vegetables and cereals (rainfed rice, maize).

Table 1. Perception of indigenous indicators for predicting the nature of the rainy season (wet or dry)

Nature of the rainy season		
Indicators	Wet season	Dry season
Biological indicators	-Abundant foliage, flowering and fruiting of *Vitellaria paradoxa, Lannea microcarpa, Lannea acida*, *Tamarindus indica* and *Adansonia digitata* before the start of the rainy season -Many fruit trees produce at the same time -Migratory birds move from south to north in April-May -Red ants move from the shallows to the slopes with their eggs	-Low foliage, flowering and fruiting of *Vitellaria paradoxa*, *Lannea microarpa, Lannea acida*, *Tamarindus indica* and *Adansonia digitata* -Abundant fruiting of *Sclerocarya birrea* -Tree fruiting occurs at different times -Termite mounds near water sources
Astronomical indicators	-Observations of the position of the sun, moon, and star constellations in May, June and August	-Observations of the position of the sun, moon, and star constellations in May, June and August
Meteorological indicators	-Cold intensity and duration (over three months) -Heat intensity in March, April and May -Formation of dark clouds in April-May towards the south -Winds shift from west to east in May-June -First rains accompanied by hail -Wet years follow dry years, and vice versa -If heavy rain falls in the second decade of June -If the first rain falls at night or early in the morning	-Less intense, short-lived cold (two months) -Cold period interrupted by heat waves (frequent dry spells during rainy season) -Frequency and intensity of east to west winds -Frequency of daytime rainfall -Intense and irregular rains that sometimes occur in May -Uneven distribution of rains over the season -Late start of the rainy season (toward July) -Late sowing period (around mid-July)

Table 2. Perception of indigenous indicators for predicting the start (early or late) of the rainy season

Indicators	**Early start to the rainy season**	**Late start to the rainy season**
Biological indicators	-Abundant fruiting of *Vitellaria paradoxa, Lannea microcarpa, Lannea acida* before the onset of the season. -Fruiting of *Mangifera indica* at the same time -Birds migration from south to north (April-May) -The strong presence of some migratory birds	-Late fruiting of *Lannea microcarpa*, *Lannea acida, Vitellaria paradoxa*, *Sclerocarya birrea* -Fruiting of *Mangifera indica* occurs at different times (pockets of drought during the rainy season)
Meteorological indicators	-Heavy cloud formation in April to the south -Winds shift from west to east in May-June -Heat intensity in March, April and May -Intensity and duration of cold period	-Less intense, short-lived cold (two months) -Winds shift from east to west in May-June -Cold persists into March -Winds shift from east to west in May-June

Table 3. Perception of indigenous indicators for predicting the end (early or late) of the rainy season

Indicators	**Early end of the rainy season**	**Late end of the rainy season**
Biological indicators	-Low fruiting of *Vitellaria paradoxa, Lannea microcarpa* -Migratory birds (“*Teng-Luili”*) build their nests with east-facing openings -Presence of termite and ant mounds near water sources -Black millipedes (iules) in fields and fallow land	-Abundant fruiting of *Vitellaria paradoxa, Lannea microcarpa* -Migratory birds (“*Teng-Luili*”) build their nest with the opening facing west -Passage of migratory birds from south to north in April-May -Presence of red millipedes in fields and fallows
Meteorological indicators	-Short cold period (two months) -Heavy rains at the start of the season (May) -Uneven rainfall distribution throughout the rainy season -Rains are accompanied by strong winds -Sowing period begins in mid-July	-Duration of cold period (three months) -Heat intensity in March, April and May -Rainy season begins around mid-June -Low rainfall that fall at the start of the season and their distribution during the season -Weak winds during the rainy season

4. Discussion

4.1 Farmers' Perception of Indigenous Seasonal Forecast Indicators

Farmers in the North Central region of Burkina Faso use the combination of several categories seasonal forecast indicators to adapt to the adverse effects of climate variability and change. The intensity and duration of cold weather and the heat intensity are meteorological indicators that predict a wet season or an early start of the rainy season in the region. Experienced farmers make assumptions about the coming season by observing natural phenomena such as the period, intensity and duration of cold or hot temperatures (Ogallo et al., 2000). According to farmers in the North Central, cold and warm temperatures are usually associated with a wet rainy season. Smallholder farmers in Bikita District (Zimbabwe) have observed that extreme winter temperatures (between May and August) are usually associated with a good farming season (Mafongoya et al., 2021). Several reports agree that an intense cold season lasting three to four months heralds good rains for the coming season (Bergeret, 2002).

Winds blowing from west to east (May-June) herald a wet rainy season or an early start of the season. At the Fulani of northern Burkina Faso, winds blowing from west to east herald a very good season for people and animals, while winds blowing from east to west are harbingers of major natural disasters (lack of rain, poor harvests, long herd movements). Similarly, Winds from the southwest herald the sowing season (Bergeret, 2002). The shift of winds from west to east could reflects the penetration of the West African monsoon, which can be early or late depending on the year. The start of the rainy season is linked to the early or late penetration of the West African monsoon, which moves from southwest to northwest (Dékoula et al., 2018). According to Sultan and Janicot (2003), the mean date for the preonset occurrence of the West African monsoon is14 May during the period 1968-1990. The mean date for the onset occurrence of the monsoon is 24 June during the same period.

This study shows that farmers are able to predict a wet or dry season, as well as an early or late cessation of rains, based intra-seasonal rainfall variability observed in May and June. The pattern of intra-seasonal rainfall variability at the start of the season could be a predictor for the coming rainy season. Indeed, Lodoun et al. (2013) showed that the pattern of intra-seasonal rainfall distribution in May and June is predictive of the start date of the cropping season (false start or real) and the nature of the season (wet or dry). Few farmers in the North Central refer to the alternating wet and dry years to predict the coming season. According to them, deficient seasons follow wet seasons, and vice versa. Kaboré et al. (2017) observed alternating dry and wet years between 1961 and 2015 in this area.

Farmers also predict the coming season in relation to the phenology of food plants. Consequently, the abundant leaf renewal, flowering and fruiting of *Vitellaria paradoxa*, *Lannea microcarpa*, *Lannea acida*, *Tamarindus indica* and *Adansonia digitata* before the onset of the rainy season heralds an early start season (or a wet season). In Burkina Faso, fruiting of *Lannea microcarpa* heralds the start of crop sowing for farmers (Dialla, 2005). The flowering of *Millettia thonningii*, *Vitellaria paradoxa* and *Delonix regia* species, and the bursting of *Ceiba pentandra* fruit are temporal markers of the start of the rainy season (sowing period) in the Guinean zone of Togo (Agbodan et al., 2020). Among small-scale farmers in the Chiredzi (Zimbabwe), abundant flowering and fruiting of *Mangifera indica* (observed primarily at the start of the season) is seen as an indicator of a wet rainy season (Zvobgo et al., 2023). Similarly, heavy flowering of *Adansonia digitata* indicates a good rainy season (Mafongoya et al., 2021). However, abundant fruiting of *Sclerocarya birrea* predicts imminent drought (Bergeret, 2002; Jiri et al., 2015). Phenological changes in plants are inextricably linked to climatic variations and can therefore serve as key events for local populations (Cleland et al., 2007; Rosenzweig et al., 2008). The variation in leafing, flowering and fruiting periods depends on factors both intrinsic and extrinsic to the plant (Nguemo et al., 2004; Mallard, 2016). Climate is an extrinsic factor, which plays a dominant role in the onset of phenological phases.

The behaviour of migratory birds (arrival period, presence, orientation of nest access) in April-May is used by farmers to predict the start of the season. Indeed, in the Lake Chad region, the westward orientation of *Poliemaetus bellicosus* nest openings heralds a wet rainy season and good flooding, while eastward orientation presages drought (Nimrod, 2020). The appearance of red ants announces that substantial rainfall is coming (Jiri et al., 2016).

Customary festivals and the dreams or musings of certain resource people are religious or magical indicators to which farmers refer in order to know in advance how the season will unfold. According to Dialla (2005), the ‘‘*Tengsoaba*’’ (traditional land manager in *Mossi* villages) performs sacrifices to intercede between the living and the ancestral spirits who influence the rains. Predictions are made based on the behaviour of sacrificed animals (usually a chicken). These include the time they take to fall, the direction in which they fall, the position of the body at the moment of fall and the place where the blood is spilled. ‘‘*Tengsoaba*’’ and other traditional specialists may receive rain predictions from ancestors or gods in dreams or stories. Our results are similar to those of Yaka et al. (2012) who showed that in Burkina Faso, indigenous seasonal forecasts are based on environmental, religious or magical signs.

Indigenous seasonal forecast information help farmers in making the right decisions when in choosing plots and crop varieties, rotation, and sowing dates. Farmers in Bonam locality (Namentenga) generally wait for 10 to 12 days of dry weather in June before sowing maize. This period generally occurs between mid-June and early July, and coincides with the visible phase of the 8th lunar cycle of the year (Roncoli et al., 2001). Climatic risks such as late onset and early cessation of rains, long dry spells can affect agricultural yields and income. Irrigation appears to be an adaptation option in the face of this uncertainty. Kaboré et al. (2019), using a binary *Logit* model, showed that lower rainfall and late onset of the rains influence the probability of adopting irrigation at 5% threshold in the North Central region. In Benin, the use of indigenous seasonal climate forecasts increased a maize producer's net income by at least 3%, implying that indigenous seasonal climate forecasts are valuable goods (Amegnaglo et al., 2022). Indigenous seasonal forecasts also help farmers to predict climatic events, such as seasonal droughts (Bergeret, 2002; Jiri et al., 2015). Indeed, Mujere et al. (2023) maintain that indigenous knowledge system is capable of predicting seasonal droughts in way that the local communities depend on when making farmers decisions and devising appropriate adaptions measures to climate change. Subsistence farmers in developing countries still rely on indigenous knowledge systems to adapt to climate variability. In the Delta State of Nigeria, indigenous knowledge preferred to scientific systems of weather forecasting (Ebhuoma and Stimatele, 2019).

4.2 Factors Affecting the Reliability of Indigenous Seasonal Forecast Indicators

Not all of these indicators appear to be sufficiently reliable to provide accurate information to potential users. Indeed, some biological indicators are based on the phenology of food plant species. On the other hand, this study reveals a low diversity of food plants enabling farmers to make seasonal predictions. However, these species have become rare and are experiencing a decline in fruit production. Indeed, Bambara et al. (2013) report a decline in fruit production from wild and domestic woody plants in the Sahelian (Tougou) and Sudano-Sahelian (Donsin) zones of Burkina Faso, attributable to the adverse effects of climate change and increasing human pressures. For example, *Vitellaria paradoxa*, *Lannea microcarpa*, *Tamarindus indica* and *Ximenia americana* have become rare in the Sudano-Sahelian zone of Burkina Faso (Boulsa Department) (Kaboré, 2020). The scarcity and decline in fruit production are likely to affect the reliability of biological indicators. Indeed, in East Africa, the extinction of some plants and animals, desertification in pastoral areas, and the degradation of vegetation resulting from rapid urbanization and high population growth affect the biological indicators (Radeney et al., 2019).

Planet Earth has been experiencing a warming in average temperatures since 1950 (IPCC, 2013). A drop in nutrients and water availability in migration areas can affect the reproductive cycle of some vulnerable migratory birds. Likewise, global warming also may favor the proliferation of infectious diseases, affecting the population of vulnerable migratory birds. These ecological factors could threaten the survival of many migratory birds species. According to Moller et al. (2008), ongoing climate change will increasingly threaten vulnerable migratory birds species, increasing their risks of extinction. The disappearance of these birds could affect the reliability of some biological indicators based on the observation of migratory birds behaviour. For example, in northern Ghana, some animal and birds behaviour such as the movement of migratory birds, which was used to predict the likelihood of weather patterns of seasons, has been adversely affected by the changing climatic conditions (Jabik, 2022).

Farmers in the North Central region of Burkina Faso have observed that the classic cold season of yesteryear (December to February) has become warmer in recent decades (Kaboré et al., 2019). With this warming trend, farmers will not be able to make reliable predictions based on the intensity and duration of the cold period. Meteorological indicators related to rainfall are varying, and could experience a strong variability with climate change. Indeed, in West Africa, the length of rainy season is varying, with the number of rainy days changing from one year to the other (Sultan and Janicot, 2003; Traore et al., 2013). The adverse effects of climate change could affect rainfall indicators and make them less reliable. In Burkina Faso, indigenous climate forecasts are becoming less reliable due to climate change over the past two decades (Ingram et al., 2002; Roncoli et al., 2008). Likewise, distortions in the transmission of indicators from one generation to the next also call into question the reliability of these forecasts (Roncoli et al., 2008). The results of this study are in line with the hypotheses previously put forward, namely "The existence of indigenous seasonal forecast indicators and factors affecting their reliability".

5. Conclusion

In the North Central region of Burkina Faso, climatic risks affect agricultural production systems. Farmers use indigenous knowledge to mitigate these risks. They combine several categories of indigenous indicators to make forecasts or hypotheses on the nature of the rainy season, the onset and the cessation of the season in the short, medium and long term. These indicators are meteorological, biological, astronomical, religious or magical in nature. This knowledge is transmitted on from one generation to the other through oral tradition. Indigenous seasonal climate forecasts information guide farmers in their choice of crop plots, varieties, rotation, and sowing dates. An indicator is said to be reliable and beneficial when it can provide the farmer with actual seasonal climatic information, enabling him to implement his adaptation strategy. Global warming, degradation of plant resources and increasing anthropogenic pressure are threatening the reliability of indigenous seasonal forecast indicators. Species such as *Vitellaria paradoxa*, *Lannea microcarpa*, *Lannea acida*, *Tamarindus indica* and *Adansonia digitata* should be preserved and promoted for their important role in predicting rainy seasons. In perspective, a comparative study between indigenous knowledge and scientific climate information is therefore needed to determine the degree of concordance. The combination of indigenous knowledge of seasonal forecasts and scientific climate information would strengthen Sahelian farmers ' ability to adapt to climate variability and change.

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Authors contributions

Dr. KPN is responsible for study design, data collection and drafting the manuscript. Doctors ZAO, BD, KS and CPJA revised the manuscript. Prof. OA also revised the manuscript. All authors read and approved the final manuscript.

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