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Review paper

Role of Biodiversity in Ecological Sustainability: An Ecoagricultural Perspective

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ABSTRACT

According to growing evidence, the level of internal control of function in agroecosystems is substantially determined by the amount of plant and animal diversification present. Biodiversity in agroecosystems provides a number of ecological functions in addition to food production, including as nutrient recycling, microclimate management, local hydrological process regulation, suppression of undesired species, and noxious chemical detoxification. The importance of biodiversity in crop protection, soil fertility and human health is examined in detail in this paper. It is suggested that the sustainability of biodiversity-mediated renewal processes and ecological services is dependent on the preservation of biological integrity and variety in agroecosystems. Agroecosystem management and design strategies that improve functional biodiversity in agricultural fields are discussed.

1. Introduction

All species of plants, animals, and microorganisms that exist and interact within an ecosystem are referred to as biodiversity (Vandermeer & Perfecto, 1995). All agricultural plants and animals owe their existence to natural biodiversity. The vast majority of domestic crops utilised in global agriculture are derived from wild species that have been domesticated, selectively bred, and hybridised. The majority of the world's surviving diversity hotspots are home to populations of variable and adaptive landraces, as well as wild and weedy crop cousins, all of which provide rich genetic resources for crop development (Harlan, 1975). Biodiversity provides ecological benefits in agricultural systems that go beyond the production of food, fibre, fuel, and revenue. Nutrient recycling, management of local microclimate, regulation of local hydrological processes, regulation of the number of undesired

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species, and toxic chemical detoxification are just a few examples. A critical need is to provide enough food production and supply for a growing population in a world where biological, terrestrial, and aquatic resources have already been severely damaged or depleted (Figure 1).

A profound shift in human lifestyle started at the end of the Pleistocene epoch and the start of the present epoch, known as the Holocene, according to geologists. That shift happened first in the Near East, ten to twelve millennia ago, during the Neolithic Age, according to researchers. As the previous ice age ended, the warming trend resulted in a plethora of plant and animal life in that region, providing people with an abundance of food supplies as well as suitable locations for frequent, and ultimately permanent, residence (Harlan, 1975; Hillel, 1992). As a result, human cultures abandoned their previous existence as nomadic hunter-gatherers and became sedentary food producers, relying on their carefully maintained crops and cattle for survival. Plants and animals (e.g., wheat, rice, maize, cattle, swine, and poultry) propagated through agriculture are among the most common and widely distributed creatures.

Humans have actually become the dominant species on the planet as a result of these creatures. Humans and their domesticated animals acquired an inextricable mutual reliance as a result. The net result of agricultural biodiversity simplification is an artificial ecosystem that requires constant human intervention, whereas in natural ecosystems, internal regulation of function is a product of plant biodiversity through energy and nutrient flows, and this form of control is progressively lost under agricultural intensification (Swift & Anderson, 1993). Commercial seed-bed preparation and automated planting, for example, have replaced natural seed dispersion systems; chemical pesticides have replaced natural controls on weed, insect, and disease populations; and genetic modification has replaced natural plant evolution and selection processes. Even decomposition is affected since plant growth is harvested and soil fertility is maintained using fertilisers rather than nutrient recycling (Cox and Atkins, 1979).

Poor management techniques have caused deterioration within the agricultural areas itself. Denudation of the vegetative cover, along with surface pulverisation from tillage or cattle or mechanical trampling, has left the soil exposed to wind and water erosion during rainstorms. In severe situations, the fertile topsoil has been swept away altogether, exposing the less fruitful subsoil (or even infertile bedrock). As a result, soil productivity is severely harmed, as is its ability to support many types of life (Cary & Fierer, 2014).

As a result, contemporary agricultural systems have grown productive, but only by relying heavily on outside inputs. A rising number of scientists, farmers, and members of the general public are concerned about the long-term viability of food production systems that are extremely input-dependent and environmentally simplistic. Questions have been raised concerning contemporary farming's rising reliance on nonrenewable resources, biodiversity loss, land loss due to soil erosion, and a significant reliance on chemical fertilisers and pesticides. Farm chemicals are questioned because of their high expense, but they also have ramifications for human and animal health, food quality and safety, and environmental quality (Harlan, 1975). The commercial agricultural sectors of emerging nations have comparable issues, but the bigger challenge for them is figuring out innovative strategies to boost small farm output that benefit the rural poor while both conserving and regenerating the resource base (hillsides, rainfed, and marginal soils) (Altieri, 1995).

Fortunately, the situation isn't completely hopeless. Many of the problems mentioned may be avoided or reduced. New trends and possibilities offer promise for averting additional biodiversity risks. The rate of human population increase appears to be slowing. Furthermore, agriculture has already begun to develop and implement improved production methods, as well as biological management and conservation, with the goal of conserving, if not improving, the diversity of life on Earth (Edwards et al., 1993; Smith et al., 1995). The new ideas are being fueled by a rising understanding of the value of biodiversity in agriculture.

Traditional farmers of the Third World, on the other hand, are not unfamiliar with biodiversity. Plant variety in the form of polycultures and/or agroforestry patterns is, in fact, a distinguishing feature of traditional agricultural systems. In reality, the species richness of conventional agroecosystems' biotic components is equivalent to that of many natural ecosystems. These systems can help to promote dietary diversity and revenue, as well as production stability, risk minimization, reduced pest and disease incidence, efficient labour usage, intensification of output with limited resources, and return maximisation at low levels of technology. Traditional multi-cropping systems are thought to contribute up to 15% of the world's food supply. Farmers in Latin America combine maize, potatoes, and other crops to cultivate 70-90 percent of their beans. On 60% of the region's maize-growing land, maize is intercropped (Francis, 1986).

Traditional agroforestry systems in the tropics, on the other hand, typically have over 100 annual and perennial plant species per field, which are utilised for construction materials, firewood, tools, medicine, animal feed, and human sustenance. The trees in these systems not only provide beneficial products, but they also reduce nutrient leaching and soil erosion, and they replenish critical nutrients by pumping them from the lower soil layers (Zhang et al., 2021). The Huastec Indians' home gardens in Mexico and the Amazonian Kayapo and Bora Indians' agroforestry systems are two examples (Toledo, 1985).

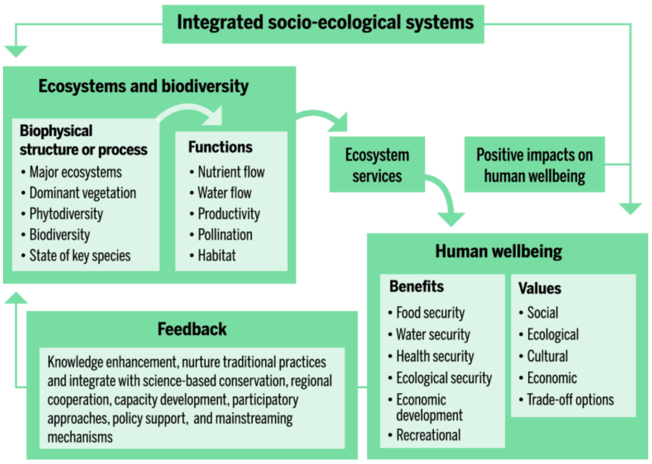

Figure 1. Linkages between ecosystems, biodiversity, and human wellbeing (Xu et al., 2019)

2. Dependence of Agriculture on Biodiversity

Agricultural breeding has always been done using the organisms' near genetic relatives (either wild genotypes or domesticated variations or strains). In situ genetic diversity is frequently seen as a resource for crop development in the future (Ladizinsky, 1989). Different strains might have different genes, including ones that provide tolerance to pests and environmental challenges. Recently, new techniques have emerged that allow desirable features (genes) to be transferred not merely between strains of the same species, but also between species, considerably expanding the variety of genetic resources accessible to agriculture (albeit the new techniques also introduce new risks). In any case, raising plants and animals for agricultural purposes was and continues to be reliant on the diversity of living forms found in nature, i.e. natural biodiversity. Microbial species that live on plants and animals, and are especially common in the soil, are even more numerous and diverse. They, too, aid in pest control, as well as degrade wastes (including pathogenic and poisonous agents) and convert them into nutrients for life's continuous regeneration, as well as create and stabilise soil structure. Nitrogen fixing bacteria can be symbiotic (as in Rhizobium bacteria that adhere to the roots of legumes) or nonsymbiotic (as in freeliving bacteria). Mycorrhizal fungi, which grow in connection with crop roots and aid in the absorption of phosphorus and other relatively immobile nutrients, serve a different purpose (Hartel, 2005).

Agriculture is thus dependent on biodiversity in both apparent and unseen ways. Biodiversity provides not only immediate functional benefits, but also long-term protection against extinction and evolutionary adaptability in the face of future climatic change (Lande, 1988; Six et al., 2006). Natural and guided selection use genetic diversity in wild populations as a substrate. As a result, a reduction in variety endangers agriculture, as well as all of life's processes on Earth, which are essentially interrelated.

Pollination declines have been documented on every continent except Antarctica (Kearns et al., 1998), and under pollination for some crops due to pollinator shortages has already reached 70% in some areas (Reddi, 1987). Pollinators play an important role in agricultural productivity, thus this is crucial (Buchmann & Nabhan, 1996). Isolated radish and mustard plants were used in an experiment to demonstrate the effect of habitat isolation (which occurs frequently in agricultural regions when native areas are converted to agriculture) on pollination (Steffan-Dewenter & Tscharntke, 1999). The areas were set up in an agricultural environment at varied distances from a species-rich grassland. As the islands became more isolated, the number of bee visits each hour decreased, as did the taxonomic variety of the visitors. Fruit and seed set also decreased as the distance between the grasslands grew greater. Another research found that the quantity of woody border in agricultural fields had a considerable favourable influence on the overall richness of insects at the family level (Mänd et al., 2002).

3. Biodiversity and insect pest management

Crop diversification has long been utilised by small-scale farmers in the tropics to reduce the risk of crop failure. Vegetation or crop diversity has long been advised as a means of mitigating pest issues, and infestations have been blamed on a lack of it (Tonhasca and Byrne, 1994). The repercussions of biodiversity loss are more visible than ever in the field of agricultural pest management. The spread of agricultural monocultures at the expense of natural vegetation, resulting in a decrease in local habitat variety, is increasingly connected to agroecosystem instability, which manifests itself as the worsening of most insect pest issues (Altieri & Letourneau, 1982). Ecologists have disputed whether more variety promotes stability for years. There are several critical theoretical studies on this topic in the literature, as well as publications that utilise agricultural examples to support the theory (Andow, 1991). The majority of research finds that combining specific plant species with the principal host of a specialised herbivore produces a reasonably consistent result: specialised species are more abundant in monocultures than polycultures. To explain why insect groups in agroecosystems can be maintained by designing vegetational designs that support natural enemies and/or directly prevent pest assault, four primary ecological theories have been proposed (Altieri, 1999). Experiments show that diversifying cropping systems frequently results in lower herbivore populations, according to the literature. According to the research, the more diverse agroecosystems are, and the longer this variety is preserved, the more internal linkages form, promoting higher insect stability. It is obvious, however, that the insect community's stability is determined not just by its trophic variety, but also by the trophic levels' real density dependency (Southwood & Way, 1970). In other words, stability will be determined by the accuracy with which any given trophic connection responds to a population rise at a lower level. According to the available literature, knowledge and consideration of (1) crop arrangement in time and space, (2) the composition and abundance of non-crop vegetation within and around fields, (3) the soil type, (4) the surrounding environment, and (5) the type and intensity of management are all necessary for the design of vegetation management strategies. The degree of connection of insect populations with one or more of the system's vegetational components determines their sensitivity to environmental interventions. Extending the cropping season or arranging temporal or geographical cropping sequences may allow naturally existing biological control agents to maintain greater population levels on alternate hosts or prey throughout the year (Evans et al., 2011).

Many polyphagous predators have much larger concentrations along the borders, according to several studies (15-30m). Carabids have shown similar impacts in fields with specifically built borders (beetle banks) that increase predator numbers inside nearby crop rows. The distances at which natural enemies enter the crop might be used to determine the best field margin spacing in monocultures (Boatman, 1994). Some methods have an impact on the overall population of pests. Mechanical barriers, such as companion crops that prevent herbivores from dispersing across the polyculture; a lack of stimulation that encourages herbivores landing on a non-hos t to flee the plot fast; and microclimate affects are some of these (Zhu et al., 2000).

4. Biodiversity, soil fertility and plant health

The kind and frequency of soil disturbance regimes is a significant component of annual cropping systems. Tillage and planting on a regular basis brings the tilled region back to an earlier stage of ecological succession. Tillage and residue management induce physical disturbance of the soil, which is a key component in influencing soil biotic activity and species diversity in agroecosystems (Evans et al., 2011; Rillig & Mummey, 2006). Tillage disrupts at least 15-25 cm of the soil surface, replacing stratified surface soil layers with a tilled zone that is more uniform in terms of physical features and residue distribution. Nutrient cycling, variations in C and N inputs, the soil physical environment, and the detrimental effects of synthetic chemical usage on soil microbial and faunal activity are the key influences of agricultural management methods on soil biological activity. Microbial populations and activity are typically increased to a larger extent in systems that boost below-ground C and N inputs by include legumes and/or fibrous rooted crops in rotations than in systems that use commercial fertilisers. Reduced tillage (with residues placed on the surface) promotes a more stable environment, encouraging the growth of more diversified decomposer communities and slower nutrient turnover. According to available research, no-till systems support a larger ratio of fungal to bacteria, whereas traditionally tilled systems may benefit bacterial decomposers (Hendrix et al., 1990). However, heavy pesticide usage in such systems might have a deleterious impact on soil biodiversity. Under contrast to normal tillage, nutrient reserves in reduced tillage are stratified, with the highest concentrations of organic matter and microbial communities near the soil surface. When compared to traditional ploughing with the moldboard plough, stratification of crop residues, organic matter, and soil organisms typically reduces N cycling. For optimal grain crop growth and yield, increased microbial immobilisation of soluble in the surface of reduced tillage soils may necessitate improved fertility or tillage management strategies (Harlan, 1975; Paoletti et al., 1994). Direct introduction of organisms into the soil can also help to boost biotic populations. Earthworms have been used for soil conditioning, improved soil structure, and fertility in a variety of situations. Direct manipulations of microflora to improve plant performance include inoculating seeds or roots with rhizobia, mycorrhizae, and Trichoderma (Miller, 1990, 2020). The fact that pathogens produce little or no illness in some soils, despite a seemingly favourable environment, suggests that soils with high fertility and high quantities of organic matter increase natural biocontrol of pathogens (Baker & Cook, 1974). *Phytophtora cinnamoni*, which causes severe root rot in avocado plantations in Australia, failed to flourish in soils that were comparable in numerous ways to surrounding soils sustaining native rain forests. The continual application of green manure and cultivation of cover crops in the groves that were not impacted by root rot seems to have kept the soil in a highly rich and biologically active state. The high cycle of nutrients contributes significantly to the fertility of rain forest soils. When the rain forest was cut and avocados or other crops were grown, nutrient turnover and availability reduced, microbial activity dropped, and *P. cinnamoni* infection became significant (Campbell, 1989; Epstein, 2014).

5. Biodiversity & human health

Despite increased awareness in the relationship between nature and well-being, experts in the built environment have limited knowledge or articulated this link. The goal of this research is to look for evidence of the health advantages of urban nature and biodiversity in the literature. The emphasis is on interactions in the urban environment on a daily and local basis. The main question is whether urban biodiversity strategies have a health benefit. There is strong evidence that urban greening has a positive influence on people's health and well-being. Because policies on urban biodiversity are an extension of policies on urban nature and green space, these results equally apply to biodiversity policies. However, it's uncertain if biodiversity provides more health benefits than 'nature' alone. At the urban scale, there has been minimal research on this aspect of the health-nature link. At bigger dimensions, like at the world scale, however, linkages are more known (Ganz et al., 2014; Khieu et al., 2014).

Because it may reduce disease-causing soil organisms and offer clean air, water, and food, soil biodiversity is increasingly recognised as benefiting human health. However, poor land management and environmental change are harming below-ground populations across the world, and the accompanying losses in soil biodiversity limit and degrade these advantages. Importantly, recent research suggests that if soil biodiversity is managed responsibly, it may be preserved and substantially recovered. Improved management approaches that promote the biological complexity and resilience of soil biodiversity offer an untapped resource with the potential to benefit human health. It is critical to consider the geographical distribution of belowground species in order to sustain soil biodiversity. The availability of information on the biogeography of soil biodiversity has increased in recent years. Many species are uncommon and have restricted distributions, generally limited to certain soil types or geographical locations, according to global distributions of soil taxa ranging from bacteria to bigger animals (Rillig & Mummey, 2006; Sánchez-Moreno & Ferris, 2007).

As can be seen from the above, soil biodiversity may play an important role in ensuring a more reliable food supply and a greater nutritional content of the food produced. However, the last century's development of agricultural methods has overlooked the importance of soil biodiversity. Agricultural intensification's cornerstones—ploughing and the use of agrochemicals and fertilizer—have all been related to a loss of soil biodiversity. Soil biodiversity, it seems obvious, is an underappreciated resource for preserving or increasing human health through improved soil management (Sprigg et al., 2014).

Some agroecological management strategies are known to preserve and improve soil biodiversity for human, animal, and plant health, as mentioned above. However, more feasible approaches must be developed and, more importantly, their usage must be promoted as widely as possible.

Soils and soil biodiversity are disappearing at an alarming rate, with serious consequences for human health throughout the world. It is past time to recognise and manage soil biodiversity as an underutilised resource for achieving long-term sustainability goals related to global human health, not only for improving soils, food security, disease control, water and air quality, but also because soil biodiversity is linked to all life and provides a broader, fundamental ecological foundation for collaborating with other disciplines to improve human health.

6. Disease Control

Crop failure is anticipated to be reduced through genetic variety, which will lead to increased output stability. Mixed-species and multispecies cropping systems, which are typical in subsistence farm units, may provide similar advantages. Uniform monoculture crops, on the other hand, which stand like battalions of identical troops in close formation, may provide large yields under ideal conditions but fail miserably in suboptimal or aberrant ones (Alavanja et al., 2013; Evans et al., 2011; Rillig & Mummey, 2006).

Many historical instances may be recounted to demonstrate that, while monoculture stands or concentrations of crops and livestock with similar genetic features may be more productive in the short term, they also carry the danger of succumbing to changing conditions sooner or later. In the past, catastrophic disease outbreaks, pest invasions, and climate oddities have resulted in widespread agricultural and animal devastation. Famine has ensued from such epidemics, particularly when there was a lack of diversity and no types or breeds that could endure the catastrophic outbreaks.

The infestation of red rust on wheat in Roman times, mass poisoning from ergot-tainted rye during the Middle Ages in Europe, the failure of France's fabled vineyards in the late nineteenth century, and the potato famine that struck Ireland in the 1840s and 1850s are just a few examples of disastrous outbreaks. The fungus *Phytophthora infestans*, which mistakenly arrived from North America and damaged the genetically homogeneous potato stock that served as the backbone of Irish farms, was responsible for the latter. In only the famine years, around 1.1 million people perished of malnutrition, typhus, and other famine-related illnesses, while 1.5 million more moved to North America (Mokyr, 2004). Many farmers in places where scab has been severe have been forced to stop farming because to a lack of profitable alternative crops (McMullen et al., 1997; Six et al., 2006). Finally, increasing biodiversity is the best protection against future failures, as it allows for crop development and the discovery of adequate alternatives.

7. Conclusion

Many academics, farmers, and politicians throughout the world are increasingly focused on finding self-sustaining, low-input, diverse, and energy-efficient agricultural systems. Restoring the agricultural landscape's functional biodiversity is a fundamental approach in sustainable agriculture (Altieri, 1999). Biodiversity provides important ecological services, and when properly built across time and place, can result in agroecosystems that can support their own soil fertility, crop protection, and production. Crop rotations and sequences can increase diversity over time, and cover crops, intercropping, agroforestry, crop/livestock mixes, and other techniques can increase diversity across space. Correct biodiversification results in pest control through the restoration of natural insect pest, disease, and nematode control, as well as optimal nutrient recycling and soil conservation through the activation of soil biota, all of which lead to sustainable yields, energy conservation, and less reliance on external inputs.

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