

Special Section:

Rhythms of the Earth: Ecological Calendars and Anticipating the Anthropogenic Climate Crisis

Key Points:

- The Tuareg of Illizi (Algeria) report on multiple climate change impacts including temperature irregularities and severe drought events
- These reports are aligned with scientifically measured climate observations and predictions
- The Tuareg do not explicitly report on decadal trends, which has implications for their ability to adapt to such changes

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Climate Change Impacts Can Be Differentially Perceived Across Time Scales: A Study Among the Tuareg of the Algerian Sahara

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Abstract As an Indigenous community of Algeria and the broader Sahel, the Tuareg hold unique ecological knowledge, which might contribute to broader models of place-based climate change impacts. Between January and April 2019, we carried out semi-structured interviews ($N = 23$) and focus group discussions ($N = 3$) in five villages of the province of Illizi, Algeria, to document the local Tuareg community's timeline and ecological calendar, both of which are instruments used to understand place-based reports of climate change impacts. The livelihoods of the Tuareg of Illizi are finely tuned to climate variability as reflected in changes reported in the cadence of events in their ecological calendar (marked by cyclical climatic and religious events). Participants reported rain and temperature irregularities and severe drought events, which have impacted their pastoral and semi-pastoral livelihoods. These reports are aligned with scientifically measured climate observations and predictions. Paradoxically, although participants recall with detail the climatic disasters that happened in the region over the last century, the Tuareg do not explicitly report decadal trends in the frequency of extreme events. The differential perception of climate change impacts across scales can have important implications for undertaking climate change adaptation measures.

Plain Language Summary Climate change impacts are perceived by communities across the world. The Tuareg of Illizi (Algeria) have animal rearing livelihoods relying on local resources and have deep knowledge of the desert environment and its climatic conditions. Here, we discuss that Tuareg communities perceive a diversity climate change impacts (on climate, vegetation, and fauna) affecting yearly cyclical activities, but they do not explicitly recognize climate change trends happening over decades. This may hamper adaptation as these trends are predicted to continue or even worsen in the future.

1. Introduction

Climate change is one of humanity's most complex and existential challenges as it impacts both the economy and the environment, including those environmental aspects that form the fundamental basis of human wellbeing: clean air, safe drinking water, sufficient and nutritious food, and secure shelter (IPCC, 2022; Sofonov, 2019; WHO, 2012). Climate change is expressed in increasing frequency of extreme events, it directly and indirectly impacts on education and health, and alters social relations (IPCC, 2022). Climate change impacts have led to the loss of wealth as well as access to land (Snorek et al., 2017), and thus can contribute to the loss of cultural heritage, Indigenous and local knowledge, and language diversity in societies intrinsically linked to their natural environments (Dunn, 2018; Eira et al., 2018). Climate change impacts in culture have been reported across several groups, from Pacific Islanders (McAdoo et al., 2009; Straza et al., 2018) to Sámi reindeer herders in the Arctic (Eira et al., 2018).

Despite growing agreement among the scientific community about global trends (IPCC, 2022), the differentiated local impacts of climate change as well as the possible responses to these impacts remain contested by different social groups (Straza et al., 2018). This is so, not only because the physical impacts of climate change have uneven geographical distributions, but also because people have different perceptions of uncertainty, risks, and

urgency (Hulme, 2009; Jacques, 2012; Oreskes, 2004) that result in different distribution of preparedness and resilience among social groups across the globe (Barnett & O'Neill, 2010; Snorek et al., 2014).

Among other factors, place-based knowledge and skills can largely affect societies' capacity to react and adapt to climate change impacts (Schlingmann et al., 2021). Indigenous and local knowledge and practices are important components of climate-related local planning and response to cyclic events and natural disasters (Charan et al., 2017; Fletcher et al., 2013; Plotz et al., 2017). Through generations, Indigenous peoples and local communities living in close relation with nature have accumulated very precise knowledge on celestial, meteorological and ecological phenomena (e.g., Garteizgogeoasoa et al., 2020; Orlove et al., 2000). This knowledge has allowed them to anticipate weather conditions and seasonal events and to accordingly adapt their livelihood activities (Acharya, 2011; Reyes-García et al., 2018; Turner & Singh, 2011). Combining Indigenous and local knowledge with climate science has been beneficial to many communities, as the combination of both types of knowledge provide a better understanding of climate change drivers and potential impacts (Alexander et al., 2011; Boillat & Berkes, 2013; Jolly et al., 2002; Kassam, 2009a; Nickels et al., 2005; Nyong et al., 2007; Rapinski et al., 2017). However, to effectively incorporate Indigenous and local knowledge to climate and disaster planning, this knowledge must be recognized as valuable, identified, and documented, and included through all stages of the climate change and disaster risk management planning processes (Straza et al., 2018) and knowledge holders should have their rights recognized (Reyes-García et al., 2022).

Some of the ways in which Indigenous and local knowledge systems give meaning to time and report changes is through community historical timelines and ecological calendars. Community historical timelines are analytical tools to chronologically report on the main events affecting a community by placing them in chronological order (McNaught et al., 2011). Ecological calendars, also known as seasonal, natural, or phenological calendars, are based on ecological, phenological, or climatic events observed locally in the physical environment inhabited by the community (Kassam et al., 2018). Ecological calendars are frameworks that link temporal and spatial scales, contributing to landscape management and stewardship (Akulki, 2004; Franco, 2015; Kassam, 2009a, 2009b; Krupnik & Jolly, 2002; Orlove et al., 2008). While the well-known celestial calendars (e.g., Gregorian) are based on the movements of the sun and the moon, ecological calendars emphasize the relative timing of environmental processes. Communities use both ecological and celestial calendars in tracking events that happen with different periodicity (from daily to inter-annual). When adequately used, community timelines and ecological calendars can provide a baseline for understanding local perceptions of climate change impacts and support local planning to adapt to environmental changes (Chambers et al., 2021; Yang et al., 2019).

Dryland ecosystems, which occupy 40% of the terrestrial surface, are particularly affected by climate change. The area occupied by dryland ecosystem is expected to expand by 10% by the end of the 21st century (IUCN, 2019). The people inhabiting dryland ecosystems have unique strategies to cope with the climatic variability of their environment, but climate change reduces their capacity to cope with environmental conditions (IUCN, 2019). Yet, how their coping and adaptive capacities are reduced is poorly understood. As state-level climate change mitigation and adaptation planning is often implemented in participation with local communities, understanding communities' climate change perceptions can contribute to the plans' success. This research is the first to describe the community timelines and ecological calendars of the Tuareg peoples of Algeria. The Tuareg are an Indigenous pastoral community adapted to the hyper-arid conditions of the Sahara Desert. We enquire whether Tuareg people have observed climate-related changes across two different time dimensions, a longitudinal dimension captured by the community timeline and a cyclical dimension captured by changes in the ecological calendar.

Algeria is particularly vulnerable to climate change, with slow-onset impacts such as from increased desertification and erosion to fast-onset impacts like water scarcity and flash floods (Sahoune et al., 2013). Algeria's National Climate Plan sets out targets for climate mitigation and adaptation in participation with local communities including adapting local agricultural calendars. In our discussion, we elaborate on how Tuareg reports of climate-related changes are reflected within the academic climate change literature and in what ways reports on climate change impacts can contribute to climate change adaptation planning in dryland ecosystems.

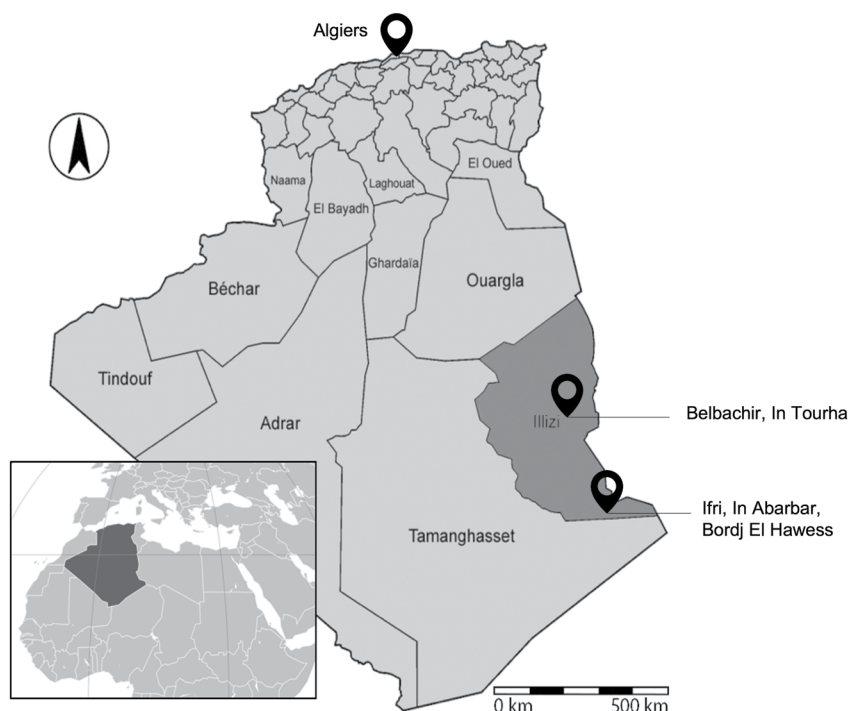


Figure 1. Geographical location of the study area.

2. Materials and Methods

2.1. The People and the Study Area

The Tuareg are a pastoral community indigenous to the Sahelo-Saharan region spanning from the Maghreb to sub-Saharan Africa. Their territories are found across Libya, Algeria, Mali, Niger, Burkina Faso, with some small communities in Chad and Nigeria (Bernus, 2016). The Tuareg are traditionally pastoralists and raise herds of camels, cattle, sheep, and goats (Miara et al., 2019). Despite contradicting views around whether pastoral livelihoods have contributed to environmental degradation in the Sahel (Mortimore & Turner, 2005; Warren, 1995), the fact remains that pastoral societies have persisted in extreme dry conditions since the end of the African Humid Period (6,000–5,000 years ago) and that Tuareg pastoralism seems well adapted to the Saharan dryland (Brierley et al., 2018).

Like many Indigenous peoples around the world, Tuareg efforts to preserve their cultural identity and territories for future generations represent a commitment to what is termed as “indigeneity” (Steeves, 2018). Tuareg culture is rooted in an environmental ethic represented in their lifestyle and traditions and demonstrates an intimate understanding of their environment honed over generations (Bernus, 2016). Tuareg pastoral lifestyle demands vast knowledge of how to steward the land in a way that perpetuates fodder sources (native trees and grasses) to enable them to maintain herds of grazing and browsing livestock in resource-scarce environments (Brierley et al., 2018). While many Tuareg have been forced to transit into sedentary or semi-sedentary pastoral lifestyles, partly due to the greater frequency of drought events (Snorek, 2016), nomadic pastoralism remains an important part of Tuareg cultural identity and lifestyle (Snorek et al., 2014).

Algeria hosts the fourth largest Tuareg population after Niger, Mali and Burkina Faso. This study focuses on the Tuareg living in the *wilaya* (province) of Illizi in the South-East of Algeria. Illizi is about 1,800 km by road from the capital of Algiers (Figure 1). To the east, the province borders with Tunisia, Libya and Niger. To the west, it borders with the province of Tamanrasset and to the north with the province of Ouargla (Figure 1). The region occupies an area of 284,618 km² (~1/9 of the total surface of Algeria). Most of this area is rangeland (28, 450, 102 ha). The land used by cropland agriculture only covers 11,698 ha (OTNP, 2009). The total population of Illizi is estimated at 57,100 inhabitants of whom 43% are under 15 years of age. Most of the population in the province are Tuareg who speak “Tamasheq,” an Amazigh or Berber language (Bernus, 2016).

Table 1
Participants in Semi-Structured Interviews According to Age, Gender, and Profession (n = 19)

		Breeder	Touristic guide	Farmer	Artisan	Total
Young	Men	2	3	0	0	5
	Women	2	0	0	1	3
Old	Men	5	0	2	0	7
	Women	1	0	1	2	4
	Total	10	3	3	3	19

The region is composed of three landform types: dunes, plateaus, and lowlands (NAID, 2015). Soils are diverse with various types of edaphic accumulation: ablation, saline, sandy (dunes and nebkhas), and alluvial soils (OTNP, 2009). Vegetation grows mainly along the wadis or watercourses, which are the only environments allowing the presence of perennial plants.

The climate of Illizi is typical of the Saharan desert characterized by relatively high air temperature, low humidity, and very little precipitation (OTNP, 2009). The daily average temperature in summer is between 42.4°C maximum and 25.6°C minimum. In winter, the daily average temperature varies between 22° maximum and 7°C minimum. As for most of the Sahara, the distribution of rainfall in Illizi is irregular (Yan et al., 2016). The winds are generally light to moderate and the most frequent blow from the southeast and east. The strongest winds often blow during the months

of March, April, May, and September. Their speed can reach 120 km/hr, and they can lead to the formation of sandstorms that force the local population to take refuge indoors for hours.

2.2. Data Collection and Analysis

Between January and April 2019, we documented the Tuareg community timeline, ecological calendar, and reports of climate change impacts following a standardized protocol developed to document and compare local indicators of climate change impacts (LICCI) across Indigenous Peoples and local communities around the world (Reyes-García et al., 2020). The protocol used has been developed by the LICCI project, which aims to show the potential of Indigenous and local knowledge systems to improve scientific understanding of physical, biological, and socioeconomic climate change impacts as locally perceived (www.licci.eu).

We conducted fieldwork in the center and south of the Illizi province, in the villages of In Tourha and Belbachir (near the town of Illizi), and Bordj El Hawes, In Abarbar and Ifri (near Djanet; Figure 1). The research team have long-term trust relationships with the Tuareg of Illizi, which facilitated the implementation of the pre-designed protocol. After explaining the project's scope and objectives and after answering all participants' questions, we requested participants' Free, Prior and Informed Consent to participate. Literate participants signed a written consent form, and we used an oral script for illiterate people, which was signed by a witness. The research protocol was approved by the Ethics committee of the Universitat Autònoma de Barcelona (CEEAH 4781).

To collect qualitative data about the community's timeline (last 120 years), the ecological calendar, and observed climate change impacts, we used semi-structured interviews and discussed interview responses in focus groups with elder community members.

2.2.1. Semi-Structured Interviews

Two types of semi-structured interviews were conducted with different samples. First, to get a deep understanding of local livelihoods, important historical events, and the local ecological calendar, we targeted people who had knowledge about the locality (i.e., local experts). Specifically, we conducted interviews with local elders and people having a local authority role, including four tribal chiefs of over 67 years of age. One of the elders had tribal and spiritual authority over two villages (In Tourha and Belbachir). All the four interviewees were men. In these interviews, we asked about local livelihoods, including the activities people do for a living, the timing (i.e., yearly, seasonally) and location of the activities, and the household members or community groups in charge of or participating in those activities. We also asked about the local timeline, including the history of the study site, important events in the community that everyone remembers, and when these events happened (e.g., in relation to national events).

Second, to document climate-related changes in ecological calendars we selected informants using a “quota sampling” (Sudman, 1966) aiming at capturing gender, age, and livelihood diversity. In total, 19 people were interviewed in the five study villages: Ifri (4), Belbachir (6), Bordj El Hawess (3), In Tourha (2), In Abarbar (4). Sample size differs across villages depending on the number of people available and willing to participate. Our sampling is biased toward men (12 out of 19) because in the study site strong reservations exist preventing women to speak to foreigners. Participants included breeders, tourist guides, farmers, and craftsmen (Table 1).



Figure 2. Focus Group Discussion with elder Tuaregs.

Both young and old people were interviewed, with the distinction between the two groups being locally defined. In general, the Tuareg consider people under 50 to be young.

The purpose of semi-structured interviews was to investigate the perceived changes in elements of the atmospheric (i.e., temperature, precipitation, seasons, air masses), biophysical (i.e., freshwater physical systems, soil, wild fauna and flora, land cover change and degradation), and socioeconomic system (i.e., livelihoods, species cultivated, livestock, human health, infrastructure). We inquired about what changes the interviewee had noticed in the environment and since when they have noticed these changes. We asked informants to describe the changes observed and to report if they perceived the change to be directly related to climate change. The protocol's full details are available online (Reyes-García et al., 2020).

2.2.2. Focus Group Discussions

We organized Focus Group Discussions (FGDs) to validate, through the group collective memory, observations collected from individuals. The FGDs meetings were organized with the help of village chiefs who invited a group of mostly elder community members with a long experience in the community (Figure 2). Three FGDs were organized: Ifri and In Abarbar (seven participants), Bordj El Hawess (four participants), and Belbachir and In Tourha (five participants). In FGDs, we discussed observations reported in semi-structured interviews that were either contradictory or unclear. Ambiguous observations were presented to the groups to assess whether there was a consensual perspective, and we noted the result as “Agreed” or “Disagreed” without the need of or after debate (Reyes-García et al., 2020).

Temporal information on activities mentioned in participants' responses during the first set of semi-structured interviews were organized and synthesized in a chronological manner to produce the community timeline and its calendar. The LICCI classification system (Reyes-García et al., 2020) was used to classify responses from the second set of semi-structured interviews and FGDs.

3. Data

Data for this article was uploaded to the LICCI database and was uploaded to Zenodo (Miara, 2022).

4. Results

4.1. Community Timeline

The oldest remembered events are two political events: a war between the Tuareg and the Chaamba (Arab-speaking tribes from the north of the Sahara) in 1900 and the start of the French colonization in 1911. Nevertheless, the local Tuareg chronology is mainly marked by natural disasters ($N = 10$) that have generally afflicted the region, or that have impacted specific localities of regional importance (e.g., the capital, the biggest oases). The most common natural disasters mentioned are floods or drought causing significant material and human losses (Figure 3).

According to our participants, there was a great drought lasting several years that resulted in a large famine across the region in 1940. The Tuareg have a clear memory of this period, when many people died of starvation. The first floods remembered by participants were in 1946, when heavy rains destroyed the city market of Illizi which had been established in 1945 and where many Tuareg, Chadian and Malian traders operate (Figure 3). This market was destroyed and most of the traders, who settled near the city, died. The following year, other floods enabled the growth of very abundant vegetation, completely changing the landscape of the region. At this time, several plants not previously known in the region spontaneously appeared in the landscape (e.g., *tourha*, *Calotropis procera* (Aiton) Aiton fil., *nejem*, *Cynodon dactylon* (L.) Pers., and *diss*, *Ampelodesmos mauritanicus* (Poir.) T. Durand & Schinz). In 1954, and later in 1964, the floods made the inhabitants flee to the Tassili Mountains. Informants also

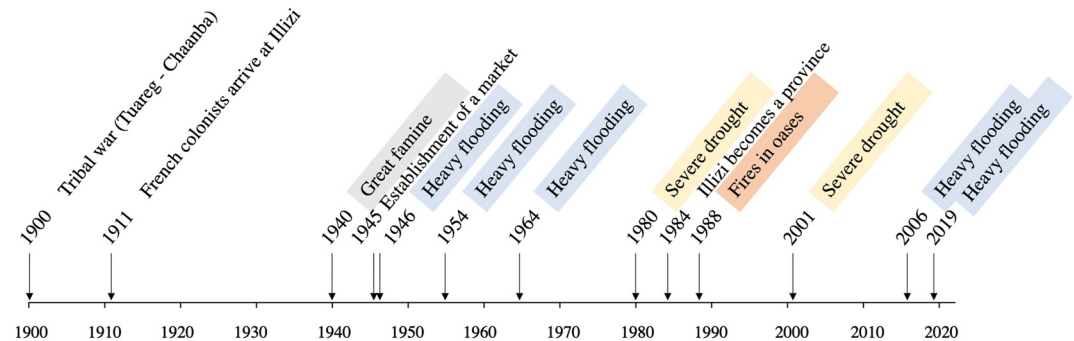


Figure 3. Tuareg community timeline (Illizi). Political events not related to the environment are not colored, temperature-related events (drought and fire) are colored in yellow, and orange and rainfall-related events (flooding) in blue. We colored the 1940 Great Famine in gray as it is not a climatic extreme event in itself.

remember a strong drought that occurred in 1980, when many Tuareg from Algeria fled to neighboring countries (i.e., Libya, Niger, Chad and Mali).

The promotion of Illizi as an administrative province (*wilaya*) and the town of Illizi as its provincial seat in 1984 also mark the local timeline. Informants recall that after these events, the local population of the region benefited from a large state budget which allowed the construction of roads, houses, and infrastructure.

In 1988, after years of drought, fires destroyed many palm trees in the oasis of Aharhar (near the Tassili Mountains), having an important impact on local date production. A period of repeated droughts lasted until 2001, when a very severe drought was experienced. In 2006, the region suffered from very heavy floods which caused the death of many people including the legendary singer of the Tuareg, Othman Badi. The Tuareg say that the height of these flood waters reached 3 m in the city of Illizi. Finally, floods in 2019 also caused significant material damage.

4.2. Ecological Calendar

The Tuareg structure their ecological calendar in two seasons divided by temperature and precipitation: a cold and a hot season (Figure 4). Traditionally, the cold season is also rainy and lasts for about 2 months. The longer hot season also includes a rainy period.

For the Tuareg, the beginning of the ecological calendar is the onset of the cold and rainy season, when pastoralists and other livestock owners take their herds of cows and camels into wild pastures in the Tassili Mountains. This pastoral movement relates to the growth of grass in the mountains. The animals, which have all tribal ownership marks, are left unaccompanied in these grazing lands for the length of the rainy season (Figure 4, “Settled grazing”). At the end of the rainy season owners return to the area to pick them up. The animals do not risk being lost or stolen as this practice is carefully framed and severely enforced by tribal laws.

During the cold and rainy period, while cows and camels are in the mountains, Tuareg practicing nomadic pastoralism settle in the lowlands, near waterflows (wadis) where they benefit from the availability of water and grass to feed their sheep. At this time, the Tuareg plant temporary gardens with vegetables such as tomatoes (*Solanum lycopersicum* L.), salad (*Lactuca sativa* L.), and zucchini (*Cucurbita pepo* L.) for self-consumption. They also plant *bechna* (*Panicum miliaceum* L., millet), a cereal crop widely used as fodder and food. The Tuareg mostly appreciate millet's nutritional value as fodder for sheep and goats. Millet is also very important to the Tuareg as food, and it is used in several local food recipes, including local bread (mella). Millet is considered the ally of Tuareg women who practice force-feeding (a beauty ritual to fatten young women), mixing it with dates and camel milk. The Tuareg also use millet as medicine, particularly against constipation (Miara et al., 2019).

The period after the cold and rainy season and before the rainy period that occurs during the hot season is considered as the most difficult period for the Tuareg. This is the season when sandstorms occur, sometimes with an intensity that can kill livestock and dry out grazing plants. During this period, the Tuareg harvest their millet, but stop all movements. Animals are placed in shelters to protect them from the very frequent and sometimes

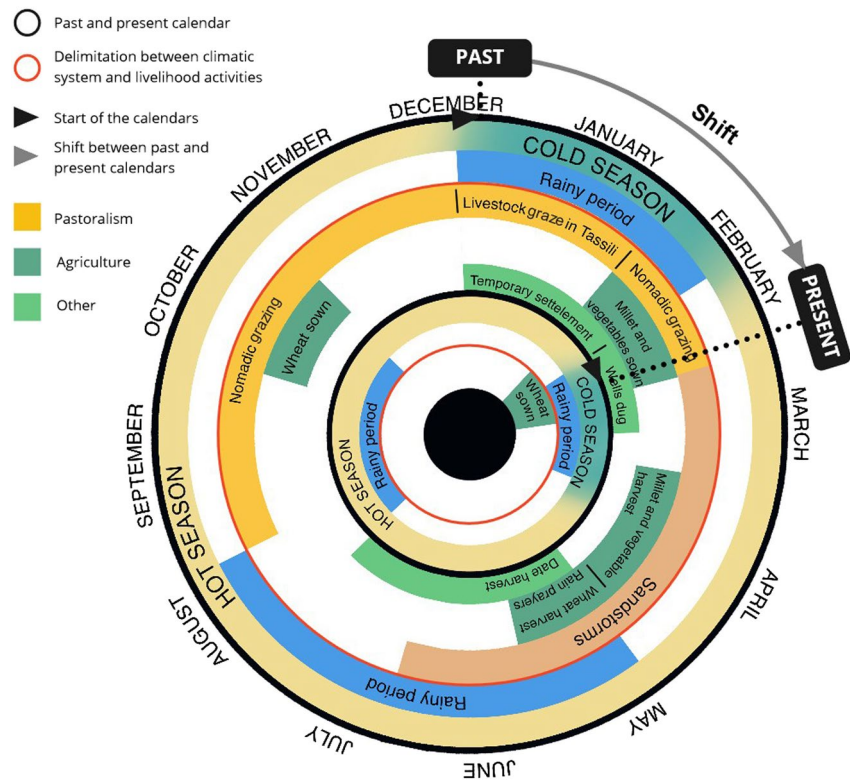


Figure 4. Past and present ecological calendar of Tuareg community of Illizi. The present calendar's seasons occur at a different period than in the past, but only one livelihood activity has been shifted in time, wheat sowing (presented in the figure).

devastating sandstorms. Despite these potential impacts, sandstorms are also considered an important part of the seasonal cycle as, according to some participants, they clean the air and the soil and prepare them for the following cycle. During this time, community members have to hand-dig shallow wells to obtain the water infiltrated into the ground from waterflows (*wadis*) that have dried up.

Just before the start of the rainy period that occurs during the hot season, the Tuareg settle near or in the oases and villages with their animals and begin the harvests of dates from cultivated date palms in the oases, a practice called *amaris*. Such harvest is deeply associated to praying rituals for the rain that should occur during the hot season. Indeed, for the Tuareg date harvest is accompanied by various religious rituals including prayers and charity actions (*sadaka*) during which part of the date harvest is given to the poorest community members. These practices are preconceived to help ensure good rains. The rains of the hot season are irregular, sudden, strong, and sometimes devastating, but also make it possible to fill the wells and *wadis* and ensure drinking water until the onset of the cold and rainy season. These rains are of great importance to Tuareg pastoral practice. Tuareg think that the best years are the years when rain falls in abundance during the hot season. After the rains, the Tuareg move around the desert allowing the livestock to graze on the abundant grass. However, if the hot season rains fail, Tuareg will migrate away from their tribal lands to near permanent waterflows where the livestock can graze.

In addition to millet, the Tuareg also grow wheat. Traditionally, the Tuareg sow wheat towards the end of the hot season and harvest it at the start of the rains that occur during the hot season. Like millet, wheat holds a special importance among the Tuareg for being the base of bread making and other special dishes including couscous, which is eaten every Friday after visiting the mosque. In the past, when traditional wheat varieties were sown, the wheat cycle lasted 7 months. Currently non-local, short-cycle varieties are being used for which the wheat cycle is considerably shorter (Figure 4).

Tuareg celebrations are linked to the ecological calendar, as well as to daily cycles, and the Muslim lunar calendar. The Tuareg celebrate Muslim religious events including Aid El Kebir, the feast of sacrifice where Muslims offer sacrifices (sheep, cattle, camels) to God, and Aid el Seghir, which celebrates the end of the youth month

LICCI	Level of agreement
1. Changes in the frequency of fog or misty days (fog has decreased)	Full agreement
2. Changes in the frequency of fog or misty days (fewer mists)	Agreement after debate
3. Changes in the frequency of cold days (more cold days)	Full agreement
4. Changes in mean temperature (the climate is colder)	Full agreement
5. Changes in the frequency of frost days (no frosts now)	Full agreement
6. Changes in the number of windy days (less wind)	Full agreement
7. Changes in the frequency of sand or dust storms (less sand storms)	Agreement after debate
8. Changes in sunshine intensity (sunshine has increased)	Full agreement
9. Changes in mean rainfall (less rain)	Full agreement
10. Changes in river / stream water flow, volume, level and/or depth (less water in the rivers)	Full agreement
11. Changes in the length / duration of drought (prolonged drought)	Agreement after debate
12. Changes in the timing (onset or end) of seasons (the cold season start later)	Full agreement
13. Changes in the timing (onset or end) of seasons (the hot season starts later)	Agreement after debate
14. Changes in the abundance of terrestrial fauna (some animals are less abundant)	Full agreement
15. Changes in the abundance of terrestrial fauna (some animals are more abundant)	Agreement after debate
16. Changes in the abundance of freshwater fish (fish are less abundant in ponds)	Agreement after debate
17. Changes in the abundance of freshwater animal species, excluding fish (frogs have disappeared)	Full agreement
18. Changes in land cover (plant cover has decreased)	Agreement after debate
19. Changes in the abundance of wild plant or fungi species stated as invasive (some plants appeared in great numbers)	Full agreement
20. Changes in cultivated species' fruit size (some fruits have decreased in size)	Agreement after debate

Figure 5. Local Indicators of Climate Change Impacts (LICCI) identified by the Tuareg of Illizi. The Figure indicates level of agreement with climate change as main driver each of the three Focus Group Discussions (FGDs): full agreement is indicated in green, and agreement after debate in orange.

of Ramadhan. The Tuareg also celebrate El Mawlid Nabawi, the day of Prophet Mohamed's birth. During these celebrations, Tuareg local tribes have song and dance competitions. The Sebiba is another festive day of Achoura, where Allah saved the prophet Josephus from the Pharaoh who was drowned in the sea. On this day, the Tuareg local tribes also celebrate dance and song competitions. Daily at night, the ritual of *tindi* is practiced by Tuareg women and men. This ritual consists of singing songs that speak of the courage and strength of men as well as historical accounts. Women sing and play the drums and men dance to the rhythm of these songs.

4.3. Perceived Climate-Related Changes

Our semi-structured interviews resulted in 20 LICCI. There was no consensus in the listing of 15 indicators of climate change impacts, but all the indicators were validated during FGDs (Figure 5).

Changes in elements of the atmospheric system, including a higher cloud cover, colder temperature, a delay in the start of the cold and the hot seasons, less wind, sandstorm intensity, and rain were mentioned by informants. In particular, respondents mentioned that the fight against drought is increasingly difficult as digging deeper and new wells or rationing the use of water become less effective in provisioning it. Some local community members, but not all, also mentioned changes in the physical system around them that were directly linked to climate change, especially a decrease in the river's volume. The Tuareg also reported changes in abundance of local fauna and flora, including increased presence of invasive species.

Interestingly, although the visual analysis of Figure 3 suggests that floods (a sign of water abundance among the Tuareg) were more abundant before the 1970 s, and have only happened twice since then, a decrease in the number of flood events was not mentioned by the Tuareg as one of local indicators of climate change impact.

Similarly, informants did not mention that drought and drought-related events are more common in recent times, although this trend is evidenced from the community timeline.

In contrast, two of the indicators of climate change impacts mentioned directly relate to temporal seasonal shifts of the hot and cold season and, in particular, to the seasonality of the rainy periods (Figures 4 and 5). The Tuareg have noticed a shift in the cold season and its associated rainy period, which has shifted from mid-December to mid-February in the past to early February-late March in the present. Informants also reported that the rainy period of the hot season had shifted from May–August to August–October (Figure 4). This change has a direct impact on agricultural activities, specifically shifting the moment when wheat is sown and thus shortening the wheat growing season (from October–May to February–May; Figure 4). Despite the reported changes in climate and environment, the Tuareg mentioned that other cultural and livelihood activities are carried out at the same times as in the past. Some informants believe that the present is a temporary challenging period due to “God’s wrath” and pray that climatic and ecological conditions will soon revert to their former state. However, informants told us that the number of pastoralists and herds has decreased, as many people have decided to settle down, transitioning into sedentary or semi-sedentary pastoral or non-pastoral lifestyles. Sedentary or semi-sedentary Tuareg rely on agricultural activities to a larger extent than nomadic pastoralists.

5. Discussion

The main result of this work is that, while both longitudinal (across years) and cyclical (yearly) temporal changes are perceived by the Tuareg of Illizi, only cyclical changes are consciously identified and related to climate change.

As for other Indigenous peoples and local communities (e.g., Leclerc et al., 2013; Ruggieri et al., 2021), the Tuareg local timeline is clearly dominated by ecological events (Figure 3). Both extreme events happening decades ago and community responses to those events remain anchored in Tuareg collective memory, potentially informing present and future reactions to similar events. For example, the Tuaregs have a clear memory of the extreme droughts occurring in the 1940’s, which were also recorded by the philosopher Albert Camus (Kassoul & Maougal, 2006), when many people died of starvation after several drought years.

The temporal analysis of the Tuareg community timeline seems to indicate a shift in the periodic occurrence of extreme climatic events, and specifically a reduction of the welcome floods and an increase in drought events in the last 50 years. This pattern corresponds to observations done with instrumental data. For example, tree ring record analysis also suggests that the drought events occurring in the 1980 s and then in the 2000 s have been identified as the most severe droughts experienced in the region since the Middle Ages (Touchan et al., 2008), in consonance with Tuareg’s perception of the gravity of these droughts. Moreover, according to weather predictions under climate change models for the region (Barkhordarian et al., 2013; Niang et al., 2014), these patterns will likely be aggravated in the future, and affect larger areas and neighboring communities as hyper-arid dryland areas expand (IUCN, 2019).

However, it should be noted that the interdecadal trends signaling an increase of extreme drought events are implicitly inferred from the timeline, and not explicitly identified by community members when directly asked about climate-driven changes. Informants relate current climate hardship to divine origins, and they consider that this temporary situation will revert to past conditions with appropriate moral and spiritual behavior. Association of climate change impacts with God’s will and resorting to prayer when crises encountered is given a theological explanation, including weather driven crises, has also been observed amongst other African communities (Cuní-Sánchez et al., 2012, 2018; Haron, 2017; Mubaya et al., 2012), in Europe (Gómez-Baggethun et al., 2012) and in Asia (Byg & Salick, 2009).

Climate change impacts the intensity, duration, timing, frequency, or quantity of various elements of the atmospheric system (e.g., sunshine, precipitation, temperature, wind, etc.) leading to temporal shifts in the beginning and end of locally defined seasons (IPCC, 2022). As ecological calendars are used to keep track of time-based seasonal changes in the habitat, it is not surprising that changes in the succession of cyclical events are quickly identified, particularly for people who depend on these calendars for their livelihood activities (Ahmed & Atiqul Haq, 2019; Chambers et al., 2021; Keyston Foundation, 2020; Savo et al., 2016). For the Tuareg, changes in the ecological calendar seem to be already impacting agricultural activities, specifically shortening the wheat growth season. In turn, this shift impacts the yields of most wheat local varieties, which are not adapted to current

conditions and are being abandoned. Far from being an isolated case, the result dovetails with previous research showing how changes in climatic conditions can lead to agrobiodiversity loss (Labeyrie et al., 2021; Ruggieri et al., 2021). Local reports of climate change impacts on the agricultural calendar may facilitate cooperation between state authorities and local dryland populations around the implementation of the aspects of National Climate Change plans relating to agricultural planning by establishing a common ground for decision-making and action.

Perceived cyclical changes also impact pastoralism (e.g., pastoral transhumance itineraries), even though pastoralist activities are carried out at the same time as in the past. Pastoralism is mostly impacted by a decrease of the number of herders and herds, with former nomadic herders becoming sedentary or semi-sedentary. This shift is often fueled by an extreme event (Snorek, 2016). Semi-sedentary pastoralists complement their animal's diets with fodder bought from governmental agencies who offer reduced prices to support pastoralist activities. Tuareg also benefit from subsidies to practice agriculture (e.g., sustained prices for seeds) and to obtain aid for well excavation (Snorek et al., 2017), which enable new sedentary lifestyles. Sedentary life brings a new comfort, but informants also mentioned that sedentarism is accompanied by a weakening of old traditions such as tindi. While the increasing frequency of extreme events may lead to increased sedentarism in the future, conversion of rangelands to cultivated lands intensifies the degradation of dryland ecosystems (IUCN, 2019). National Climate Change adaptation plans should envision alternatives to this potentially reinforcing feedback loop.

In contrast, for the Tuareg who continue to lead a nomadic life, cultural traditions and religion continue to be central to their daily activity. The non-urbanized landscape around these mobile Tuareg is considered holy and pure, especially in contrast to urban areas. The Tuareg believe life in the desert keeps them away from sins and allows them to better consecrate time to prayer and to God. As in other parts of the world (e.g., Castagnetti et al., 2021), their ecological calendar interweaves ecological and spiritual cycles. For example, prayers offered during the date harvest aim both to thank God for the harvest and to ask for rain. Spiritual cycles shape the relation people have with the land, contribute to respectful and sustainable landscape management practices, and strengthen local identity (Castagnetti et al., 2021).

Previous research shows that religious and spiritual practices are important to cope with recurrent disturbance and have contributed to develop institutional devices that are used in environmental extremes, such as sharing resources with the most needy, a collective response to crises that contributes to the maintenance of long-term resilience of social–ecological systems (Gómez-Baggethun et al., 2012). Here, we observe that spiritual values offer some cultural resilience to climate change impacts as they affect some peoples' choices to continue pastoralist lifestyles. At the same time, in Tuareg cultural practice there is little to explain climate change beyond that it is “God's wrath” or “God's will.” Combined with the lack of perceived decadal trends, a sense of hopelessness can hamper adaptation and give rise to inaction or feelings of inevitability. As new case studies emerge reporting the influence of cultural preferences, access to information, and wealth as determinants of the adaptation strategies taken by Indigenous peoples and local communities (e.g., Amani et al., 2022; Cuní-Sánchez et al., 2012, 2018; Hayati et al., 2010; Kaganzi et al., 2021), further research is needed to understand if being able perceive interdecadal trends also determines adaptation at local scales.

6. Conclusions

Indigenous peoples' and local communities' climatological and ecological knowledge has allowed them to adapt their livelihoods to local, sometimes harsh, conditions. Our study documents LICCI. This information has the potential to contribute to the Algerian National Climate Change plan, as one of its goals is to identify climate change impacts on society. In that sense, our study shows that the Tuareg of the Algerian desert observe changes in the local weather and ecological systems, although only changes in seasonal cycles are consciously identified and related to climatic changes. We observe various adaptation strategies to seasonal changes impacting agricultural practices, whereas inter-decadal increased frequency of extreme events seems to lead to a gradual abandonment of nomadic pastoralism. These results can inform climate change adaptation planning across expanding hyper-arid areas of dryland ecosystems.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

Data used in this article has been uploaded to Zenodo (Miara, 2022) [Dataset]. Original audio recordings and notes are not published to ensure anonymity.

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