**REVITALIZING BENEFICIAL SOIL MICROBES: WHY INDIGENOUS SOIL KNOWLEDGE AND CONSERVATION PRACTICES IN AFRICA STILL RELEVANT TO SUSTAINABLE FARMING?**

**ABSTRACT**

***Research Gap:*** *Against the backdrop of a range of documented* *Western-centric farming practices and approaches that ignored the relevance of Indigenous soil knowledge (IKS) and Conservation agriculture (CA) in revitalizing and preserving beneficial soil microbes, the study aimed to fill a yawning gap on often overlooked continent’s indigenous base farming strategies which are still essential in restoring and enhancing beneficial soil microbial populations.*

***Methodology:*** *The study was conducted in Chimanimani district of Zimbabwe. It adopted a constructivist research design incorporating a qualitative approach. The sample consisted of 45 research respondents. A purposive sampling was used to select key informants such as extension officers, ecologists, Western-trained scientists and traditional leaders. Snowball sampling helped to identify additional participants such as small-scale farmers and community elders with relevant insights. The study used semi-structured interviews, observations, and content analysis to establish socio-environmental implications emanated from declining microbial populations in rural communities.* *The data collected were coded, analyzed thematically, and discussed in light of relevant literature.*

***Key findings****: The findings revealed that ignoring the significance of ISK and CA in restoring beneficial soil microbes have posed serious socio-environmental implications on humans and soil ecosystems. Most of the challenges emerged, namely water scarcity, climate-induced disasters, degradation, pollution and human-nature conflict continued to destroy soil microbial populations. Thus, the study found that ISK based in conservation practices is still relevant in sustaining African agriculture. However, the study also revealed that Western-centric practices which often overlook the continent’s rich traditions adversely affect sustainability.*

***Implications:*** *The findings implied that* *a call for conservation-based practices with a more comprehensive understanding of soil health and sustainability in various agricultural contexts becomes urgent.* *Additionally, the results also implied that by overlooking ISK and CA,* *African rural communities continued to live on borrowed time, in which their future becomes uncertain and precarious.*

***Keywords: Beneficial Soil Microbes, Conservation Agriculture, Indigenous Soil Knowledge, Sustainability & Sustainable Farming.***

**1. Introduction and Background**

Although soils are fundamental to life on this Earth, human pressures, Western-centric soil knowledge and activities on agricultural soils have resulted on rapid diminishing of beneficial soil microbes in Africa as well as Zimbabwe in particular. Thereby, ignoring the significance of ISK and CA in revitalizing and enhancing beneficial soil microbial populations, have posed serious implications on humans, soil ecosystems, and sustainability. Beneficial soil microbes in the context of ISK and sustainability, refers to microorganisms like bacteria and fungi that play an essential role in soil health and plant growth, as well as performing vital functions like nutrient cycling, decomposition, and disease suppression (Timofeeva, Galyamova & Sedykh, 2022; Wippel, 2023). According to Hayat et al. (2010), soil beneficial bacteria includes rhizobium, bradyrhizobium, azorhizobium, allorhizoum, sinorhizobium, mesorhizobium, azotobacter, azospirillum, bacillus and klebsiella sp. Beneficial-fungal soil microbes include saprophytes and mycorrhizae (Shah et al., 2021). These microbes are still relevant in plant nutrient uptake and involved in a wide range of biological processes (Timofeeva, Galyamova & Sedykh, 2022).

Beneficial soil microbes in terms of soil fertility, play a major part in breaking down organic matter into simpler compounds, convert insoluble forms of nutrients into forms readily available for plant uptake such as phosphorous and potassium. Shah et al. (2021) support the view that a range of beneficial bacteria, such as rhizobia, can convert atmospheric nitrogen into usable ammonia for plants and reducing the need for overdependence on synthetic fertilizers. Additionally, mycorrhizal fungi forms a symbiotic relationship with plant roots, extending the root system and improving water and nutrient uptake especially phosphorous. Shah et al. (2021) add that by promoting natural processes, microbes can reduce the need for inorganic fertilizers, pesticides, and other chemical inputs, leading to more sustainable and environmentally friendly farming practices in Africa. Thus, healthy soils, enriched with beneficial microbes, are more resilient and productive as well as contributing to long-term sustainability of African farming systems.

Sustainability as panacea to African agricultural progress emphasizes the need for long-term, self-sustaining approaches to farming and human-nature coexistence that draw from African traditions and indigenous knowledge systems (Chirisa & Nel, 2022; Chanda et al., 2025). As a broad concept sustainable farming is a holistic farming approach that prioritizes the long-term health of the environment, the economy, and the society in general, while ensuring security for everyone as well as a balanced ecosystem (Hiywotu, 2025). This means that sustainable farming aims to meet human food and textile needs without compromising the ability of future generations to meet their own, focusing on long-term resource conservation and environmentally friendly practices (Kaponda & Chiwaridzo, 2024; Sithole & Olorunfemi, 2024; Hiywotu, 2025). Resultantly, sustainable farming practices such as those based in local soil knowledge and Conservation Agriculture (CA) remain the panacea to addressing challenges related to the lack of beneficial soil microbes in African rural communities.

ISK, in the context African sustainable farming practices, refers to the traditional, culturally-specific understandings, skills, and practices that local African communities have developed over generations regarding soil properties, management, and use, often passed down through oral traditions and practical experiences (Makwara, 2013; Manyevere et al., 2020). WinklerPrins & Sandor (2002) traced that local or indigenous soil knowledge is clearly a cross or mix between knowledge itself and practice, and the two are historically and frequently difficult to separate. Thus, in most instances, the formerly colonized African communities were and still struggling in applying local soil knowledge into practice. This problem aggravated by both the colonial and post-colonial practices (Matsapa, 2023) in which the application of local soil knowledge as ‘real knowledge’ was undervalued by purely Western-centric approaches to agriculture, especially the Western-trained scientists who were well-versed with exotic soil knowledge and epistemologies. This shows that colonial legacies and the dominance of Western soil knowledge, and activities have marginalized the African indigenous soil knowledge and related skills, creating a disconnection between the local realities and African sustainable farming practices.

The justification of this study lies in its potential to challenge and expand current approaches to African agriculture by highlighting the value of often-overlooked ISK and CA in restoring and enhancing beneficial microbial populations in African marginalized communities. It explores how ISK, which emphasizes harmonious coexistence between humans and soil ecosystems, and the revitalization of beneficial soil microbes, can offer sustainable solutions to contemporary agro-based circumstances. By examining the problems emanating from ignoring the relevance of ISK in conserving beneficial soil microbes, the study seeks to revitalize beneficial soil microbes and sustaining African rural farming practices that have largely been influenced by Western epistemologies, and instead, propose an integrated, African-centered approach that is deeply rooted in culturally-specific understandings, skills, and practices. Against this background, Africans should have largely taken advantage of their ISK and CA by positively responding to the old adage wisdom transmitted to them by their forefathers (Chigidi, 2021; Tirivangasi & Nyamunda, 2024). However, these African rural communities persistently failed to benefit from the historical sustainable farming practices (Hobbs, Sayre & Gupta, 2008; Habig & Swanepoel, 2015; Chipfakacha, 2019; Angmo et al., 2024). This research is crucial for enhancing sustainable farming practices in Africa, as it advocates for a return to the continent's rich heritage of the local knowledge base, offering a more inclusive and culturally relevant path toward sustainable agriculture.

**1.2 Study objectives:**

* To investigate the impact of declining beneficial soil microbes on the sustainability of African farming systems.
* To assess the effectiveness of conservation agriculture in restoring and enhancing beneficial soil microbial populations.

**2. LITERATURE REVIEW**

Focusing on sustaining African rural farming continues to proffer serious implications emanating from the diminishing beneficial soil microbes. Although there is limited literature to assess the extent in which these microbes are diminishing, this literature review section analyzed the reasons behind the lack of soil microbes and ascertained the African worldview of ISK as the bedrock of sustainable agriculture. The related literature of this study was obtained from research articles and reviews, reports, textbooks and theses.

**2.1 Colonial and post-colonial practices**

The world over, colonization and post-colonial practices have brought the neglect of local knowledge in many indigenous societies (Ngoyi, 2021; Chirisa & Nel, 2022). Colonialists ignored the fact that indigenous peoples are a part of, and not separate from, nature, and as such policies that enhance the co-relationship of humans and agricultural soils while adaptive are a necessity now than before (Chirisa & Nel, 2022). For instance, when Chirinda Forest in Zimbabwe was in the hands of westerns, they imposed policies that discriminated against indigenous people from acquiring forest resources (Ndumeya, 2020). As a consequence, where policy makers are insensitive to economic, religio-cultural, and socio-ecological practices of the locals they govern, the latter resist the policies by clandestinely overexploiting their natural resources (Thondhlana & Cundill, 2017; Ndumeya, 2020; Masakure & Ndumeya, 2021). Thus, policies that neglect the traditional base of the locals in balancing co-relations of humans and their natural environment, may aggravate climate change and its induced disasters, intensify interactions and creating microbial uncertainties. This aforesaid view gives a credit to the adoption of local soil knowledge in offering more viable environmental management skills and sustainable farming practices in Africa and beyond.

The climate-induced disasters that significantly impacts beneficial soil microbes have been perpetually emanated from both colonial and post-colonial practices, in which the traditional base of the locals was taken for granted. Studies agree that anthropogenic factors have contributed much to climate change and disasters such as floods, landslides and droughts (Sipeyiye, 2020; Chanza *et al*., 2020; Musarandega & Masocha, 2023; Dube, 2024b). Literature revealed that beneficial microbes are at risk of diminishing due to the adverse effects of climate change. For example, a recent study by Huang et al. (2021) reveal that frequent and intense tropical cyclone disturbances can have widespread and strong effects on nitrogen and iron cycles, and their associated microbial communities. Along with the aforesaid view, Kumar, Rawat & Amule (2016) argue that increased rainfall, landslides and flooding can lead to the loss of soil microbes and nutrients through erosion, degradation and leaching. However, another recent literature substantiate that extreme heat events can stress or kill beneficial microbes, reducing their abundance and diversity. This argument ascertains the critical role played by water and beneficial soil microbes in sustaining rural agriculture (Yabalak et al., 2023). Thus, drought conditions in the areas like Sahel region, can severely reduce beneficial microbial population in the soil, especially in the rhizosphere (the area around the plant roots) and adversely affect plant health and soil fertility in general (Jansson & Hofmockel, 2020).

**2.2 Over-application of chemical fertilizers**

In most communities, synthetic fertilizers are seen as essential components in agriculture since they raise soil fertility and crop yield (Alori*,* Adekiya, & Adegbite, 2020). Contrarily, it also harms the environment and human health since it alters the physical characteristics of the soil, throws off the ecological balance between the soil's micro flora and environment, and interferes with a variety of soil activities. Due to these activities, the soil is of low quality, which affects the systems that sustain livelihood and food security. According to Baweja, Kumar & Kumar (2020), there are serious warning indications in rain-fed and irrigation-irrigated farmed regions, including soil erosion, loss of soil organic matter, and nutrient imbalance brought on by an excessive use of chemical fertilizers. Thus, the overuse of chemical fertilizers has brought about negative impact on the environment, agricultural production, soil health, and human health. Chemical fertilizer application lowers the number of soil bacteria (Fazelian & Yousefzadi, 2022). The soil becomes more acidic faster as a result of increased usage of chemical fertilizers. Consequently, acidic soil hinders plant roots, making them more vulnerable to infections. The above studies are in line with the conclusion that the continuous over-application of synthetic inorganic fertilizers has resulted in the deterioration of the natural ecosystems in which the growth of beneficial soil microbes is perpetually altered.

**2.3 Excessive use of Chemicals**

Herbicides, commonly used for controlling unwanted plants, often disturb the balance of soil ecosystems by altering microbial diversity, disrupting nutrient cycling, and affecting organic matter breakdown (Michael et al., 2024). Although current literature shows that herbicides can either inhibit or stimulate soil microbial activities, depending on their type, concentration, environmental conditions (Craven et al., 2018), indigenous farmers must be well versed of the chemicals’ long-term effects on microbial diversity. For example, old and recent studies corroborated that the chronic administration of herbicides, such as glyphosate to soybeans has been shown to have adverse effects on symbiotic N-fixing bacteria (Michael et al., 2024). Other studies suggest that glyphosate and other pesticides, for instance, may have indirect impacts in competing with trace nutrients, leading to an increase in pathogenic soil microorganisms that may be brought on by stressed plants (Johal, & Huber, 2009). Ipsilantis, et al*.* (2012) also argue that the fungicide carbendazim reduces AM fungal colonization of pepper plants. Some agricultural pesticides have been indirectly connected to increasing populations of dangerous microbes (Lehman et al*.* 2015). In justifying the negative impact of the chronic use of herbicides, Tudararo-Aherobo & Ataikiru (2020) argue that the effects of chemicals on soil microbes are very intense and also have intense impact on soil fertility and plant growth. Therefore, the above literature hints that the excessive utilization of chemicals in controlling weeds and pests may endanger natural soil processes and destroy a range of beneficial soil microbes.

**2.4 Excessive tillage, over-reliance on cash crops and the natural environment**

A post-colonial shift from subsistence to over-reliance on cash crops and natural soils among rural communities have resulted in land rush and invasion of preserved areas such as sacred forests and river banks. During the 21st century, conservation goals along with modernization and external pressures impacted indigenous peoples way of life, lead to abrupt changes in farming practices, broader tensions over clashing values and beliefs, erosion of their cultural heritage as well as degradation of the natural environment (Zimmerman, McDonald & McQuinn, 2020). However, before colonialism, these communities value communal existence, strong bonds with their ecosystems, and respect for elders, while they pass down traditional soil knowledge, like sustainable use of land resources and promoting harmony with nature (Sipeyiye, 2020). Against this backdrop, over-reliance on cash crops such as bananas, and prospects for virgin soils in Zimbabwe posed challenges resulted in stiff competition for arable land among the producers with smaller pieces of land and over-tillage of already existing lands.

**2.5 The African Worldview of ISK as the Bedrock of Sustainable Agriculture**

The African worldview ascertains the core understanding of the socio-human, natural, and spiritual factors of given societal values and beliefs. Sipeyiye (2020) reiterates that the African worldview is a three-tier structure that comprises the human world, the natural world and the spiritual world. African societies have their own way of studying, managing and interpreting the natural environment. This means that African traditions hold significant knowledge (Chanda et al., 2025) of soils and environments, attained by experience and testing through many generations of living close to the land (WinklerPrins & Sandor, 2002). The African worldview also establishes what is possible, actual, desirable, acceptable, and essential in each of the spheres of the social, material, physical, and supernatural (Dube & Sipeyiye, 2021). In the case of ISK and sustainable agriculture, the environmental knowledge embedded in local cultures provides a long-term perspective on sustainable farming practices and management. In this regard, ISK and conservation-based practices are the most precious assets of all indigenous communities that can be intelligently exploited to maximize agricultural benefits for both the current and future generation (Teron & Borthakur, 2009). While it is normal for small scale farmers to take instructions from the scientific community, it is also essential for researchers and policy-makers to understand the local farmers’ knowledge of their soil characteristics, microbial diversity and management (Manyevere et al., 2020).

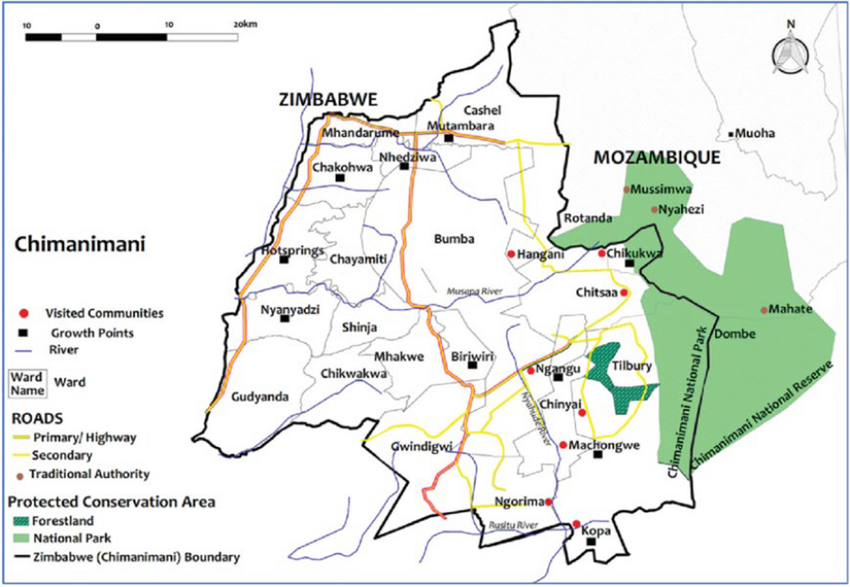
**3. MATERIAL AND METHODS**

**3.1 Theoretical framework**

The study employed the re-imagination of nature theory as a lens in revitalizing beneficial soil microbes which play a crucial role in enhancing the significance of ISK and conservation-based practices, leading to environmental stability, human security, as well as sustainable farming. This theory justifies the significance of an integration of African traditions with the current environmental worldview that recognizes the interconnectedness of humans and nature. Khan et al. (2021) defines this current worldview as a new ecological design that can minimize the adverse environmental impacts by integrating traditional values with the soil ecosystems. The theory is the opposite of the disenchantment theory, which emphasizes the complete undoing of the locals’ traditional base (Reader, 2021; McPherso, 2020). Sipeyiye (2020) supports the view that the disenchantment of the nature theory has been driven by the modern Western worldview that reduces nature to material without life or spirit. Consequently, climate-induced disturbances, intensified pollution and degradation, and heightened human-nature conflict have always emanated from the unbalanced human interaction with nature, technology, and other living entities. Traditional ways of perceiving nature as alive and sacred are replenished with modern scientific recognitions, viewing nature as readily available resources to be exploited by human beings. The theory supports the need to revisit ISK that promotes CA as the only essential way to address the emerged socio-environmental circumstances. One weakness of this theory is that the sacredness of nature may be viewed as an essentiality to the extent of forgetting the communal existence of indigenous communities. However, it must be noted that as nature vitalizes the need for life, human beings also need agricultural soils, food, shelter, health services, and energy (Pinello, 2022). Therefore, an integrated, African-centered framework that is hinged on the locals’ traditions becomes a necessity.

**3.2 Methodological prima**

The study adopted a constructivist research design incorporating a qualitative approach. The constructivist philosophy explored the meaning embedded in deep local cultures in the context of socio-environmental challenges encountered by the African rural communities. This qualitative research approach allowed for an in-depth engagement with ISK and conservation practices of the Zimbabweans living in marginalized rural areas, such as Ngorima, in Chimanimani district. The study was conducted within 8 visited communities of Chimanimani district in Zimbabwe **(Fig. 1).** Entry into the research field was done at the beginning of December 2023 and ended at the end of February 2025. The age groups of participants in this study ranged between twenty-two and eighty years. The sample size was 45 participants which is ten percent of the target population of four hundred and fifty. For this research, data was collected through observations and semi-structured interviews with selected informants. A purposive sampling technique was used to select key informants such as traditional leaders, extension officers, ecologists, and Western-trained scientists. Additionally, snowball sampling helped to identify additional participants such as the local small-scale farmers and community elders with relevant insights on application of synthetic fertilizers, herbicides and pesticides, local knowledge, indigenous conservation strategies and sustainable agriculture. The data collection process involved conducting semi-structured interviews with all the participants, and observed their activities. Additionally, a focus group discussion was conducted with the selected participants from a range of community elders and small-scale farmers. The data collected were coded, analyzed thematically, and discussed in light of relevant literature. Thematic analysis is an important process of identifying patterns or themes within qualitative data (Maguire & Delahunt, 2017). The study also upheld the necessary ethical guidelines for undertaking the study. In line with these guidelines, observations and interviews were done in a non-intrusive way in which anonymity was upheld, and the pictures that compromised the integrity of the observed people and the community at large were not displayed by the researcher. Therefore, participants were informed of the purpose of the research and were guaranteed their privacy and confidentiality.



**Fig 1.** Map of Chimanimani District showing 8 visited communities. Source: Spiegel et al. (2022)

**4. RESULTS**

**4.1 The Impact of Declining Beneficial Soil Microbes on the Sustainability of African Farming Systems**

Three sub-thematic headings emerged from observations made by the study and the participants’ interview responses on the impact of declining beneficial soil microbes on the sustainability of African farming systems. These sub-thematic headings include, agricultural water scarcity and climate-induced disturbances, intensified degradation and water pollution, and a heightened human-nature conflict.

**4.1.1 Agricultural Water Scarcity and Climate-induced Disturbances**

The study observed that residents in Zimbabwean rural communities fueled agricultural water scarcity by ignoring the relevance of ISK that has been played a crucial role conserving both water sources and beneficial soil microbes. From the interview responses of traditional leaders, extension officers and local elderly participants, the researcher observed that the local soil knowledge is prerequisite for water preservation strategy, with which conservation is embedded within the local peoples’ way of life. One of the ecologists narrated that:

“-There is adequate proof that the local knowledge and indigenous resource governance mechanisms generate water resource abundance and ecological stability. In Rusitu Valley, for instance, the people of Nyabamba and Dzingire carry on spiritual and cultural ceremonies that manage their land resource use and providing protection of the powerful, perennial and sacred Nyabamba River. However, as long as western models and policies are rooted in anti-local knowledge, the locals resisted the policies by contesting with their own water sources. These contestations have resulted in the perpetuated deforestation, degradation and river channelization, in which the river pollution is also intensified-”.

In relation to the above narration, cash crop farmers in rural areas complained that the formerly clean and perennial rivers were turned into muddy water that is unconducive for irrigating their crops. Ecologists, Western-trained scientists and local extension officers concur that water sources such as rainfall, wetlands, riverbeds, streams and rivers are crucial for microbial diversity, acting as a solvent in decomposition organic matter, medium for nutrient transport, and a habitat for diverse beneficial microbes, as well as impacting their survival, growth, and interactions. However, some small scale farmers contrasted that they currently adopted a new belief in contrary with their traditions that overlooks the consequences of ignoring their traditional knowledge base.

Traditional leaders and local elderly participants agreed that the neglect of local soil knowledge which is culturally-centered has exposed the vulnerable indigenous communities to natural disasters and hazards such as cyclones, floods, and landslides. These calamities disturb sustainable farming practices, due to the diminishing of beneficial soil microbes and nutrients through leaching and the removal of top soil by floods. For example, due to floods caused by Cyclone Idai, squatter farming in indigenous named Nyabamba River was destroyed to the extent of abnormal widening of the river. Ecologists concurred that cyclones exploited the vulnerability and environmental exposure to which the indigenous people have been subjected to. Traditional leaders and local elderly participants corroborated that Cyclone Idai that mostly affected Mozambique and Zimbabwe swept away the local peoples’ crop fields on 15 March 2019. Those with banana fields not physically affected by the aforesaid disturbances also narrated that although they did not know how their crops were affected, the yield decline ascertains the adverse effects of cyclones on their plants. However, ecologists, Western-trained scientists and extension officers explained that cyclones have contributed to the diminishing of soil microbes such as sinorhizobium and mesorhizobium, and other important nutrients, as a result of leaching and erosion.

Participants of the study corroborated that the neglect of the traditional base of the locals have resulted in cyclones and droughts which play a major role in diminishing beneficial soil microbes. However, about five percent of participants contrasted that climate change and its induced calamities have nothing to do with the local cultures and agricultural practices of the locals. According to some participants of this study, cyclones and drought, for instance, scientifically emanated from the disruption of global weather patterns by both El Nino and La Nina occurrences, leading to extreme weather events. One of the young small scale farmers narrated that:

“-We are living in a civilized and globalized world, in which the available local resources must be utilized for maximum profit. For example, with my new opened banana field in riverbeds, I was able to harvest 100 tons of bananas in 2018, leading to the diversification into the piggery enterprise the following year. For easy management of weeds, I chronically utilized herbicides, such as glyphosates and diquat. The only major challenge which I noticed was that the more you apply both inorganic fertilizers and herbicides, the faster the soil will lose its fertility. This was also the major reason for diversifying to piggery project -”.

However, some of the above activities such as riverbeds agriculture, over application of synthetic fertilizers and herbicides are against the local traditional base that emphasizes the conservation of riverbeds, wetlands as well as the natural ecosystems that have promoted sustainability since immemorial. As a consequence, these anthropogenic activities have contributed to the diminishing of beneficial soil microbes such as, rhizobium, bradyrhizobium, azotobacter, azospirillum, bacillus and klebsiella sp, agricultural water scarcity and climate induced disturbances.

**4.1.2 Intensified Degradation and Water Pollution**

From the narrations given by traditional authorities and local elderly participants, future generations in most indigenous communities are more vulnerable to the consequences of environmental degradation and water pollution than is commonly assumed. The researcher observed that the consequences of degradation and water pollution generally counteracting sustainable agriculture in rural areas. Degradation itself seriously disturbed the diversity of beneficial soil microbes that essential for sustainability. Ecologists and extension officers corroborated that the diminishing of beneficial soil microbes in rural lands has resulted in land rush, as well as the perpetuation of foreign approaches with the anticipation of increasing crop yields. However, these approaches significantly destroy the beneficial soil microbes. This research reveals that as deforestation and the environmental delicacy of rural areas in the 2000s have been disguised by the surging trend of annual rainfall, future challenges associated with intensified degradation and water pollution may be serious. One of the local elderly participants indicated that:

“-The future population in these already marginalized rural areas might be more susceptible to the consequences of environmental degradation, such as droughts, floods, landslides and heat waves, than the present. These consequences aggravate tensions between the natural environment and human beings as well as hindering sustainable agriculture. However, our local traditions matters that every member in rural areas must consider the lives of future generations by enhancing sustainable agricultural practices-”.

Ecologists concurred that the reduction of riverbed cover in many perennial rivers resulted in serious degradation and water pollution. Thus, from 2019 up to 2024, there was a serious damage of vegetation and land cover in general. Activities such as squatter farming and illegal mining that are anti-microbial diversity have perpetuated vegetation clearance. One of the youths mined in Nyabamba River and its beds highlighted that they clear the land before mining and in most instances, they also channelize the water if the gold belt is found in the river. This resulted in more bare land and muddy water in Nyabamba that is unsuitable to sustain agricultural activities and aquatic life. Ecologists also hinted that human activities along the river have resulted in river sedimentation that also reduced the local peoples’ ecological resilience microbial diversity and food security. Some of the challenges emanated from the river sedimentation include, reduced water clarity, destruction of aquatic habitats by burying plant life and aquatic eggs, increased water temperature due to sediments absorbing direct sunlight, flood risk due to a raised riverbed, and potential contamination of the river with pollutants carried by sediments particles, which can further destroy aquatic life.

**4.1.3 Heightened Human-nature Conflict**

The study found that sacred places such as Nyabamba River and its beds, Nyamhepo Forest, Pene and Chimbiya Mountains in Rusitu Valley were protected and respected through the culturally-specific local soil knowledge and traditional base. However, these places have since been converted into agricultural land and mines. The scenario has resulted in direct conflict with the environment and the existing natural systems, such as wildlife, aquatic life and forests along the riverbeds. The youth participants who opened their banana farms in previously prohibited riverbeds indicated that there are limited means of survival, resulting in the uneasy coexistence with the natural system. For instance, the youth narrated that; “as youths with limited options for survival, we find ourselves ignoring the local traditions of the rural community”. This situation has intensified the conflict between nature and human beings. In this instance, nature represents the agricultural soils, beneficial soil microbes, aquatic life and wildlife which use forests, mountains, and rivers and its beds as their habitat. There habitat and food systems were seriously destroyed by human activities. Through the intensification of human-wildlife conflict and the loss of microbial diversity, sustainable agriculture is also at danger.

Participants of this study revealed that human-nature conflict was heightened by deforestation, river sedimentation, degradation and pollution. They noticed that by over depending on natural resources, that indigenous population is always at conflict with soils, riverbeds, wetlands, aquatic life and wildlife. Human-wildlife conflict mostly emanated from the cutting down of trees along the riverbeds. These riverbeds were formerly habitat and source food for various animals such as baboons, monkeys and wild pigs. One of the local elderly participants also unfolded that the locals depends on nature for food, but their farming and mining activities that turned the fresh water into muddy have seriously affected sustainable agricultural practices and food access of the locals. In the context of food access and availability, the locals in many instances depend on rivers, where get mukunga fish. An ecologist defines mukunga as a fresh water river fish that is several feet long and resembles with a pointed mouth and little developed fins. The researcher also observed that the muddy water and sediments have adverse effects on as far as Lucite River in Mozambique. This shows that human activities in Nyabamba have heightened the local peoples’ conflict with the natural environment and sustainable agriculture at large.

**4.2 The effectiveness of CA in Restoring and Enhancing Beneficial Soil Microbial populations**

Ecologists and extension officers defined CA as an approach based indigenous soil knowledge with three major principles, namely, zero tillage or maintain a semi-permanent organic soil cover, retention of crop residue and crop rotation. This definition was in line with the narrations of traditional leaders and local elderly participants. They narrated that in order to enhance sustainability, they must look back to conservation practices, in which environmentally friendly farming practices, such as the minimum of the soil cover, crop residue retention as well as rotating a range of crops in the same acre must be adopted. Ecologists revealed that the key principles of CA help to mitigate adverse effects of climate change on rural-agricultural soils and target the growing demand for sustainable agriculture, as well as production in rural communities.

Similarly, one of the local extension officers narrated that conservation-based practices like the utilization of permanent beds with crop residue retention, minimization of soil disturbances and a varied crop rotation play a significant role in preserving beneficial microbes, leading to the increase of their life cycles and reproductive processes. In contrary to the above narrations, Western-trained agricultural scientist argued that conventional agriculture, also known as modern agriculture is well known for producing higher yields than that of conservation agriculture. In refuting this argument, ecologists and some extension officers argue that for many years, mechanical tillage has destroyed soil micro-organisms and soil fauna that are still relevant in taking over the tillage function and soil nutrients balancing. From the above narrations, the researcher observed that a conservation-based approach which integrates the values of ISK gave in the maximum beneficial soil microbial diversity and activity in varied crop rotating systems under zero tillage. Additionally, as beneficial soil are crucial for sustainable farming, African rural communities must utilizing their ISK in adopting the principles of CA, in which the highest soil microbial diversity may be enhanced.

Ecologists and some extension officers were against the use of chemicals as a method of controlling weeds and pest management in CA. They narrated that by over utilized chemicals, local farmers are killing the beneficial soil microbes that are also crucial for sustainability. For sustainability’s sake, farmers must re-imagine the relevance of beneficial microbial diversity in agricultural soils. Although an integrated weeds and pests management may be added to CA principles, minimal use of chronic pesticides and herbicides is a necessity since one of the requirements of CA is to enhance sustainable soil biological activities and promoting the diversity of beneficial soil microbes. The study revealed that in controlling weeds and pests, other alternatives which promote the presents of soil micro-organisms in agricultural soils are needed. For example, since immemorial a varied crop rotation was adopted as disease and pest management strategy. Traditional leaders and the local elderly participants viewed crop rotation as a concept of ISK hinged on cultural control of plant diseases and pests. Scientifically, this study observed that as long as varied rotations increase beneficial soil microbial diversity, the destructive danger of pests and disease outbreaks may be mitigated, since the biological diversity also helps to keep the pathogenic organisms in check. Therefore, for sustainability of agricultural soils, CA approach with minimized use of chemicals anti-beneficial soil microbial diversity is a necessity now than before.

**5. DISCUSSIONS**

Against the backdrop of neglecting the relevance of ISK in revitalizing beneficial soil microbes that are prerequisite for the sustainability of African farming systems, this research gives several insights into the implications emanated from the lack of beneficial microbes in agricultural soils. Most of the challenges emerged, namely agricultural water scarcity and climate-induced disturbances, intensified degradation and water pollution, and a heightened human-nature conflict have perpetuated the diminishing of beneficial microbes in African agricultural soils. This perpetuation has hindered African sustainable farming which is a necessity now than before. Studies by Kumar, Rawat & Amule (2016), Jansson & Hofmockel (2020), Baweja, Kumar & Kumar (2020), Yabalak et al. (2023), and Michael et al. (2024) similarly observed that the diminishing of beneficial soil microbes seriously counteracting sustainability of agriculture. For sustainability’s sake, the revitalization of beneficial soil microbes together with the key principles of ISK is now needed, rather than advocating for the wait and see attitude, in which things may go out of hand while still waiting. This observation resonates with the arguments by Angmo et al. (2024), who advocate for conservation agriculture practices with a more comprehensive understanding of soil health and sustainability in various agricultural contexts.

The study justified that ISK is still relevant in sustaining African rural agriculture. The study argued that by ignoring the relevance of ISK that has been played a crucial role in conserving both water sources and beneficial soil microbes, African rural communities continued to live on borrowed time, in which their future becomes uncertain and precarious. In order escape the situation, the study advocates for the adoption of CA that was defined as an approach based in ISK with three major principles, namely, zero tillage or maintain a semi-permanent organic soil cover, retention of crop residue and crop rotation. WinklerPrins & Sandor (2002) and Manyevere et al. (2020) concurred indigenous culture hold significant knowledge of soils, environments, conservation and sustainability, attained by experience and testing through many generations of living close to the land. However, Chanda et al (2025) averred Western-centric approaches and activities, which often overlook the continent's rich indigenous traditions adversely affect sustainability. Although the study accepted that there is no one size fit all in solving African problems, policy-makers, African governments and researchers must integrate ISK with other context-specific instructions from the scientific community. In a similar analysis, Manyevere et al. (2020) argued that while it is normal for small scale farmers to take instructions from the scientific community, it is also essential for researchers and policy-makers to understand the local farmers’ knowledge of their soil characteristics, microbial diversity and management.

As the core for African sustainable agriculture, the study also acknowledged the African worldview of ISK which ascertains positive interactions between the agricultural soils, soil microbes and human beings. This resonates with the definition of ISK that emanated from traditional, culturally-specific understandings, skills, and practices that local African communities have developed over generations regarding soil properties, management, and use, often passed down through oral traditions and practical experiences (Makwara, 2013; Manyevere et al., 2020; Chirisa & Nel, 2022). This African worldview also establishes what is possible, probable, actual, desirable, acceptable, and essential in each of the spheres of the social, material, physical, and supernatural (Dube & Sipeyiye, 2021). The findings corroborate with the assumption of the re-imagination of nature theory that emphasizes the revitalization of local peoples’ traditional base (Reader, 2021; McPherso, 2020). Therefore, according to the study, there is a need to revitalize the local soil knowledge to successfully address the biggest agricultural issues that are currently facing the African rural communities.

The study ascertainedthe role of CA in revitalizing beneficial soil microbes. The study justified that conservation-based practices play a significant role in preserving and revitalizing beneficial microbes, leading to the increase of their life cycles and reproductive processes. Similarly, Angmo et al. (2024) revealed that minimizing soil disturbance plays a crucial role in revitalizing the microbial community. On the other hand, results of this study also revealed that conventional agriculture, also known as modern agriculture is well known for producing higher yields than that of conservation agriculture. Many studies accepted that although mechanical farming is well known for maximum yield, it had contributed much to the diminishing of soil microbes in rural-agricultural soils which are panacea for sustainable farming (Hobbs, Sayre & Gupta, 2008; Habig & Swanepoel, 2015; Chipfakacha, 2019). For example, through modern agriculture that accept the chronic use of chemicals and deeper tillage of the soils, the microbes are perpetually destroyed. Tudararo-Aherobo & Ataikiru (2020) concurred that the modern agriculture that enhances the overuse of chemicals have intense effects on the non-target beneficial soil microbes. Hence, the study came to a conclusion that a conservation-based approach which integrates the values of ISK gave in the maximum beneficial soil microbial diversity and activity in varied crop rotating systems under zero tillage.

**5.1 Limitations and Opportunities for further Study**

The study expects that there might be loopholes in presenting data because the study employed a qualitative research methodology. Although qualitative methodology might have drawbacks for this study, such as statistical limitations in data presentation, the study faithfully committed to the qualitative methodological prima that calls for the trustworthiness of the results (Korstijens& Moser, 2018). Future research might consider adopting a mixed methods research approach, if possible. The study finally noted that the implications emanated from declining microbial populations are not limited to Africa, but other continents such as Asia.

**6. CONCLUSION AND RECOMMENDATIONS**

The study concluded that neglecting the relevance of ISK in revitalizing beneficial soil microbes have seriously impacted the sustainability of African farming. Most of the implications emerged, namely water scarcity, climate-induced disasters, degradation, pollution and human-nature conflict continued to destroy beneficial soil microbes. The study emphasized that ISK is still relevant in sustaining African agriculture as it historically known for playing a vital role in conserving nature, particularly soil microbes. However, Western-centric approaches and activities which often overlook the continent’s rich traditions adversely affect sustainability. The African worldview of ISK is the core for African sustainable farming as it ascertains positive interactions between beneficial soil microbes, agricultural soils, plants and humans. Africans must fully adopt CA as a practical way in revitalizing beneficial soil microbes as well as enhancing sustainability. The study recommended that researchers, policy-makers and African governments must do away with the wait and see attitude because the situation may reach the climax while still waiting. One size fit all solutions to African problems must be avoided and as a result, conservation agriculture practices with more comprehensive understanding of soil health and sustainability in various agricultural contexts must be adopted. Thus, an integrated, African-centred approach becomes a necessity now than before.

Ethical Approval:

As per international standards or university standards written ethical approval has been collected and preserved by the author(s).

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

**REFERENCES**

Alori, E.T., Adekiya, A.O., & Adegbite, K.A. (2020). “Impact of Agricultural Practices on Soil Health”. In Giri, B., Varma, A., (Eds). Soil Health (pp. 89-98), Springer, Cham, Switzerland. 10.1007/978-3-030-44364-1\_5.

Angmo, P., Sharma, S., Sidhu, H.S., & Saini, K.S. (2024). Conservation Agriculture Practices Impact on Biological and Microbial Diversity in Earthworm Cast under Maize-wheat System. *Current Research on Microbial Sciences,* Vol*.* 7 (2024): 100273.

Baweja, P., Kumar, S., & Kumar, G. (2020). “Fertilizers and Pesticides: Their Impact on Soil Health and Environment”. In Giri, B., & Varma, A., (Eds). Soil Health(pp. 265-285), Springer, Cham, Switzerland. DOI: 10. 1007/978-3-030-44364-1\_15.

Chanda, T.C., Bwalya, P., Chisebe, S., Domboka, R.P., & Banda, E. (2025). Decolonizing Peace in Africa: Why African Traditions Hold a Key to Sustainable Peace? *Asian Research Journal of Arts and Social Sciences,* Vol*.* 23(2): 86-97. <https://doi.org/10.9734/arjarss/2025/v23i2642>

Chanza, N., Siyongwana, P. Q., Williams-Bruinders, L., Gundu-Jakarasi, V., Mudavanhu, C., Sithole, V. B., & Manyani, A. (2020). Closing Gaps in Disaster Management and Response: Drawing on Local Experience with Cyclone Idai in Chimanimani, Zimbabwe. *International Journal of Disaster Risk Science* (2020) 11, 655-666.

Chigidi, W. L. (2021). Matters of Survival: A Case of Heavy Handed Didactic Moralism in Ndau Cautionary Folktales. *Journal of African Literature Association*. DOI: 10.1080/21674736.2021.1901538

Chipfakacha, R. (2019). “Effects of Conservation Farming in Zimbabwe: A Case of Umguza in the post 2000 Land Reform Programme”. (Doctoral Dissertation, University of South Africa).

Chirisa, I., & Nel, V. (2022). Socio-Ecological Dynamics within Rural Settlements: Evidence from Mbire District in Zimbabwe. *Journal of Land and Rural Studies*. 10.1177/232102492210249221090003

Craven, M., Myburgh, C., Rhode, O., & Saayman-Du Toit, J. (2018). The Effects of Herbicides on Soil Life. Part 2- Beneficial Fungi and Bacteria. *SA Grain*, Vol. 20(10): 46-48.

Dube, E. E., & Sipeyiye, M. (2021). Rethinking Doro (traditional brew) in the Worldview of the Ndau of Zimbabwe: A Post-colonial Reflection. *Indilinga: African Journal of Indigenous Knowledge Systems,* Vol. 20(1): 1-12.

Dube, E.E.N. (2024b). The Place of Water in the Ndau Religion of Zimbabwe. *HTS Theological Studies*, Vol. 80(2), a10041. <https://doi.org/10.4102/hts.v8012.10041>

Fazelian, N., & Yousefzadi, M. (2022). “Nano-biofertilizers for Enhanced Nutrient use Efficiency”. In *Nano-enabled Agrochemicals in Agriculture*, eds. M. Ghorbanpour, and M. A. Shahid (Academic Press), 145–158.

Habig, J., & Swanepoel, C. (2015). Effects of Conservation Agriculture and Fertilization on Soil microbial Diversity and Activity. *Environments,* 2015, 2: 358-384. DOI: 10.3390/environments2030358

Haung, H., Yuan, S., Wen, G., Bi, X., Haung, L., & Zhou, M. (2021). Identifying the Development of a Tropical Depression into a Tropical Storm over the South China Sea. *American Meteorological Society,* Vol. 36: 1299-1328. DOI: 10.1175/WAF-D-20-018.

Hayat, R., Ali, S., Amara, U., & Ahmed, I. (2010). Soil Beneficial Bacteria and their Role in Plant Growth Promotion: A Review. Ann Microbiol, 60: 579-598. DOI: 10.1007/s113213-010-0117-1

Hiywotu, A.M. (2025). Advancing Sustainable Agriculture for goal 2: Zero Hunger-a Comprehensive Overview of Practices, Policies and Technologies, *Agroecology and Sustainable Food Systems*. DOI: 10.1080/21683565.2025.2451344

Hobbs, P.R., Sayre, K., & Gupta, R. (2008). The Role of Conservation Agriculture in Sustainable Agriculture. *Philosophical Transactions of the Royal Society*, 363, 543-555. DOI:10.1098/rstb.2007.2169.

<https://doi.org/10.3390/plants11162119>

Ipsilantis, I., Samourelis, C., & Karpouzas, D.G. (2012). The Impact of Biological Pesticides on Arbuscular Mycorrhizal Fungi. *Soil Biol. Biochem*, *4:* 147–155.

Jansson, J.K., & Hofmockel, K.S. (2020). Soil Microbes and Climate. *Nature Review Microbiology*, Vol. 18(2020): 35-46.

Kaponda, T., & Chiwaridzo, O.P. (2024). “Enhancing Food Security through Sustainable Agriculture: A Case Study of the Pfumvudza/Intwasa Program in Zimbabwe”. In J. Garwi, R. Masengu and O. Chiwaridzo (Eds), Sustainable Practices for Agriculture and Marketing Convergence (pp. 251-280). IGI Global Scientific Publishing. <https://doi.org/10.4018/979-8-3693-2011-2ch011>

Korstjens, I., & Moser, A. (2018). Series: Practical guidance to qualitative research*.* Part 4: Trustworthiness and publishing. *European Journal of General Practice*, Vol. 24(1): 120-124.

Kumar, V., Rawat, A.K., & Amule, F.C. (2016). Climate Change Impact on Beneficial Soil Microbial Community: A Review. *Nature Environment and Pollution Technology*, Vol. 15(2): 619-625.

Lehman, R.M., Cambardella., C.A., Stott, D.E., Acosta-Martinez, V., Manter, D.K., Buyer, J.S., Maul, J.E., Smith, J.L., Collins, H.P., Halvorson, J.J., & Kremer, R.J., 2015. Understanding and Enhancing Soil Biological Health: The Solution for Reversing Soil Degradation. *Sustainability*, Vol. *7*(1): 988-1027.

Maguire, M., & Delahunt, B. (2017). Doing Thematic Analysis: A Practical, Step-by-step for Learning and Teaching Scholars. *AISHE. J*, Vol. 8(3): 3351-3365.

Makwara, E.C. (2013). Indigenous Knowledge Systems and Mdern Weather Forecasting: Exploring the linkages. Journal of Agriculture and Sustainability, 1: 98-141.

Manyevere, A., Mnkeni, P.N.S., Laker, M.C., & Muchaonyerwa, P. (2020). The Use of Indigenous Knowledge Systems in Soil Classifications, Appraisal and Soil Productivity Rating for Maize Cropping: A Case of Xhosa Speaking People in Raymond Mhlaba Municipality, South Africa. *INDILINGA-African Journal of Indigenous Knowledge Systems,* Vol. 19(1): 96-109.

Masakure, C., & Ndumeya, N. (2021). ‘The trees do not belong to Chief Maranke but to the Native Reserves Trust’: The Politics of Timber Resource Exploitation in African Reserves, Colonial Zimbabwe, 1924-1948. *Historia*, Vol. 66(2021), 61-87.

Matsapa, W. (2023). Revitalizing Indigenous Names in Balancing Environmental Science: A Case of Ignored Names of Places in Rusitu Valley. *Dzimbahwe Journal of Multidisciplinary Research*, Vol. 4(1): 54-68.

McPherso, D. (2022). *“Introduction: Towards Re-Enchantment. A Neo-Aristotelian Perspective”.* Cambridge, Cambridge University Press.

Michael, E.C., Chikukula, A.A., Duger, D.R., Ibeneme, U.J., Olukayode, O.J., Okpro, O., & Akpome. A. (2024). Herbicides Effects on Soil Functions: A Review. *Asian Soil Research Journal*, Vol. 8(4): 34-41. https://doi.org/10.9734/asrj/2024/v8i4160

Musarandega, H., & Masocha, W. (2023). Disasters and Education System: Cyclone Idai and Schooling Disruption in Eastern Chimanimani, Zimbabwe. *Jamba: Journal of Disaster Risk Studies,* Vol. 15(1), a1349.

Ndumeya, N. (2020). Conserving Wildlife Resources in Zimbabwe: Reflections on Chirinda Forest, 1920-1979. *Environment and History*, Vol. 2(3): 413-442.

Ngoyi, N. (2021). *“African Legacy”.* Gweru, Senga Publishers.

Pinello, F. P. (2022). The World Disenchantment, Re-enchantment, Neo-tribalism and The Free Masonry. *International Journal of Scientific and Research Publications,* Vol.12(7): 186-195.

Reader, J., Jandric, P., Peters, M. A., Barnnet, R., Garbowski, M., Lipinska, V., Rider, S., Bhatt, I., Clarke, A., Hashemi, M., Bevan, A., Trozzo, E, MacKenzie, A., Aldern, J.J., Matias, C.E., Stewart, G.T., Mika, C., McLaren, P., Fawns, T., Knox, J., Savin-Baden, M., Jackson, L., Hood, N., Tesar, M., Fuller, S., & Baker. C*.* (2020). Enchantment-Disenchantment—Re-enchantment: Postdigital Relationships between Science, Philosophy, and Religion, *Postdigital Science and Education* (2021) 3: 934-965.

Shah, K.K., Tripathi, S., Tiwari, I., Shrestha, J., Modi, B.,Paudel, N., & Das, D.B. (2021). The Role of Soil Microbes in Sustainable Crop Production and Soil Health: A Review. *Agricultural Science and Technology*, Vol. 13(2): 109-118. DOI: 10.15547/ast.2021.02.01.9

Sipeyiye, M. (2020). “Rethinking Environmental Sustainability through the Ndau Notion of Communal Existence”. In N. P. Matholeni, G. K. Boateng & M Manyonganise (Eds.), *Mother Earth, Mother Africa & African Indigenous Religions* (pp. 85-105). Stellenbosch, AFRICAN SUN MeDIA.

Sithole, A., & Olorunfemi, O.D. (2024). Sustainable Agricultural Practices in Sub-Saharan Africa: A Review of Adoption Trends, Impacts, and Challenges among Amallholder farmers. *Sustainability*, 16: 9766. <https://doi.org/10.3390/su16229766>

Spiegel, S.G., Kachena, L., & Gudhlanga, L. (2022). Climate Disasters, Altered Migration and Pandemic Shocks: (im)mobilities and interrelated struggles in a border region. *Mobilities*, Vol. 18(2): 328-347. DOI: 10.1080/17450101.2022.2099756

Teron, R., & Borthakur, S.K. (2009). Traditional Knowledge relating to the Use of Flora and Fauna as Indicators in Predicting Annual Seasons among Karbi Tribe of Assam. *Indian Journal of Traditional Knowledge*, Vol. 8(4): 518-524.

Thondhlana, G., & Cundill, G. (2017). Local People and Conservation Officials’ Perceptions on Relationships and Conflicts in South African Protected Areas. *International Journal of Biodiversity Science, Ecosystem Services and Management*, Vol. 13(1): 202-215.

Timofeeva, A., Galyamova, M., & Sedykh, S. (2022). Prospects for Using Phosphate-Solubilizing Microorganisms as Natural Fertilizers in Agriculture. *Plants,* 11, 2019.

Tirivangasi, H.M., & Nyamunda, L. (2024). The interplay of Christianity and Ndau African Traditional Religion in Shaping Climate Change Adaptation in Zimbabwe: An Afrocentric Analysis. *Sustainable Development*, 1-12. https://doi.org/10.1002/sd.3231

Tudararo-Aherobo, L.E., & Ataikiru, T.L. (2020). Effects of Chronic Use of Herbicides on Soil Physicochemical and Microbiological Characteristics*. Microbiology Research Journal International*, Vol. 30(5): 9-19. <https://doi.org/10.9734/MRJI/2020/v30i530215>

WinklerPrins, A.M.G.A., & Sandor, J.A. (2002). Local Soil Knowledge: Insights, Applications and Challenges. *Geoderma,* 111 (2003) 165-170. [www.elsevier.com/locate/geoderma](http://www.elsevier.com/locate/geoderma)

Wippel, K. (2024). Plant and Microbial Features Governing an Endophytic Lifestyle. *Current Option in Plant Biology*, 2023, 76:102483.

Yabalak, E., Akay, S., Kayan, B., Gizir, A.M., & Yang. Y. (2023). Solubility and Decomposition of Organic Compounds in Subcritical Water. *Molecules* 28, 1000. <https://doi.org/10.3390/molecules28031000>

Zablotowicz, R.M., & Reddy, K.N. (2004). Impact of Glyphosate on the *Bradyrhizobium Japonicum* Symbiosis with Glyphosate-resistant Transgenic Soybean: A Mini Review. *J. Environ. Qual*, *33*, 825–831.

Zimmermann, A., McQuinn, B., & Macdonald, D.W. (2020). Levels of Conflict over Wildlife: Understanding and Addressing the Right Problem. *Conservation Science and Practice*. 2:e259. <https://doi.org/10.1111/csp2.259>