10 Indigenous Knowledge and Agro-ecology: Integrating Traditional Practices for Sustainable Agriculture

Expedito Nuwategeka[1]*, Martine Nyeko[2], Beatrice Arwenyo[3], Christine Oryema[4], Francis Atube[5], Harriet Angwech[4], Alfonse Opio[4] and Geoffrey Maxwell Malinga[4]

[1]Department of Geography, Gulu University, Gulu, Uganda; [2]Department of Biosystems Engineering, Gulu University, Gulu, Uganda; [3]Department of Chemistry, Gulu University, Gulu, Uganda; [4]Department of Biology, Gulu University, Gulu, Uganda; [5]Department of Agriculture Education, Gulu University, Gulu, Uganda

Abstract

Indigenous knowledge (IK) is one of the key tenets in sustaining agro-ecological niches as communities strive to achieve sustainable agriculture in the face of global challenges such as climate change. Sustainable agriculture has been used in recent times to mean farming, which can meet society's current food, fodder, and textile needs without compromising future generations' abilities to meet their own. Using a wide range of case studies, we explore the role of IK in understanding the agro-ecological services and practices that promote sustainable agriculture. First, we analyze the concept of sustainable agriculture, then discuss IK. Second, IK integration in agricultural and environmental management is presented. Finally, we conclude by making a case for knowledge cross-fertilization for enhanced synergies in the drive to achieve sustainable agriculture.

Keywords: Indigenous knowledge, agro-ecology, knowledge integration, sustainable agriculture

10.1 Introduction

Agro-ecological environments are under stress due to highly intensive and extensive agricultural practices that have been developed to satisfy the ever-increasing demand for food, fodder, fiber, and energy. Unlike the extensive system, an intensive agriculture is a characteristically high-input and high-yield system that depends on technology and mechanization to maximize production on a limited amount of land. The extensive agriculture is common where smallholder farmers rely on the practices with limited access to expensive technology.

According to FAO (2023a), agriculture employed up to 873 million people in 2021, translating to approximately 27% of the global workforce. By 2019, half of the world's habitable land was used for agriculture, where three-quarters of all agricultural land was dedicated to livestock production (Ritchie and Roser, 2019; FAO, 2020). This scenario has led to ecological simplification (Nichols *et al*., 2017), resulting in loss of biodiversity, soil degradation, water

*Corresponding author: exnuwategeka@gu.ac.ug

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stress, and modification of local agro-climatic conditions. Therefore, when agricultural practices are used for ecological stability, numerous ecological benefits such as soil stabilization, nutrient cycling, biodiversity conservation, and favorable climate moderation are achieved. The beneficial agro-ecological undertakings may include organic farming practices, crop rotations, use of animal manures or compost, and cover cropping (Nichols *et al*., 2017; Sundberg, 2022). A successful integration of these practices can greatly lead to sustainable agricultural undertakings.

Sustainable agriculture aims at fostering ecological, economic, and social stability, where communities are able to derive from agriculture their present needs without compromising the ability of future generations to also get their own needs (Siebrecht, 2020). It favors techniques that emulate nature to preserve soil fertility, prevent water pollution, and protect biodiversity, thereby creating a peaceful environment and coexistence. Sundberg (2022) expounds that agricultural sustainability also means the whole ecological system is more resilient to droughts, floods, and other impacts of climate change.

Agro-ecology, as a component of sustainable agriculture, according to Malézieux (2012), is not about promoting a few magic bullet solutions that are divorced from local contexts through top-down approaches. This means the solutions must be generated from and applicable to/in the local context of the farmers. Therefore, the contextual nature of these solutions is hinged on the agro-production knowledge that is indigenous to particular ecological settings. In this chapter, we explore the central role of indigenous knowledge (IK) in supporting agricultural undertakings that can be sustainable. We move from the concept of sustainable agriculture and then delve into the notion of the nature of IK before discussing how IK can be a valuable tool in achieving sustainable agro-ecological benefits.

Indigenous agricultural practices of water conservation, pest control and management, soil conservation, and crop and animal production have been developed, tested, and certified within a local context, and therefore, fulfilling the cardinal requirement of bottom-up development interventions. This condition favors what Siebrecht (2020) refers to as knowledge translation, the process of getting knowledge used by stakeholders. Since trial and error are at the root of most IK-based innovations (Akullo *et al*., 2007; Buthelezi and Hughes, 2014; Ezeanya-Esiobu, 2019), they may lack some empirical experimentation in their formulation. We do not approach IK in a romanticized manner in our discussions in this chapter, but recognize the underlying limitations it may have, embrace the positives, and advocate for knowledge cross-fertilization with other knowledge, especially conventional agricultural knowledge. This is aimed at tapping into complementary synergies that can project sustainability in agricultural undertakings, which can also lead to the design of biodiverse, energy-efficient, resource-conserving, and resilient farming systems.

10.2 Sustainable Agriculture

Agriculture plays a vital role in the sustenance of human life on Earth. It is the source of food, fiber, and in some cases fuel. It employs more than 27% of the world workforce (FAO, 2022). Agriculture advances opportunities for equity and development. In some developing countries, agriculture contributes to over 25% of the gross domestic product (World Bank, 2023). As to whether these benefits are sustainable leaves a lot to be desired. The notion of sustainable agriculture is therefore important in ensuring that the current agricultural practices do not compromise the needs of the future generations' agriculture. For example, most of the growth and technological advancement in agriculture aim at increasing productivity of land as a finite resource. This advancement, including introduction of fertilizers, agrochemicals, such as weedicide, pesticide, herbicides, and many others, can have dangerous environmental consequences such as soil erosion, river and lake eutrophication, and many others, if not properly used. In addition, exposure to agricultural pesticides and chemicals, for example, glyphosate, has been linked to health concerns.

The philosophy and practices of sustainable agriculture require that practitioners integrate three main objectives into the farming systems (Fig. 10.1): a healthy environment, economic

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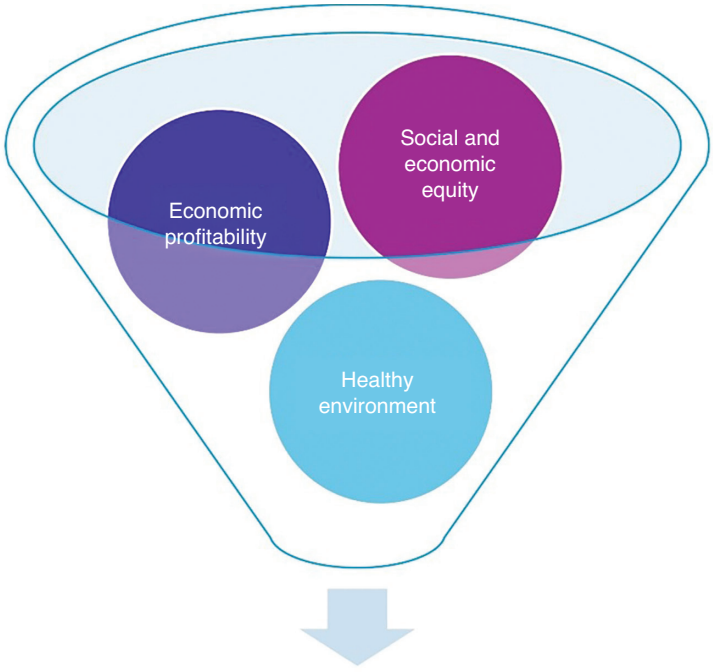


Fig. 10.1. The blending components of economic, social, and environmental aspects for sustainable agriculture.

profitability, and social and economic equity (Velten *et al.*, 2015).

Sustainable agriculture must ensure that the environment in which agriculture is practiced remains healthy (environmental health). It is a farming system that allows for more effective use of natural resources, reduces agricultural environmental impacts, and increases farmers' capacity to adapt to climate change and climatic variability without endangering the ability of the present or future generations to meet their own needs. Sustainable agriculture ensures that the productivity of the land is maintained. The following farming practices are essential for land productivity management: crop rotation involves growing a given plant in a field for one growing season, followed by planting a different crop in the same field for the subsequent growing season (Pooniyan, 2023). According to Sharma and Kanta (2021), crops planted in low nutrient soil are susceptible to developing diseases and attracting pests. In no-tillage system, crops are planted without triggering soil disturbance (Heritage Perth, 2014). This strategy preserves soil structure, thus minimizing erosion. Further, the application of organic manure involves turning organic waste into useful compost (Sachan, 2023). This process enriches the soil, reduces the need for chemical fertilizers, and minimizes waste. Therefore, to realize sustainable agriculture, there is need for favorable legislation (Velten *et al.*, 2015). This will promote food security, protect water quality, and promote biodiversity.

Unfortunately, most of the current agricultural practices in the world are unsustainable and characterized by use of too much (unregulated) synthetic chemicals, growing and producing genetically modified organisms, which require use of too much environmentally unfriendly pesticides that are harmful to both humans and environment. According to Statista (2024), 46.3 million metric tons of nitrogen fertilizers were consumed in 1965. By 2021 however, this

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consumption had risen to 195.38 million tons. Nitrogenous fertilizers are the leading cause of eutrophication (Arwenyo *et al*., 2023), which is linked to algae blooms and oxygen shortages in the water for aquatic animals. Additionally, it has been reported that biochar when added to soil influences microbial colonization, legume root nodulation, and dry matter accumulation and legacy effect (Xin *et al*., 2022; Uzoh *et al*., 2025). Similarly, by 2019 approximately 190 million hectares globally were planted with genetically engineered crops (Shahbandeh, 2024). The USA is currently the leading producer of genetically modified crops followed by Brazil and Argentina. Additionally, monocultures that are associated with use of heavy machinery and deforestation, overproduction, and food waste are among other associated practices that have rendered agriculture unsustainable.

Sustainable agriculture should also ensure economic viability of the sector. Farmers must get economic profitability out of their enterprises. Those practicing sustainable agriculture must therefore seek efficient use of resources and cost-effective methods of production. Paradoxically, we note that some of the most abject poverty in the world is found among the farming communities (Dixon *et al*., 2001), which is even true in areas with medium to high rainfall and significant agricultural development potential. Deliberate effort is therefore needed to make agriculture commercially viable if it is to remain sustainable. Depending on the region and the farming communities, interventions can range from mindset change of the farming communities, so as to exploit their aspirations and ideas, to enhancing agricultural information and human capital. Absence of reliable information may lead to poor decisions and wastage of resources.

In addition, improving technologies and management of natural resources would result in high return on agricultural investment. This is so because better management of natural resources ensures stability in the supply of environmental goods and services that are essential for the sustenance of agricultural production systems, majorly farm-based systems. Thus, supply of essential nutrients is hinged on the biogeochemical cycles of elements such as water, nitrogen, carbon, and sulfur. The natural flow of these substances is coupled to the physical climate system (Ciais *et al*., 2013). For example, a complementary function of carbon sequestration is provided by agricultural lands where biomass, together with better tillage practices, cover cropping, and mulching, has been observed to improve water conservation and increase the storage of carbon from the atmosphere into farmland environments (Lal, 2004). For example, Fan *et al*. (2023) reported that mulching can lower runoff and soil loss by 47.4% and 76.2%, respectively.

Another economic element that could ensure sustainable agriculture is the aspect of price stabilization of agriculture output. Economic justice is one of the components of the agricultural sustainability debate. More often in developing economies, farmers face volatile prices for their produce. This leads to unstable incomes and economic distress. Price stabilization that minimizes price fluctuation and ensures fair remuneration to farmers is essential. Most farming communities are grappling with the necessary evil of middlemen who manipulate markets and prices to the disadvantage of the smallholder farmers. According to Oguoma *et al*. (2010), farmers encounter high production costs in their efforts to boost production but hardly get fair pricing of their products from the middlemen, the bulk of whom are farm gate buyers. The real profit goes to the middlemen who buy up the farm products at almost give away prices and sell at outrageous prices to consumers. This practice economically impoverishes the farmers, making agriculture an agent of economic deprivation instead of economic emancipation.

Furthermore, sustainable agriculture must provide social and economic equity for all those involved (producer, processor, retailers, and consumers). This can be achieved by ensuring fair wages and safe working conditions. Equity issues also include non-engagement in child labor, especially in institutionalized agricultural enterprises such as tea estates in the Global South. Worldwide, the majority of child labor (70%) is found in the agriculture sector; more than 112 million children work in agriculture, including in farming, fishing, aquaculture, forestry, and livestock (FAO, 2023b). The scenario points to the lost opportunities for children to go to school and acquire education, which could change their socio-economic status and that of their

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families in future. Generations of low-skilled labor force and poor-quality demographics have been produced by agricultural undertakings (Adamu, 2015), which rob children of opportunities for formal schooling in the name of getting "quick money" in the form of wages.

Although women make up 43% of the global agricultural labor force (FAO, 2022), they face serious discrimination. For instance, in many parts of the world, women are denied the right to access to credit and financial services, land and livestock ownership, equal pay, and participation in decision making entities. Thus, there is need for policies that promote gender equality at all levels. Moreover, women could be empowered with business planning and entrepreneurial skills to encourage them participate more meaningfully toward sustainable farming.

In conclusion, sustainable agriculture is about how we grow food, fodder, and fiber while ensuring the resilience of the production systems for generations to come (Velten *et al.*, 2015). The systems have social, economic, and environmental components; and all three are equally important in the drive to ensuring sustainable agriculture. In sustaining agriculture, the knowledge component is very crucial because it guides production and resource conservation. One of the knowledge assets possessed by smallholder farmers in the Global South is IK. This knowledge has been developed within an ecosystem encompassing all aspects of life and is therefore location specific, tested, and certified. Section 10.3 explores the nature of IK.

10.3 Nature of IK

People throughout the world are exploring alternative ethical foundations, cosmologies, paradigms, and philosophies in search of models, which may sustain nature rather than destroy it (Charles and Cajete, 2020). Mankind has survived on knowledge to solve various problems. As mankind is dispersed across the Earth, what is knowledge to a particular group might be insignificant to another in a different setting. Environmental factors, language, and biological and cultural dispositions influence what every group classifies and values as knowledge (Ezeanya-Esiobu, 2019). The localization and domestication of knowledge have led to the birth of IK across the globe. Different scholars have differently defined IK. While Ubisi *et al.* (2019) define it as knowledge that is unique to a specific society or culture, Mbah *et al.* (2021) embrace the UNESCO view that it is understandings, skills, and philosophies developed by societies with long histories of interaction with their natural surroundings.

Most definitions (Ajibade, 2003; Akullo *et al.*, 2007; Abebe, 2011; Gadgil *et al.*, 2021) relate the knowledge with the localities where it is developed through the intimate human–environment relationship. Therefore, in this chapter, we consider IK as a social construction of reality expressed in a set of ideas, beliefs, practices, and notions that are developed by natives inhabiting a distinct geographical space. This definition differentiates "local knowledge" from "indigenous knowledge" given that different terms such as ethno-science, local science, village science, traditional science, people's science, indigenous technical knowledge, and rural people's knowledge (Williams and Muchena, 1991) have been used to mean IK, when they may not actually mean so. While local knowledge may not necessarily be 'indigenous,' IK is developed by natives who claim ancestry to the place as pointed out by Charles and Cajete (2020) that indigeneity means being of and within a place.

IK has gained international recognition for its role in solving challenges facing mankind. For example, the Yunnan Initiative (2000) acknowledges the importance of agrobiodiversity as a resource for local and indigenous communities. Article 8.j of the Convention on Biological Diversity (1995) calls for the wider use and application of knowledge, innovations, and practices of indigenous and local communities that are relevant to the conservation of biodiversity. Other international agreements and conventions that entrench IK include the Earth Summit (1992), UN World Conference on Sustainable Development (Rio + 20) (2012), and the WCED (1987).

IK is distinct as it has peculiar attributes that differentiate it from other knowledge systems. It has a local character in origin. Inoue and Moreira (2016) note that IK is embedded and bounded in the local and by the importance of the community and its moral values. This means it is developed to

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address local challenges that are only specific to a place. So, the knowledge is pragmatic in nature, as Ezeanya-Esiobu (2019) points out that the knowledge has an automatic reaction, meaning that it responds to an immediate circumstance facing the community. UNESCO (2023) reinforces this argument that IK informs decision making about the fundamental aspects of day-to-day life.

Relatedly, since knowledge is developed in a "stimulus-response" way, and knowing that there are ever-changing social and environmental stimuli, then IK is dynamic and innovative. As it is a by-product of the very lives of its adherents and does not subscribe to rigid interpretations due to the changing nature of man's interaction with his environment (Ezeanya-Esiobu, 2019), this knowledge is always under construction, reconstruction, evolving, and metamorphosing. The knowledge embraces new discoveries as it discards the no-longer-applicable aspects of its body, making it relevant to any existing stimulus.

IK is both conservative and dynamic. It is conservative in that valuable traditional knowledge is preserved, and the dynamics in that knowledge is reconstructed in response to contemporary realities (Beckloff, 2008). The conservative nature of IK is seen in its preservative character, where its important community heritage is guarded and held in high regard. The dynamic nature is expressed in the way it is able to metamorphose when new realities emerge. IK springs from the past but continues to be constructed in the present as it adjusts to ever-changing contexts (Maurial, 1999; Mwadime, 1999; Semali, 1999; Nsamenang, 2004).

IK is holistic—it does not separate disciplines as if they were different parts of the same system but rather views life/nature as a whole. When one part of the knowledge is removed or isolated, then it leads to the collapse of the entire knowledge. Essentially, practices cannot be separated from language, economics, nor spirituality. They are inter-woven into a strong code that has sustenance at its base. UNESCO (2023) emphasizes that this knowledge is integral to a cultural complex that also encompasses language, systems of classification, resource use practices, social interactions, ritual, and spirituality. For example, agricultural practices of planting and harvesting that are rooted in IK cannot be separated from spirituality and belief systems (Buthelezi and Hughes, 2014; Baye and Teshome, 2020).

In its nature, IK is nurturing. IK practices are based on an ecological exchange, not economic exchanges. This implies that there is restraint in resource exploitation, where production is for subsistence needs (Desta and Smithson, 2010). For this reason, IK is ecologically sensitive to the capacity of the environment and does not inflict ecological stress on environmental resources. This is because communalism and group solidarity (Okpilike, 2012) are at the center of this knowledge, not individualism. Specifically, in Africa, IK is hinged on the "ubuntu" philosophy—the overarching concept of humanity first.

It is based on experience acquired from observations over time. Thus, the observations are a product of an iterative process of trial and error (Akullo *et al*., 2007; Buthelezi and Hughes, 2014; Ezeanya-Esiobu, 2019). IK, therefore, represents generations of observations, analysis, and experimentation (Honward, 2023). Because of this, all IK practices are dependable because they have been tried and certified through a process of collective validation carried out by a community within its socio-ecological niche. This bottom-up process of knowledge production and consumption is a pivotal point in ensuring social as well as environmental justice, which are at the root of sustainable development. For this reason, this knowledge may be the most useful one for local-scale decision making (World Bank, 1998).

IK is socially differentiated (Salas *et al*., 2004). While it is collectively owned (Honward, 2023), the pockets of the knowledge may be held by some specialized groups segregated along age, gender, and trade lines. Some knowledge is a reserve of women, for example, knowledge related to traditional birth practices. Indigenous animal health practices are a reserve of pastoralists, and hunting a reserve of men. It is worthwhile noting that this seeming specialization does not render the knowledge into compartments. The connecting threads of language, rituals, and spirituality still run through these facets of IK. Given the nature of IK, its integration in agricultural and environmental management practices may lie at the core of sustainable agriculture. So, we explore its integration in agriculture with the view of environmental

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management in agro-ecological situations. From case reviews, Movarej *et al.* (2012) noted IK as the provider of problem-solving strategies for local communities, which helps shape local solutions to revitalizing farming systems and environment.

10.4 IK Integration in Agriculture and Environmental Management

Integrating IK into agriculture and environmental management is crucial for sustainable practices. Indigenous peoples, who have lived in harmony with their natural surroundings for generations, possess a wealth of knowledge about their local ecosystems, sustainable resource management practices, and unique cultural perspectives that can play a pivotal role in shaping effective environmental conservation strategies today (Nakashima *et al.*, 2002; Bohensky *et al.*, 2013). Therefore, incorporating indigenous farming methods into modern large-scale farming could result in a more resilient, eco-friendly, and sustainable food system that can minimize food insecurity.

Although IK, mostly in the African context, has long been overlooked and criticized (Nakashima *et al.*, 2002), many governments and international development agencies have recently recognized that IK provides the basis for participatory approaches to development that are both cost-effective and sustainable (Bohensky *et al.*, 2013; Drissi, 2022). For example, IK is known to contribute toward land use planning and soil conservation (Shiferaw *et al.*, 2013; Zwane and Masipa, 2021). Through transfer of IK, communities have developed useful land management techniques (Shiferaw *et al.*, 2013). For instance, they know soil types, optimal land use, and erosion patterns. Agricultural methods such as shifting cultivation, contour farming, terracing, and agroforestry, which are rooted in IK (Singh *et al.*, 2021; Melash *et al.*, 2023), have been used to maintain soil fertility and prevent soil degradation. These practices prioritize both ecosystem health and the physical health of the community.

Typical indigenous systems integrate livestock, trees, and crops (Zwane and Masipa, 2021). Practices such as intercropping, polyculture, crop rotation, fallowing (Fig. 10.2), and rotational grazing are used to reduce pests, enhance soil health, and promote biodiversity (Hart and Mouton, 2005; Odeyemi *et al.*, 2007; Rathore *et al.*, 2021). Many researchers have demonstrated that indigenous farmers have practiced their skills over generations (World Bank, 1998; Dominics and Fuchaka, 2016; Drissi, 2022). This, therefore, allows them to know when to rotate crops, plant, and harvest based on local climate and soil conditions and other ecological indicators. According to Sharma and Kanta (2021), in India and Nigeria, crops for rotation were selected based on how they relate to each other. This majorly minimizes competitive relationships but rather promotes supplementary relationships. For instance, Legumes such as beans and groundnuts fix nitrogen into the soil from the atmosphere with the help of their root nodules, which is then used by the crops grown after. Crops having a deep root system can pull essential nutrients, including phosphorous and potassium, from the deep soil profile up for subsequent shallow-rooted crops to utilize. Thus, the sequence of crops grown was carefully planned to sustain soil nutrients, control pest populations, suppress weeds, and build soil health.

Techniques including traditional livestock breeding methods, crop diversity, and seed saving are fundamental local agricultural practices (Zwane and Masipa, 2021) because they blend well with the production system, as well as the ecosystem of the places where they are developed and practiced. In several places, the fields were left to fallow for about 2–5 years (Sharma and Kanta, 2021). This helps the soil to regain its fertility. Moreover, during fallowing, domestic animals are grazed on the fields. This subsequently enhances the soil fertility because of their droppings.

Also, the indigenous people practice natural pest control methods to maintain healthy crops (Melash *et al.*, 2023). Biological pest control and companion planting are examples of these indigenous approaches (Rathore *et al.*, 2021). Certain crops were planted together to prevent pests (Hart and Mouton, 2005; Odeyemi *et al.*, 2007). In some cases, herbal remedies for plant diseases are used (Rathore *et al.*, 2021). For instance, farmers in Gonder, Ethiopia, control pests and diseases organically (Melash *et al.*,

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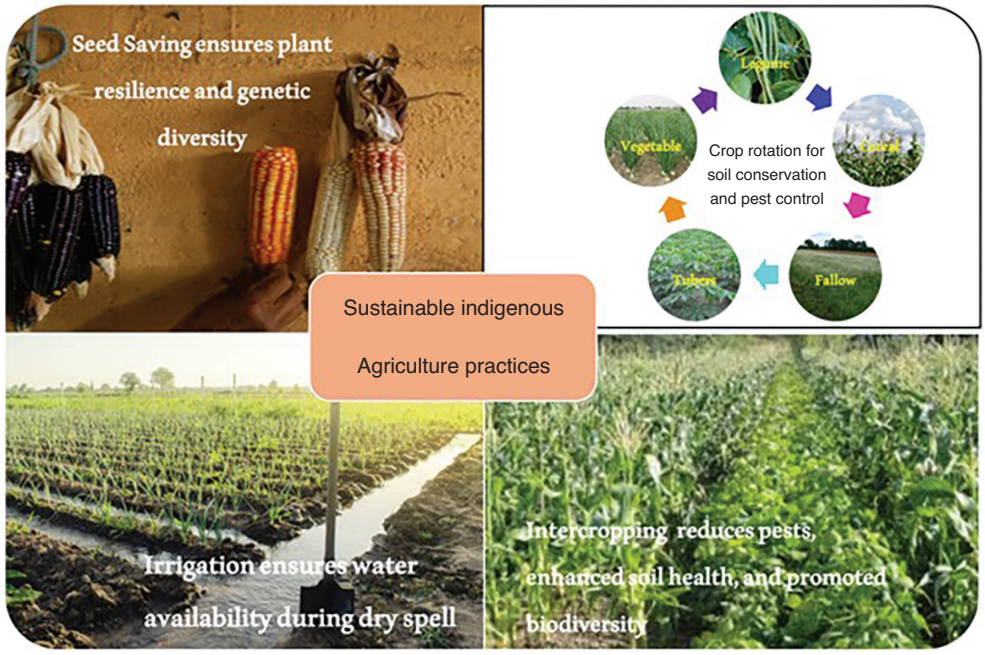


Fig. 10.2. Mozaic of sustainable indigenous agricultural practices of genetic diversity, crop rotation, water availability, and intercropping.

2023). They apply cow urine to protect their crops against pests and diseases both in the field and during storage. Plants or seeds were treated with cow urine to lessen or eliminate the effect of fungi and some insects including earthworms. This practice is ecologically beneficial to not only the plants but also soils and the *in situ* soil water conservation as different plants coexisting in the same field have a multiplicity of benefits ranging from nitrogen fixation, litter for enhancing soil organic carbon, and cover cropping to prevent soil loss from runoff.

Furthermore, IK and practices have developed creative ways of managing water resources based on their locations (Behailu *et al*., 2016). Techniques such as irrigation canals, aquifer management, and rainwater harvesting are based on IK (Kangalawe *et al*., 2014; Behailu *et al*., 2016). For example, the inhabitants of north-east region of India practiced both bamboo drip irrigation and bench terrace irrigation (Sharma and Kanta, 2021). While, in bamboo drip irrigation, hill slopes are steep with low soil depth using locally available bamboo species, bench terrace irrigation taps the hill stream as it emerges from the forest and channels to the terraces. Similarly, the people from Himalayan state use snowfall as source of water. Spreading ash over the snow converts it to water, which is collected in small ponds and canals built for irrigation. Native South Americans use several irrigation tactics to support their traditional farming systems, including Andean terraces, qanats, chinampas, and waru waru (Crop Circle Farm, 2024). These practices contribute to sustainable agriculture by ensuring water availability during dry spells. Another related practice is the zonation of production zones to match seasonal weather changes; low-lying areas are reserved for dry-season agriculture (crop growing or grazing), while higher grounds are exploited during episodes of rainfall.

In addition, farmers, in Africa specifically, have historically used various indigenous signs to predict weather based on their environment and cultural beliefs (Imoro *et al*., 2021). These indicators mostly took different forms such as animal indicators, atmospheric indicators, plant indicators, and human ailments. For example, in Kenya, the flowering of coffee trees indicates

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the beginning of rain (Filho *et al.*, 2023). Other countries, including Tanzania, Botswana, South Africa, and Zimbabwe, rely on blossoming of peach trees to predict the beginning of the rainy season. These signs were useful for making farm-level decisions, for instance, on when to plant and which crops to cultivate.

IK, particularly in the African context, has long been ignored and maligned by outsiders (Ponge, 2013). Agricultural development cannot be dissociated from the IK, for it still belongs to the agricultural communities in many parts of the world. IK goes beyond what is reflected in farming methods and techniques as it also includes environmental knowledge, perception, and consciousness or intuition, and it frequently involves calculating the motion of the moon or the sun, astrology, environmental conditions, geology, and meteorology (Limpo *et al.*, 2022). Integration of traditional agriculture with modern agriculture can thus bridge the huge gap between indigenous and modern peasants (Singh and Singh, 2017). In summary, there is a need to recognize the role of IK and practices in the conservation of biological diversity and environmental management. Provided researchers take the local farmers' needs into consideration, the modern practices for improving agriculture can realize many advantages for farmers. In the optimum integration of indigenous and innovative agriculture approaches, new techniques can emerge in ways that do not harm the natural sources but promote sustainability. Integrated agricultural systems based on IK and traditional practices can provide several options of adaptive and sustainable systems with the capacity to preserve the survival of biota and mitigate major climatic variations. Moreover, the integration of both indigenous wisdom and modern technologies to improve agricultural practices offers an avenue to new collaborative and innovative ways of thinking.

10.5 IK, Sustainable Agro-ecology, and Climate Change

Many traditional societies have built up knowledge over long periods about environmental change and have developed elaborate strategies to recognize and cope with these changes. Understanding and undertaking IK help to reveal the functional flexibility of local farming strategies and can provide a gauge of local adaptive capacity and ability to cope with climate risks, especially drought (Grey *et al.*, 2020). Worldwide, however, applications of traditional knowledge systems in mitigation and adaptation to climate change have long been neglected in developing and implementing climate change policy and have only recently become part of the climate change discourse (Lam *et al.*, 2020). Traditional and indigenous peoples have valuable lessons to offer about successful and unsuccessful adaptations to climate change, lessons which could be vital in the context of global climate change (Macchi *et al.*, 2008).

It is worth noting that among indigenous communities, climate change is locally experienced in the form of weather variability because indigenous communities and smallholder farmers do not have long-term planning horizons that are backed by wide arrays of datasets. Due to the variability of weather experienced in the form of prolonged drought, excessive rainfall, less/more-than-expected precipitation, delay in the onset and offset of rains, hailstorms, and heat waves, farmers have devised adaptation strategies based on ethno-science. Adaptation has been focused not only on responses to weather-related uncertainties but also on responses to the other attendant challenges associated with ecological changes such as new pest and disease infestations in crops and livestock (UNEP, 2008). IK has been vital in responding to these environmental challenges.

IK is still used in coping with and adapting to climate change. According to Egeru (2012), IK is a formidable and relevant area for adaptation to climate change. Robinson and Herbert (2001) highlighted that incorporating IK into climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory, and sustainable. Better still, the range of coping and adaptation mechanisms adopted by the households is not surprising, since African peoples are renowned for applying a mix of adaptation mechanisms depending on whether they are pastoralists or agro-pastoralists (Parry *et al.*, 2007).

To make a case for IK in climate change adaptation, Aliabadi *et al.* (2022) emphasize that management strategies should be tailored to the

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geographical, economic, and social conditions of different regions. Villagers will adopt a variety of adaptation strategies, taking into account their local and environmental conditions and using the local knowledge they have acquired. In the Sahel, for example, the local populations, through their IK systems, have developed and implemented extensive mitigation and adaptation strategies that have enabled them to reduce their vulnerability to past climate variability and change (Nyong *et al*., 2007). These strategies fit well with the economic and social setup of the inhabitants.

Droughts, in particular, are a very common phenomenon in many parts of the world (Spinoni *et al*., 2014). Over time, communities that are prone to drought conditions have developed particular IK to enable them to cope with water shortages and other disaster-related risks (Makondo and Thomas, 2018). Indigenous peoples in the American Pacific north-west, for instance, use dams made by beavers to enhance storage of water in times of drought. They also sow drought-resilient plants such as zucchini plants to prevent drought-related fire (Jegede, 2022). In Iran, for example, as pointed out by Aliabadi *et al*. (2022), farmers have adapted through uprooting trees with high water demand and feeding the leaves to livestock, and using water storage techniques such as clay pipes and canals to prevent excessive evaporation in order to stem the challenges posed by drought. All these traditional techniques benefit the environment and ensure agro-ecological balance.

IK-based practices of *zai* in Burkina Faso, Nigeria, and Mali along the Sahelian belt involve a traditional soil and water conservation practice of digging holes in the ground at pre-precipitation seasons to catch water and concentrate organic matter. The outcome of this practice, according to Zougmoré *et al*. (2023), is that it enhances soil structure and minimizes erosion, maintains higher infiltration rates, and conserves soil moisture, which helps to overcome seasonal dry spells, promote carbon storage in soil, and improve overall productivity due to medium- to long-term reconstitution of soil fertility.

It is evident that the smallholder farmers are confronted with a host of problems emanating from climate change stresses. Thus, farmers draw on a pool of IK practices to tackle these inter-woven challenges. The IK and practices, however, are being challenged by unfamiliar diseases, especially livestock spleen disorder, as well as increased presence of ticks, unreliable seasons, short return period of climate variability events, breakdown in social inclusion systems, and a low mastery of IK practices among younger community members (Egeru, 2012). Ifejika *et al*. (2009) observed similar trends among the agro-pastoralists in Makueni District, Kenya. As such, strengthening IK by fusing modern practices to adaptation with the cultural practices and knowledge offers a greater opportunity for resilience and adaptation to changing climatic conditions and circumstances. The integration of IK into the agricultural knowledge and information systems toward sustainability is essentially a process of exchange of information from one community to another or from one project to another project (Movarej *et al*., 2012).

10.6 Conclusion

In conclusion, IK is an inherent knowledge passed from generation to generation. Through this knowledge, society learns the discipline to sustain the environmental resources. Thus, integrating IK in modern agricultural and environmental management strategies is vital for the sustainability of agroforestry, traditional medicine, biodiversity, water resources, and food productivity. Also, integrating these practices creates a more sustainable and resilient agricultural system. In addition, the use of IK in agricultural and environmental management is crucial for achieving the UN Sustainable Development Goals 1, 2, 3, 13, 14, and 15 (eradication of poverty, elimination of hunger, promotion of good health, climate action, life under water, and life on land, respectively) and for ensuring a healthier and more resilient Earth. When IK is not sufficiently acknowledged and integrated into formal climate risk reduction and adaptation strategies, it may result in limited success for external interventions. Since external knowledge can be incorporated into IK systems, this can help to augment and reinforce indigenous capabilities for the acquisition, absorption, and use of imported technology. There is a need for integration of local and IK systems and external interventions to build household livelihoods that are resilient to climate risks.

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