

Loss of Agricultural Biodiversity: A Growing Threat in the Era of Climate Change

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Abstract

Agricultural biodiversity, the variety of crops, livestock, and microorganisms essential for food production, is under severe threat due to the escalating impacts of climate change. Rising temperatures, shifting precipitation patterns, and increased frequency of extreme weather events are disrupting ecosystems, reducing the resilience of agricultural systems, and leading to the loss of vital genetic resources. This decline in biodiversity undermines food security, as monocultures and genetically uniform crops become more vulnerable to pests, diseases, and changing environmental conditions. Traditional crop varieties and indigenous livestock breeds, which possess unique adaptive traits, are disappearing at an alarming rate, further eroding the genetic pool necessary for future agricultural adaptation. Climate change exacerbates these challenges by altering habitats, reducing pollinator populations, and intensifying land-use pressures. The loss of agricultural biodiversity not only threatens global food supplies but also impacts livelihoods, particularly in developing regions where smallholder farmers rely heavily on diverse cropping systems. Urgent action is needed to conserve genetic resources, promote sustainable farming practices, and integrate traditional knowledge with modern science. Strategies such as seed banks, agroecological farming, and policy frameworks supporting biodiversity conservation are critical to mitigating these risks. Addressing the loss of

agricultural biodiversity is essential for building resilient food systems capable of withstanding the uncertainties of a changing climate, ensuring long-term food security, and preserving the cultural heritage tied to agricultural practices.

Keywords

Agricultural biodiversity, climate change, food security, genetic resources, sustainable farming, resilience, traditional knowledge, conservation.

Introduction

Agricultural biodiversity—the diversity of plants, animals, and microorganisms essential for agriculture—forms the foundation of global food security, ecological resilience, and sustainable livelihoods. However, this biodiversity is under unprecedented threat due to accelerating climate change. Rising global temperatures, altered precipitation patterns, and the increased frequency of extreme weather events are driving widespread ecological disruption, causing shifts in species distribution, the extinction of wild relatives of crops, and genetic erosion in cultivated varieties (Muluneh, 2021). These changes challenge the adaptive capacity of agricultural systems, particularly in regions dependent on traditional knowledge and rain-fed farming practices.

Although biodiversity plays a vital role in ensuring food system resilience—supporting pollination, nutrient cycling, pest control, and adaptation to environmental stresses—its importance remains underrecognized in mainstream climate and agricultural policies. The global food supply is becoming increasingly homogenized, with over 75% of the world's food derived from just 12 plant and five animal species (FAO, 2019). This narrowing of the genetic base not only undermines food system diversity but increases vulnerability to climate shocks and emerging pests and diseases.

This paper explores the critical intersection of climate change and agricultural biodiversity loss. Drawing on the global analysis by Muluneh (2021), it synthesizes current scientific evidence, identifies key drivers of biodiversity decline, and evaluates the cascading implications for food security. The

study further highlights conservation strategies and policy interventions needed to reverse these trends and support climate-resilient, biodiverse agricultural systems in an era of rapid environmental change.

Understanding Agricultural Biodiversity

Agricultural biodiversity, often termed agrobiodiversity, refers to the variety and variability of animals, plants, microorganisms, and ecosystems that are directly or indirectly involved in agricultural production. This diversity spans genetic differences within species, between species, and across ecosystems. It includes cultivated crops and livestock, crop wild relatives, pollinators, soil microbes, and other associated organisms that contribute to farming systems' productivity, resilience, and sustainability (FAO, 2019).

At the genetic level, agricultural biodiversity allows for the development of crop varieties and animal breeds with specific traits such as drought tolerance, disease resistance, and nutritional quality. This genetic variation is critical for adapting agriculture to changing environmental conditions, particularly under the influence of climate change (Muluneh, 2021). It also underpins traditional knowledge systems and cultural practices associated with food production and consumption.

Historically, farmers selected and maintained a diverse array of crops and livestock breeds suited to their local conditions. However, the advent of industrial agriculture has drastically narrowed this diversity. Today, just 12 plant species and 5 animal species account for more than 75% of the global food supply (FAO, 2020). This shift toward monocultures and uniform breeds has led to significant genetic erosion, reducing the capacity of agricultural systems to respond to biotic and abiotic stresses.

Agricultural biodiversity also plays a critical ecological role. It supports ecosystem functions such as pollination, pest and disease regulation, soil fertility maintenance, and water regulation—services essential for food production and ecosystem health. The presence of diverse organisms creates synergies that enhance agricultural productivity, stability,

and sustainability. Therefore, preserving and promoting agrobiodiversity is not only about safeguarding genetic resources but also about ensuring the long-term resilience of food systems in the face of climate variability and change.

Climate Change and Its Impact on Biodiversity

Climate change has emerged as one of the most significant global drivers of biodiversity loss. It alters temperature and precipitation patterns, increases the frequency and intensity of extreme weather events, and disrupts ecological balances across terrestrial and aquatic ecosystems. These climatic disruptions are contributing to habitat degradation, species migration, phenological mismatches, and ultimately, extinction (Muluneh, 2021).

Species' geographic ranges are shifting in response to warming temperatures. Observational data indicate that many species are moving toward higher altitudes at a median rate of 11 meters per decade and to higher latitudes at a rate of approximately 16.9 kilometres per decade (Muluneh, 2021). While some mobile or generalist species can adapt to these changes, narrowly adapted and endemic species often face increased extinction risks. For instance, amphibians, coral reefs, and alpine plants are particularly vulnerable due to their limited dispersal capacity and habitat specialization.

Climate-induced changes affect species not only by shifting their habitats but also by altering interspecies interactions, reproductive cycles, and physiological development. For example, altered temperatures can lead to mismatches in the timing of flowering and the activity periods of pollinators, disrupting crucial ecosystem services (Muluneh, 2021). Similarly, temperature changes have caused certain species—such as birds and amphibians—to breed earlier, sometimes misaligned with food availability, which threatens population survival.

Furthermore, climate change indirectly impacts biodiversity through increased frequency of disturbances such as wildfires, floods, droughts, and storms. These events exacerbate ecosystem fragmentation and accelerate the decline of populations already stressed by human activities

like deforestation and land-use change. High-diversity ecosystems, such as the Melanesian Islands and tropical forests, have experienced significant losses due to the combined effects of climate variability and anthropogenic pressures (Muluneh, 2021).

The introduction and expansion of invasive species under changing climates further intensify biodiversity loss. Invasive species, often more adaptable to new environmental conditions, can outcompete native flora and fauna, leading to homogenization of ecosystems (Muluneh, 2021). Such shifts undermine the ecological integrity and functional diversity necessary for agricultural resilience and food security.

Key Drivers of Agricultural Biodiversity Loss in the Climate Context

Agricultural biodiversity is a vital component of sustainable food systems, providing resilience to climate shocks, supporting ecosystem services, and ensuring the availability of genetic resources for future adaptation. However, this biodiversity is being eroded at an alarming rate, particularly in the context of accelerating climate change. While climate change itself poses direct and indirect threats to biodiversity, it often interacts synergistically with other anthropogenic drivers to intensify the loss. Understanding these interconnected drivers is essential for designing effective conservation and adaptation strategies. The following subsections explore the major drivers of agricultural biodiversity loss in the context of a changing climate, as synthesized from Muluneh (2021).

● Habitat Loss and Fragmentation

Habitat loss is one of the most immediate and significant threats to biodiversity globally. As climate change shifts the suitability of ecological zones, farmers are compelled to expand cultivation into new areas, including forests, wetlands, and marginal lands. This expansion, often in the form of monoculture plantations, results in the destruction and fragmentation of natural habitats critical for wild species, including crop wild relatives and pollinators (Muluneh, 2021). Fragmented habitats reduce the capacity of ecosystems to support diverse organisms and impede gene flow between populations, which is crucial for evolutionary adaptation.

The conversion of natural landscapes for agricultural use contributes to soil degradation, water stress, and loss of ecosystem connectivity. Particularly in biodiversity hotspots such as tropical rainforests, the intrusion of agriculture has led to the displacement or extinction of many endemic species. Climate change exacerbates these trends by making previously unsuitable lands more viable for farming, thus accelerating deforestation and habitat disruption.

- **Monoculture Expansion and Genetic Erosion**

Modern agricultural systems increasingly rely on a narrow selection of high-yielding crop varieties and livestock breeds, resulting in widespread genetic erosion. According to Muluneh (2021), more than 75% of the world's food is now derived from just 12 plant species and 5 animal species. This dramatic reduction in diversity diminishes the gene pool available for breeding and limits the resilience of crops and livestock to climate-induced stresses such as drought, salinity, pests, and diseases.

Genetic erosion is further intensified by the replacement of traditional landraces and indigenous breeds with genetically uniform commercial varieties. These modern varieties are often poorly adapted to local ecological conditions and require intensive inputs, making them more vulnerable to environmental variability. The loss of traditional knowledge associated with diverse cropping systems also contributes to the decline in agrobiodiversity.

Climate change amplifies genetic erosion by altering growing conditions, making it difficult for certain varieties or breeds to survive without significant adaptation. Without access to a broad genetic base, breeding programs face limitations in developing climate-resilient cultivars.

- **Overexploitation of Wild Biodiversity Resources**

In many regions, especially among rural and Indigenous communities, wild biodiversity serves as a critical safety net during periods of food shortage, crop failure, or income insecurity. However, climate-induced stresses—such as droughts, unpredictable rainfall, and land degradation—can

drive overharvesting of wild plants, animals, and non-timber forest products.

Muluneh (2021) highlights that overexploitation leads to the depletion of critical genetic resources, including wild crop relatives that may possess valuable traits for climate resilience. For example, wild legumes and cereals often carry genes for drought and pest resistance that are absent in cultivated varieties. Once these wild populations are lost, their genetic contributions to future food security may be permanently erased.

The degradation of forests, grasslands, and wetlands—driven by both climate change and human extraction—further compromises the ecological niches where wild biodiversity thrives. The loss of these habitats not only reduces biodiversity but also disrupts ecological processes such as pollination and seed dispersal.

● **Invasive Alien Species**

Invasive species are non-native organisms that establish, spread, and cause harm to local ecosystems. Climate change facilitates the spread and dominance of invasive species by altering environmental conditions and weakening native ecosystems. Warmer temperatures, for instance, can allow invasive pests and plants to colonize new areas, outcompeting native species and reducing overall biodiversity (Muluneh, 2021).

In agricultural landscapes, invasive species can disrupt crop production, pollination networks, and soil microbiomes. They often exhibit high adaptability and reproductive capacity, making them especially competitive in rapidly changing environments. Their proliferation can displace native species and contribute to ecological homogenization, undermining local agricultural systems that depend on diverse genetic and functional traits.

The introduction and establishment of invasive alien species—intentionally or accidentally—are further exacerbated by global trade and agricultural intensification. Climate change adds an additional layer of complexity, enabling invasives

to expand their ranges and establish in regions previously inhospitable.

● **Pollution and Agrochemical Intensification**

Modern agriculture depends heavily on synthetic fertilizers, pesticides, herbicides, and other agrochemicals to maintain productivity. However, these substances often have unintended consequences for biodiversity. Excessive nitrogen and phosphorus runoff leads to eutrophication of aquatic systems, causing fish kills and the loss of freshwater biodiversity. Pesticides, meanwhile, reduce populations of beneficial insects such as pollinators and natural pest regulators.

Climate change alters pest and disease dynamics, prompting increased use of chemical controls. As temperatures rise and pest pressures intensify, farmers may apply larger quantities of agrochemicals, further endangering soil organisms, pollinators, and biodiversity in adjacent ecosystems (Muluneh, 2021).

Moreover, pollution from fossil fuels and industrial emissions contributes to atmospheric changes that affect plant physiology and soil chemistry. These alterations have cascading effects on crop yield, genetic variation, and overall agrobiodiversity.

● **Climate-Induced Stressors and Phenological Shifts**

Climate change itself is a direct driver of biodiversity loss through temperature rise, altered rainfall patterns, and extreme weather events. These factors disrupt the phenology—the timing of biological events—of plants and animals. For instance, earlier flowering in plants or premature insect emergence can result in mismatches with pollinators, reducing reproductive success and yield (Muluneh, 2021).

Extreme events like floods, droughts, heatwaves, and cyclones can cause sudden and irreversible losses in genetic diversity. In agriculture, prolonged droughts may eliminate drought-sensitive varieties, while floods can destroy seed banks and breeding stock. These shocks accelerate the erosion of traditional varieties and breeds that have not been conserved

in formal systems.

Additionally, climate-induced sea level rise and salinity intrusion in coastal regions threaten unique agro-ecosystems such as mangrove rice paddies and estuarine fisheries, leading to the displacement of species and livelihoods.

● **Socioeconomic and Institutional Factors**

Beyond biophysical drivers, socioeconomic factors such as land tenure insecurity, market-driven crop choices, policy neglect, and inadequate conservation funding play a pivotal role in agrobiodiversity loss. Climate-induced food insecurity often compels farmers to prioritize short-term productivity over long-term sustainability. This may involve adopting high-yield monocultures or abandoning traditional practices that conserve biodiversity.

Weak institutions and lack of policy integration further hinder biodiversity conservation efforts. According to Muluneh (2021), poor governance, corruption, and fragmented land-use policies exacerbate environmental degradation and undermine community-based conservation initiatives.

Global trade policies and intellectual property rights can also restrict farmers' access to diverse seed materials, thereby limiting their ability to adapt to changing climate conditions using local genetic resources.

Impacts on Ecosystem Services and Food Security

Biodiversity underpins critical ecosystem services such as pollination, nutrient cycling, pest regulation, and soil fertility (MEA, 2005). Loss of agrobiodiversity diminishes these services, directly affecting crop yields and food production.

For instance, pollinator diversity decline is linked to climate-induced phenological mismatches between crops and their pollinators. A reduction in soil microbial diversity compromises nutrient availability and carbon sequestration. These disruptions threaten all four dimensions of food security: availability, access, utilization, and stability (Muluneh, 2021).

Climate-Induced Species Range Shifts and Extinctions

Species are shifting their geographical ranges to track suitable climates. On average, terrestrial species move 16.9 km poleward and 11.0 m upward in elevation per decade (Chen et al., 2011). Such shifts can result in altered community dynamics, range contractions, or local extinctions.

For crops, these shifts can mean loss of suitable growing areas, particularly in the tropics. For example, staple crops like maize, millet, and sorghum may see declining productivity in sub-Saharan Africa due to decreased rainfall and rising temperatures (Muluneh, 2021).

Phenotypic Plasticity and Genetic Adaptation

Some species exhibit phenotypic plasticity, allowing them to adapt to short-term climate variability. However, long-term resilience requires genetic adaptation—a process constrained by habitat fragmentation and gene flow disruption (Jump & Peñuelas, 2005).

Loss of genetic diversity within crop species reduces the potential for selection and breeding of stress-tolerant varieties. This genetic bottleneck is particularly pronounced in industrial agriculture systems that rely on narrow genetic pools (Muluneh, 2021).

Climate Change and Agroecosystem Vulnerability

● Drylands and Marginal Areas

Arid and semi-arid zones are disproportionately affected by climate change. Water scarcity, declining soil fertility, and reduced vegetation cover impair agricultural productivity and biodiversity (Muluneh, 2021). These areas are often biodiversity hotspots, and their degradation leads to cascading ecological consequences.

● Forests and Agroforestry Systems

Forests harbor a significant proportion of agricultural biodiversity, including wild relatives and traditional knowledge systems. Climate-induced deforestation not only reduces biodiversity but also carbon storage, accelerating climate feedback loops.

- **Marine and Aquatic Systems**

Rising sea temperatures and ocean acidification threaten fish biodiversity and coral reef ecosystems. Fisheries contribute significantly to food security, and their decline poses risks for coastal communities (IPCC, 2019).

Socioeconomic Dimensions of Biodiversity Loss

Smallholder farmers, pastoralists, and Indigenous communities depend heavily on local agrobiodiversity for nutrition, income, and cultural practices. Loss of biodiversity undermines their adaptive capacity and increases food insecurity.

Moreover, women play a crucial role in conserving traditional crop varieties and local breeds. Climate-driven loss of biodiversity disproportionately affects women by reducing access to diverse food sources and medicinal plants (FAO, 2019).

Conservation and Adaptation Strategies

- **In Situ and Ex Situ Conservation**

Preserving genetic diversity through seed banks, field gene banks, and in situ conservation of landraces is vital. Initiatives like the Svalbard Global Seed Vault provide global backups, while community seed banks enhance local adaptation.

- **Agroecology and Diversification**

Agroecological practices such as intercropping, agroforestry, and crop-livestock integration promote functional biodiversity. Diversification reduces climate risk and enhances resilience to pests and diseases (Altieri et al., 2015).

- **Traditional Knowledge and Participatory Breeding**

Incorporating Indigenous knowledge in breeding programs can improve crop adaptation to local conditions. Participatory plant breeding allows farmers to select traits suited to changing climates.

- **Policy and Governance**

Effective biodiversity conservation requires policies that

integrate agriculture, environment, and climate objectives. Incentives for biodiversity-friendly practices, legal protection of wild relatives, and support for smallholder innovation are crucial.

Research Gaps and Future Directions

Despite growing evidence, major knowledge gaps persist regarding the synergistic impacts of climate change and other drivers on agricultural biodiversity. Long-term monitoring, predictive modeling, and cross-disciplinary studies are needed.

Future research should focus on:

- Mapping vulnerability of crop wild relatives.
- Understanding microbiome-climate interactions.
- Scaling successful agroecological models.
- Enhancing global data sharing and conservation networks.

Conclusion

The accelerating loss of agricultural biodiversity in the context of climate change represents a serious threat to global food systems, ecological stability, and human well-being. As highlighted throughout this paper, rising temperatures, altered precipitation patterns, extreme weather events, and sea-level rise are disrupting habitats and ecosystems that support a wide range of crops, livestock, and associated organisms. These changes not only erode genetic diversity but also weaken the resilience of agricultural systems, making them more vulnerable to pests, diseases, and environmental stresses.

Traditional varieties and indigenous breeds, which embody generations of adaptation and cultural knowledge, are rapidly disappearing. Their loss constrains future breeding potential and reduces the capacity of agriculture to adapt to changing climatic conditions. Furthermore, the homogenization of global food systems, characterized by the dominance of a few species, intensifies vulnerability to climate shocks.

Addressing this crisis requires immediate and coordinated action at multiple levels. Strategies must prioritize both in situ and ex situ conservation, promotion of agroecological farming practices, support for traditional knowledge, and stronger policy frameworks that integrate biodiversity with climate resilience. Empowering local communities—particularly smallholder farmers, Indigenous peoples, and women—is essential to restoring and safeguarding agrobiodiversity.

Research and innovation should also focus on expanding genetic resource documentation, enhancing participatory breeding, and integrating climate models with biodiversity conservation planning. Only through holistic, inclusive, and forward-looking approaches can we halt the loss of agricultural biodiversity and secure a resilient, sustainable, and equitable food future for all.

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