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Harnessing indigenous knowledge and practices for effective adaptation in the Sahel

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The Sahel region of West Africa has experienced some of the most severe multidecadal rainfall variability over the past 50 years. Based on recollections of the past and observations of the present, local communities in the Sahel have developed extensive knowledge and understanding of their environment and climate that enables them to harness ecosystem services to support their livelihoods and survive environmental changes. Recent literature indicated that farmers' knowledge and perceptions of changes in the local climate are largely consistent with observed meteorological data, except for the more heterogeneous precipitation change. This understanding of changes in their environment combined with their indigenous knowledge can be particularly useful in data-sparse regions such as the Sahel. This review highlights the importance of indigenous knowledge in enabling effective adaptation in the Sahel and beyond. It outlines some future research avenues for fostering indigenous knowledge-based adaptation, including addressing barriers to mainstreaming of indigenous knowledge into climate research and policy.

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Introduction

The West African Sahel region — a semiarid and transitional zone between the Sahara desert and the Sudanian savannas — is a 'hotspot' not only of climate change exposure but also climate change impacts and is considered as one of the most vulnerable regions in Africa [1–3]. In this semiarid region, global warming is particularly enhanced, with surface temperature increasing faster than the global average [1,4]. There is evidence that anthropogenic climate change has contributed to the drying over the Sahel in the last century [1]. The region has experienced a rainfall intensification pattern with more intense rainfall throughout the rainy season, especially after the severe drought period in the 1970s [1,5–7]. In the future, temperature over the region is projected to rise faster than the global average [1]. Global warming above 2°C will double the frequency and duration of drought in the Sahel region [3].

Once home to several indigenous African kingdoms and now home to a myriad of ethnic groups and cultures, the Sahel is mainly inhabited by agricultural and pastoral communities, thus, the vagaries of climate are of great importance. Historical climate change has significantly impacted the livelihoods and all biosphere properties in the Sahel [3,8–10]. For instance, the series of historic droughts experienced in the Sahel resulted in unprecedent famine and massive social dislocation, particularly the severe droughts of the 1970s and 1980s [9,10]. Over the years, local populations in the Sahel have developed deep and sophisticated indigenous knowledge systems, based on their observations and interactions with the environment over generations, that have enabled them to harness ecosystem services to support their livelihoods and survive socioecological changes [11–17]. As climate change became a prominent global priority, understanding the importance and effectiveness of indigenous knowledge systems has also increased, especially how indigenous knowledge and practices can be harnessed to foster effective adaptation and mitigation actions [15,16,18–24]. This is imperative given the limited evidence of adaptation effectiveness across sectors and regions [25,26]. According to the latest Intergovernmental Panel on Climate Change (IPCC) report, indigenous and local knowledge can shape how climate change risk is understood and experienced, and can provide accurate and useful climate change information, observations, and solutions [21]. Such knowledge can be described as a range of cultural practices, wisdom, traditions, and ways of knowing the world [21,23]. We reviewed recent literature on crop and livestock farmers' knowledge and perceptions of changes in the climate in the Sahel and highlighted the extent to which

indigenous knowledge of climate change is consistent with the observed data. We then discussed the role of indigenous knowledge systems and practices in fostering effective adaptation in the Sahel and more broadly in Africa. We illustrated this with an in-depth analysis selected cases of effective adaptation practices in the Sahel informed by indigenous knowledge. We conclude by outlining some research avenues for fostering indigenous knowledge-based adaptation in the Sahel and beyond.

Farmers' knowledge and observed changes in the Sahel

The latest IPCC report assessed recent literature on crop and livestock farmers' knowledge and perceptions of changes in local climate in the Sahel [27]. Local farmers' knowledge and perception of changes in temperature and related stressors in the past 50 years were largely consistent with the meteorological observations [11,27–32]. However, their perception and knowledge of rainfall change are more heterogeneous. Local people's perceptions of change in the amount of rainfall was not always consistent with the observed meteorological data [27–30,32]. This consistency is also confirmed beyond the Sahel [33]. Nevertheless, farmers' knowledge and perceptions of changes in rainfall patterns (onset, cessation, intensity, and distribution) during the rainy season were consistent with the new era of climate extremes experienced in the Sahel following the severe drought periods [5–7,11,31,33–35]. This implies that rainfall patterns within the season, rather than the total amounts of rainfall, are a more important local indicator of climate change for farmers in the Sahel [30,34].

In a data-sparse region such as the Sahel, characterized by scarcity and uneven distribution of grounded data [36,37], farmers' knowledge and understanding of changes in their environment can be particularly useful [38]. For instance, current stations in the Sahel record three-hourly wind events, leaving many wind events unrecorded, and thus limiting the understanding of processes driving wind, rain, and dust to cause the erosion of Sahelian soils [37]. Tapping into farmers' observations of all instances of wind events can help improve understanding of processes driving soil erosion in the Sahel. Moreover, uncertainties in climate data in the region have huge implications for agricultural impact assessments [39]. In Northern Ghana, indigenous knowledge-forecasting systems developed over time were as accurate as scientific forecasting by the national meteorological department in forecasting rainfall events [40,41]. In addition, integrating scientific with indigenous forecasting improved forecast reliability, usefulness, and uptake [41]. Building on farmers' and local communities' rich and extensive knowledge of climate change impacts can be especially useful in improving agricultural impact assessments to inform effective adaptation planning in the agriculture sector in the Sahel and the West Africa region [30,32,42–44]. However, this requires a systematic documentation of local indicators of climate change impacts developed and used by farmers and local communities in the Sahel, a prerequisite to address barriers to transferability, integration, and scalability of indigenous knowledge to climate change research and policy [45,46]. The platform for sharing and co-constructing knowledge on adaptation strategies used by farmers in Burkina Faso can be a good example that can be expanded to the West African regions [47]. The architecture of the platform is a semantic wiki based on ontologies that formalize endogenous knowledge and adaptation practices in agriculture and food systems [47,48]. As local indicators used by indigenous people to track changes in local climate might also change in response to global warming [21,49,50], it is crucial to further understand how indigenous knowledge systems and practices could evolve and remain effective in a changing climate. This understanding can help identify, for instance, changes in management practices that respond to local climate changes. This can also provide a better understanding of how climate change can threaten the generation, transmission, and preservation of indigenous knowledge [21].

Indigenous knowledge and climate change adaptation in the Sahel

According to the latest IPCC report, global adaptation efforts have benefited from the inclusion of indigenous and local knowledge [21]. Recent global systematic reviews provided the evidence of the usefulness of indigenous knowledge for adaptation to climate change across regions, especially in tropical rural areas and drylands [20,23]. The analysis also highlighted the diversity of adaptive responses by local communities and indigenous people across the world [22,23]. In Africa, analysis of recent literature acknowledged the valuable role of indigenous knowledge for adaptation [19,24,43,50] and in maintaining food and nutrition security in a changing climate [51]. A recent analysis of the Global Adaptation Mapping Initiative (GAMI) database [25] showed that indigenous knowledge systems support the management of climate-related risks to water and agricultural production in Africa [24]. Implementation of water adaptation responses informed by indigenous knowledge is prominent in West Africa [24]. Through their rich indigenous knowledge systems, local communities in the Sahel have developed adaptation strategies that enabled them to reduce their vulnerability to climate variability and change over time [11,14–16]. Their indigenous knowledge systems have been crucial for strengthening people's resilience to and recovery from major environmental change, such as the severe droughts experienced in the region in the 1970s and 1980s [9,12,13,15,16]. We reviewed selected cases of effective indigenous knowledge-based adaptation practices in the Sahel (Table 1).

Table 1

Selected cases of effective indigenous knowledge-based adaptation practices in the Sahel.

Adaptation practices	Description	Countries	Outcomes or benefits	Supporting references
Zaï	A traditional integrated soil and water management practice that consists of digging pits in the soil during the preseason to catch water and concentrate organic matter.	Burkina Faso, Niger, and Mali	Enhances soil structure and minimizes erosion. Maintains higher infiltration rates and conserves soil moisture, which helps to overcome seasonal dry-spells. Promotes carbon storage in soil. Improves overall productivity due to medium- to long-term reconstitution of soil fertility.	[13,52,62]
Farmer-managed natural regeneration (FMNR)	It consists of deliberate retention of trees on cultivated land. It is characterized by the regeneration or regrowth of existing trees and shrubs on farmlands or from naturally occurring tree stumps, roots, and seeds. Farmers promote regeneration through pruning, mulching, and active protection.	Niger	Trees are an integral part of the agricultural system, providing food, fuel, fodder, medicinals, wood for buildings, cash commodities, as well as contributing to soil fertility, soil and water conservation, and environmental protection. Buffers climate risks and contributes to climate change mitigation.	[12,13,53,55,56]
Tailored-conservation agriculture for West Africa semiarid areas	Consists of a gradual rehabilitation of biomass production function of the soil through increased nutrient input and traditional water harvesting measures such zaï, in order to restore soil hydrological properties as a prerequisite to boosting biomass production. During this restorative phase, the regeneration of native evergreen multipurpose woody shrubs traditionally and deliberately associated with crops and managed the year around is encouraged. The final step is to shift to classical, less labor-intensive conservation agriculture practices once appropriate levels of soil fertility and water capture are enough to allow increased agroecosystem primary productivity.	Burkina Faso, Niger	Improves soil fertility, enhances soil structure, and minimizes erosion. Maintains higher infiltration rates and conserves soil moisture, which helps to overcome seasonal dry-spells. Favors soil biological activity, provides fuel woods. Promotes carbon storage in soil. Improves overall productivity due to medium- to long-term reconstitution of soil fertility erosion.	[14]
Transhumance or mobility	Consists of the seasonal movement of livestock between different pastures, often following natural cycles of temperature and vegetation. It is a form of pastoralism that has been practiced for thousands of years in the Sahel.	Sahel	Strategy for managing variability in water and pasture, and for responding to disasters and other shocks. Allows animals to access diverse and nutritious resources, avoid harsh weather and predators, and reduce the risk of overgrazing and disease.	[32,57,58]
Spatial field dispersion	Based on their knowledge of the highly variable (both in space and time) and erratic nature of rainfall patterns, farmers have developed an indigenous practice consisting of a dispersion of fields cultivated by a single household throughout the village territory. Farmers prefer to have several small, dispersed fields rather than one large field.	Niger	Increased interannual yield stability and reduction of the risk of severe food shortages.	[59,60]
Crop diversity management	Consists of the use crop and varietal diversity to respond climate change-induced changes in rainfall patterns. Examples of management practices include (i) abandonment of long-cycle varieties during drought periods, (ii) adoption of short-cycle varieties during periods with shorter rainy seasons, and (iii) reinstating of long-cycle varieties with the return of rains.	Senegal	Increased stability of food production and fodders for livestock and reduction of risk of food shortage.	[61]

The traditional integrated soil and water management practice *Zaï* is developed from indigenous knowledge systems in the Sahel to combat land degradation and improve soil productivity of previously abandoned bare soils [13,52]. By contributing effectively to rehabilitating previously abandoned and degraded bare lands and substantially increasing crop productivity, *Zaï* practice improves smallholder farmers' resilience to climate variability [13,19,52,53]. To reduce its labor requirements, *Zaï* practice has been mechanized in Burkina Faso using animal traction, resulting in significant labor and time-saving, and improved income [54].

The farmer-managed natural tree regeneration practice is another well-known indigenous innovation reflecting farmers' local ecological knowledge that triggered massive regreening across the West African Sahel [12,13,55,56]. There is extensive evidence of positive benefits, including agricultural productivity improvement, buffering climate risks and carbon sequestration [12,13,55,56]. Farmers' knowledge of these ecosystem services and benefits provided by agroforestry systems has provided the basis for guiding management practices [12].

Another example is a tailored shrub-based conservation agriculture system developed for semiarid West Africa to reduce soil degradation, improve crop productivity, and mitigate drought impacts [14]. This technology is based on indigenous and ingenious traditional local soil restoration practices by the Sahelian farmers [14]. The tailored shrub-based systems improve soil fertility and soil water conservation, reduce soil erosion, favor soil biological activity, and provide fuel woods, with only limited competition with livestock [14].

To adapt to feed and water scarcity during drought periods, Fulani herders in the Sahel usually make use of their rich and extensive knowledge of their environments and landscapes, the natural resources available (pasture, water sources, etc.), and their spatial distribution to develop effective mobility-based adaptation strategies [32,57,58]. In fact, mobility is central to the livelihoods of pastoral communities in the Sahel and is an effective adaptation strategy to scarcity of water and pasture resources resulting from droughts [32,57].

Based on their knowledge of the highly variable (both in space and time) and erratic nature of rainfall patterns, farmers in Niger have developed an indigenous practice consisting of a dispersion of fields cultivated by a single household throughout the village territory [59,60]. Assessments of this indigenous practice demonstrated its benefits in terms of increased interannual yield stability and reduction of the risk of severe food shortages [60].

Based on their observations of local environmental changes and their knowledge of the functional traits of agrobiodiversity, Sereer farmers in Senegal have adapted their crops to adapt the high seasonal variability and rising temperatures caused by climate change over this past century [61]. The modification of the variety of crops and crop varieties to respond to climate change ensures a stability in crop production and fodder availability for livestock, and a reduction in risk of food shortage.

Concluding remarks

This perspective emphasizes the sophisticated and complex understanding of the local climate by crop and livestock farmers in the Sahel, a region where meteorological stations are scarce and unevenly distributed. Except for the more heterogeneous precipitation changes, farmers' knowledge and perceptions are largely consistent with observed meteorological data. Nevertheless, with some exceptions, farmers' perceptions are yet to be substantively embraced as a contribution to adaptation discourse in climate change research field [63]. This paper also highlights the potential and usefulness of indigenous and local knowledge systems in informing policymaking and adaptation planning in the Sahel.

There is evidence that harnessing indigenous knowledge systems in adaptation responses can result in higher risk reduction compared with responses without indigenous local knowledge [24]. In other words, adaptation responses in Africa can be more effective when informed by indigenous and local knowledge [19]. Yet, very few African countries included indigenous knowledge system-based responses in their Nationally Determined Contributions (NDCs) and their national adaptation policies [24,50]. For instance, while indigenous and local knowledge have been acknowledged as a valuable resource for climate adaptation in agricultural systems in Ghana, it was only mentioned in national climate policy, without a comprehensive mainstreaming [64].

Documenting and inventory of best and most successful cases of indigenous knowledge and practice-based adaptation in the Sahel can provide the evidence base to inform further action research, policy planning, and intervention design. In addition to the NDC revision, many countries in the region are currently formulating their National Adaptation Plan. These two policy processes can be informed by such an inventory of effective indigenous knowledge-based practices.

Indigenous and local knowledge goes beyond a mere collection of local environmental information, and represents a nested information–practice–worldview knowledge system [65]. Thus, a coproduction and collaborative approach is crucial for effective mainstreaming of

indigenous knowledge and practices in adaptation planning [45]. Against the backdrop of hydroclimatic intensification currently experienced in the Sahel as well as projected future changes, understanding how resilient the indigenous knowledge systems are might provide further insights on its long-term effectiveness.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

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

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