

Agrobiodiversity Conservation through Sustainable Agricultural Practices

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Abstract

Agrobiodiversity, which includes the diversity of crops, livestock, microorganisms, and associated ecosystems used in agriculture, forms the biological foundation of global food systems and rural livelihoods. It plays a crucial role in ensuring food and nutritional security, enhancing ecosystem resilience, and supporting adaptation to climate change. However, agrobiodiversity is increasingly threatened by agricultural intensification, monocropping, genetic erosion, climate variability, land-use change, and socio-economic pressures. The widespread adoption of uniform, high-input farming systems has resulted in the loss of traditional crop varieties and locally adapted livestock breeds, thereby increasing vulnerability to biotic and abiotic stresses. Sustainable agricultural practices provide effective pathways for conserving and revitalizing agrobiodiversity while maintaining agricultural productivity and environmental integrity. This article examines the significance of agrobiodiversity in sustainable food systems and critically analyzes the role of practices such as crop diversification, conservation agriculture, agroforestry, organic farming, and integrated crop–livestock systems in enhancing biological diversity within agricultural landscapes. The article also highlights the importance of traditional knowledge, farmer-led conservation initiatives, and community-based approaches in maintaining genetic resources and promoting adaptive capacity.

Keywords: Agrobiodiversity, sustainable agriculture, crop diversity, ecosystem resilience, conservation farming, food security.

1. Introduction

Agrobiodiversity refers to the variety and variability of plants, animals, microorganisms, and ecosystems that are directly or indirectly involved in food and agricultural production. It encompasses genetic diversity within crop varieties and livestock breeds, species diversity across cultivated and associated organisms, and ecosystem diversity within agricultural landscapes [1]. As the biological foundation of agriculture, agrobiodiversity underpins food security, nutrition, livelihoods, and the resilience of farming systems across the world. Historically, agricultural systems evolved through close interactions between humans and nature, resulting in the domestication and diversification of thousands of crop species and animal breeds adapted to local environments. Traditional farming systems were characterized by mixed cropping, crop–livestock integration, and reliance on locally adapted genetic resources [2]. These systems supported high levels of biological diversity while sustaining rural communities and ecosystems. However, over the past century, rapid agricultural modernization has led to a significant narrowing of the genetic base of global food production.

The expansion of industrial agriculture, driven by the pursuit of higher yields and economic efficiency, has promoted monocultures, uniform crop varieties, and high external inputs such as synthetic fertilizers and pesticides. While these approaches have contributed to increased food production in the short term, they have also accelerated genetic erosion, reduced ecosystem complexity, and heightened vulnerability to pests, diseases, and climatic extremes [3].

Currently, a small number of crop species account for the majority of global caloric intake, raising serious concerns about the sustainability and resilience of food systems. Agrobiodiversity is increasingly recognized as a critical component of sustainable agriculture and climate adaptation. Diverse farming systems are better able to withstand environmental stresses such as droughts, floods, heat waves, and emerging pests and pathogens. Genetic diversity within crops and livestock enhances adaptive capacity by providing traits related to stress tolerance, disease resistance, and productivity under variable conditions. In the context of climate change, agrobiodiversity offers nature-based solutions that support both mitigation and adaptation objectives. Beyond productivity and resilience, agrobiodiversity contributes to a wide range of ecosystem services essential for agricultural sustainability [4]. These include soil formation and fertility maintenance, pollination, biological pest control, water regulation, and nutrient cycling. Diverse agroecosystems also support associated biodiversity, including pollinators, natural enemies of pests, soil microorganisms, and wildlife. In this way, agrobiodiversity links agricultural production with broader biodiversity conservation goals. Agrobiodiversity also holds significant socio-cultural and economic value [5]. Traditional crop varieties and livestock breeds are closely linked to cultural identities, indigenous knowledge systems, culinary traditions, and local economies. They play a vital role in dietary diversity and nutrition, particularly for smallholder and marginalized communities.

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The erosion of agrobiodiversity therefore represents not only an ecological concern but also a loss of cultural heritage and livelihood options. Despite its importance, agrobiodiversity continues to decline due to land-use change, market pressures, policy biases favoring uniform production systems, and the erosion of traditional knowledge. Addressing these challenges requires a transition toward sustainable agricultural practices that integrate ecological principles, support farmer innovation, and promote diversity-based farming systems. This article examines the role of sustainable agricultural practices in conserving and enhancing agrobiodiversity, highlighting their ecological, socio-economic, and policy relevance in building resilient and sustainable food systems.

2. Importance of Agrobiodiversity

Agrobiodiversity plays a fundamental role in sustaining agricultural productivity, ecosystem stability, and human well-being. By encompassing the diversity of crops, livestock, microorganisms, and associated ecosystems, agrobiodiversity enhances the resilience of farming systems to environmental stresses such as droughts, floods, salinity, and temperature extremes. Diverse agricultural systems are better able to withstand shocks because different species and varieties respond differently to changing conditions, reducing the risk of total crop failure [6].

Genetic diversity within crops and livestock is particularly critical for adaptation to climate change and emerging pests and diseases. Traditional crop varieties and indigenous livestock breeds often possess unique traits—such as drought tolerance, disease resistance, or nutrient efficiency—that are absent in high-yielding commercial varieties. These genetic resources provide the raw material for plant and animal breeding programs, supporting long-term food security and sustainable agricultural development. Beyond food production, agrobiodiversity underpins a wide range of ecosystem services essential for healthy agroecosystems. These include soil fertility maintenance through diverse root systems and microbial interactions, pollination by insects supported by varied habitats, natural pest control through predator-prey relationships, and efficient nutrient cycling. Such ecosystem services reduce dependence on external inputs like synthetic fertilizers and pesticides, thereby lowering production costs and environmental impacts [7]. Agrobiodiversity also holds significant social, cultural, and nutritional value. Many traditional farming systems are closely linked to local knowledge, cultural identity, and customary practices that have evolved over generations. Diverse agricultural landscapes support a wide range of foods, contributing to dietary diversity and improved nutrition. This is especially important in rural and indigenous communities, where local crops and livestock are often key sources of micronutrients and livelihood security.

Table 1: Sustainable Agricultural Practices and Their Contributions to Agrobiodiversity Conservation

Sustainable Practice	Key Characteristics	Contribution to Agrobiodiversity
Crop Diversification & Mixed Farming	Intercropping, crop rotation, polycultures, crop-livestock integration	Enhances species and genetic diversity, reduces pest and disease pressure, improves system resilience
Conservation Agriculture	Minimal tillage, permanent soil cover, diversified rotations	Improves soil biodiversity, soil structure, and nutrient cycling; supports long-term productivity
Agroforestry Systems	Integration of trees with crops and/or livestock	Provides diverse habitats, enhances ecosystem services, improves microclimate and carbon sequestration
Organic & Low-Input Farming	Reduced synthetic inputs, reliance on ecological processes	Supports pollinators, natural enemies, and soil microorganisms; conserves local varieties

Table 2: Major Threats to Agrobiodiversity and Policy-Oriented Responses

Threat	Main Drivers	Impacts on Agrobiodiversity	Potential Policy and Management Responses
Agricultural Intensification	Monocultures, high-input farming, mechanization	Genetic erosion, loss of traditional varieties and breeds	Incentives for diversified farming and agroecological practices
Land-Use Change	Urbanization, deforestation, industrial agriculture	Habitat loss for wild crop relatives and livestock breeds	Land-use planning and habitat protection measures
Climate Change	Temperature rise, altered rainfall, extreme events	Increased vulnerability of uniform systems, spread of pests and diseases	Climate-resilient varieties, diversified farming systems
Socio-economic Pressures	Market globalization, policy bias toward uniform production	Decline of traditional knowledge and local farming systems	Protection of farmers' seed rights and support for local markets

3. Threats to Agrobiodiversity

Despite its importance, agrobiodiversity is rapidly declining due to multiple interacting threats. One of the primary drivers is agricultural intensification, which has favored monoculture systems, high-yielding uniform varieties, and extensive use of chemical fertilizers, pesticides, and mechanization. While these practices have increased short-term productivity, they have often displaced traditional crop varieties and livestock breeds, leading to genetic erosion and reduced system resilience [8]. Land-use change further accelerates the loss of agrobiodiversity. Urbanization, industrial expansion, deforestation, and the conversion of diverse agricultural landscapes into large-scale commercial farms reduce habitats for wild relatives of crops and livestock. These wild species are vital reservoirs of genetic diversity, and their loss limits future opportunities for crop improvement and adaptation [9]. Climate change presents an additional and growing threat by

altering temperature and rainfall patterns, shifting growing seasons, and increasing the frequency and intensity of extreme weather events. Such changes can render traditional varieties unsuitable for their historical environments, while also increasing the spread of pests, diseases, and invasive species. Agricultural systems with low genetic diversity are particularly vulnerable to these climate-related stresses [10]. Socio-economic and institutional factors also contribute to agrobiodiversity loss. Market globalization often promotes standardized products and uniform production systems, discouraging farmers from cultivating diverse local varieties. Policy incentives and subsidies frequently favor high-input, commercial agriculture over small-scale, diversified farming. Additionally, the erosion of traditional knowledge, rural outmigration, and limited access to markets for local products further undermine the conservation and use of agrobiodiversity.

4. Sustainable Agricultural Practices for Agrobiodiversity Conservation

Sustainable agricultural practices play a crucial role in conserving agrobiodiversity by aligning food production with ecological processes. These approaches seek to optimize productivity while minimizing environmental degradation, thereby creating resilient farming systems capable of sustaining biological diversity at genetic, species, and ecosystem levels. By reducing reliance on external inputs and enhancing natural interactions, sustainable agriculture supports both conservation and livelihoods.

4.1 Crop Diversification and Mixed Farming

Crop diversification is one of the most effective strategies for conserving agrobiodiversity at the farm level. Practices such as intercropping, crop rotation, relay cropping, and polycultures increase species and genetic diversity within agricultural landscapes [4]. Diversified cropping systems reduce vulnerability to pests, diseases, and climatic variability, as the presence of multiple species interrupts pest life cycles and stabilizes yields. Mixed farming systems that integrate crops and livestock further enhance agrobiodiversity conservation. Livestock contribute organic manure, improve nutrient cycling, and provide additional income sources, while crop residues serve as feed. This integration promotes system stability, reduces waste, and strengthens ecological linkages within the farm, making production systems more resilient and sustainable.

4.2 Conservation Agriculture

Conservation agriculture is based on three core principles: minimal soil disturbance, permanent soil cover, and diversified crop rotations. Together, these practices protect soil structure, enhance soil organic matter, and foster rich communities of soil organisms such as earthworms, fungi, and bacteria [6]. Healthy soils support diverse plant species and improve water retention, which is particularly important under climate stress conditions. The reducing tillage and maintaining crop residues, conservation agriculture creates a favorable environment for below-ground biodiversity while also supporting above-ground organisms. Diversified rotations prevent the dominance of single crops, thereby contributing to genetic and species diversity and reducing dependency on chemical inputs.

4.3 Agroforestry Systems

Agroforestry systems integrate trees with crops and/or livestock, creating complex and multifunctional landscapes. These systems support high levels of biodiversity by providing varied habitats for plants, insects, birds, and microorganisms [5]. Trees contribute to microclimate regulation by reducing temperature extremes and wind speed, which benefits understory crops and livestock, biodiversity benefits, agroforestry enhances ecosystem services such as soil stabilization, water regulation, and carbon sequestration. The inclusion of fruit, fodder, and timber trees also diversifies farm outputs, improving food security and income while reducing pressure on natural forests.

4.4 Organic and Low-Input Farming

Organic and low-input farming systems rely on ecological processes, biological interactions, and natural nutrient cycles rather than synthetic fertilizers and pesticides.

These systems often support greater on-farm biodiversity, including pollinators, natural enemies of pests, and soil microorganisms, due to reduced chemical disturbance [7]. The encouraging the use of local varieties, composting, green manures, and biological pest control, organic farming promotes the conservation and continued use of diverse genetic resources. Low-input systems are particularly important for smallholder farmers, as they enhance resilience while reducing production costs and environmental impacts.

5. Role of Traditional Knowledge and Local Communities

Farmers, pastoralists, and indigenous communities are central to the conservation of agrobiodiversity. Over generations, they have developed, selected, and maintained a wide range of crop varieties and livestock breeds adapted to local environmental conditions and cultural needs. Traditional knowledge related to seed selection, breeding, planting calendars, and landscape management plays a critical role in sustaining agricultural diversity [8]. Community-based initiatives such as seed saving, community seed banks, and participatory plant breeding help preserve locally adapted genetic resources while ensuring farmers' access to diverse planting materials. Farmer-led conservation approaches strengthen local capacity, promote knowledge exchange, and allow agrobiodiversity to evolve dynamically in response to changing conditions rather than remaining static in gene banks alone.

6. Policy and Governance Dimensions

The conservation and sustainable use of agrobiodiversity require enabling policy and governance frameworks at local, national, and international levels. Policies should recognize the ecological, economic, and cultural value of diversity in agricultural systems and actively promote sustainable farming practices. Protecting farmers' rights to save, use, exchange, and sell seeds is essential for maintaining on-farm diversity. Governments can support agrobiodiversity conservation by investing in in situ and ex situ conservation measures, such as on-farm conservation programs and national gene banks. Integrating agrobiodiversity considerations into national agricultural strategies, climate change adaptation plans, and rural development programs enhances policy coherence and long-term impact. At the international level, agreements related to biodiversity conservation, food security, and genetic resources provide important frameworks for national action. Effective implementation of these agreements, combined with inclusive governance and stakeholder participation, is key to addressing agrobiodiversity loss.

7. Future Perspectives

As global food systems face increasing pressures from climate change, population growth, land degradation, and resource scarcity, agrobiodiversity will become increasingly vital for ensuring food security and sustainability. Diverse agricultural systems offer greater adaptive capacity and reduce the risks associated with uniform, high-input production models. Emerging approaches such as agroecology, digital agriculture, and participatory research provide new opportunities to document, manage, and enhance agricultural diversity. Digital tools can support the mapping and monitoring of genetic resources, while participatory research strengthens collaboration between scientists and farming communities. Long-term success in agrobiodiversity conservation will depend on integrated efforts that link science, policy, and practice.

Strengthening collaboration among farmers, researchers, policymakers, and civil society is essential for building resilient, inclusive, and sustainable agricultural systems capable of meeting future challenges.

8. Conclusion

Agrobiodiversity conservation through sustainable agricultural practices is essential for ensuring food security, ecological resilience, and sustainable livelihoods. An embracing diversity-based farming systems, integrating traditional knowledge, and implementing supportive policies, agriculture can contribute significantly to biodiversity conservation. Sustainable agriculture thus represents not only a production strategy but also a pathway toward harmonizing human needs with the conservation of biological diversity.

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