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AGRICULTURE EXTENSIFICATION AND BIODIVERSITY LOSS: INTERWOVEN CHALLENGES

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ABSTRACT

Biodiversity is the precious wealth of nature that took millions and billions of years to build. Biodiversity includes all the life forms of Earth inhabiting various ecosystems. The term Biodiversity is comprehensive, which includes genotypic, phenotypic, phylogenetic and physiological variation within the species and among the species. It plays a crucial role not only to fulfill human requirements but also in safeguarding the human against various kinds of natural disasters. Biodiversity is under threat as never before due to the global population. To meet the global food, fibers fuels and other commodities, natural areas are converted into agricultural land that disrupts the natural balance in terms of biodiversity loss. These phenomena exert a negative impact on the health of nature by increasing pollution and concentration of greenhouse gases. Agriculture is among one of the largest factors in destroying biodiversity. Agricultural activities are intensifying the rate of biodiversity loss at an alarming pace that was never observed in the past to meet the global food and fiber demands. In the past, biodiversity loss was seen in response to nature's resilience to changing climatic conditions. The present situation demands the sustainable agriculture system that not only conserves nature's wealth but also fulfills the global need for food supply. This mini-review focuses on various aspects of biodiversity, definition, roles, agriculture extension, biodiversity loss and mitigating strategies.

Key words: Biodiversity, Agroforestry, Extensification, Habitat Loss, Monocropping, Intercropping, Millets.

Introduction

Nature gifted us a food basket that could be accessed by the people of every sphere in their respective ecosystems. The global population is expected to increase by nearly 2.3 billion people by the year 2050. The major fraction of this increase is contributed by developing countries. It leads to an estimated increase in food demand by 3 billion tonnes by 2050. A major part of the world's land surface excluding Antarctica and Greenland has been converted into agricultural land. All these cleared areas were considered the treasure of biodiversity. The remaining land area is very high, steep, dry or cold, making it unsuitable to be used in agriculture (Foley *et al*., 2011). Agriculture is the major driving force of biodiversity loss as it disrupts natural ecosystems, emphasizing a few plant species. It creates an ecological imbalance due to the habitat loss of many small and large creatures. This kind of artificial or manmade ecosystem also causes environmental degradation due to the release of pollutants and greenhouse gases (CO_2, N_2O, CH_4). Food production is the major factor of biodiversity loss in tropical regions due to the clearing of thick forests (Barraclough and Ghimire, 2000). The trend of clearing forest areas for crop production started in the 1990s and continues (Gibbs *et al*., 2010). Agriculture expansion causes an estimated clearing of a 5.5-million-hectare area of tropical forest (Keenan *et al*., 2015). Temperate and tropical Grassland areas (Paraguayan Chaco and Brazilian Cerrado) are also threatened by agricultural expansion (Baldi *et al*., 2015). These areas are considered among the world's richest biodiverse ecosystems despite lacking trees. Biodiverse regions are being cleared in Africa, the Middle East and Latin America to meet the current and future global food needs. Traditional farming practices maintain biodiversity while current intensive farming systems support monocropping at the cost of biodiversity loss (Rudel *et al.,* 2009).

The introduction of alien species and prolonged use of fertilizers and pesticides have a profound impact on grassland native species (Charles *et al.,* 2005). High-yielding varieties and chemical pesticides are widely used, making traditional farming practices with traditional varieties obsolete. It is accompanied by the loss of cultural diversity and food security as well. Food security is defined as food that is nutritionally adequate in terms of quality, quantity and variety and acceptable to all person irrespective of their culture (Madeley, 2002). Global climate change is threatening all the dimensions of food security (a) food availability, (b) food accessibility, (c) food utilization, and (d) systems stability. Systematic breeding programs for crop improvement under the Green Revolution undoubtedly have led to spectacular improvements in agriculture and in eradicating world hunger. New cultivars of cereals that responded well to increased inputs of water and fertilizer were developed. As a result, global agricultural production outpaced the doubling of the world's population that occurred between 1950 and 1990. There is no doubt, on the other hand, that climate change will be devastating for tropical and sub-tropical regions, bringing about major crop losses in South and Southeast Asia as well as sub-Saharan. Thus, soon rice and wheat, the major cereal crops, on which most of our world population relies, will lose their importance in the world food basket. The expected increase in global fertilizer consumption by 2030 with the current pace is 226,150,381 Mt, which reflects a 32.1% increase in comparison to current consumption (Zhang *et al.,* 2007). Intensifying fertilizer use has generated new environmental problems in terms of nutrient imbalance. Runoff nutrients from crop fields to nearby ecosystems cause ecological damage such as provocation of the algal bloom in aquatic ecosystems that disrupts freshwater biodiversity due to oxygen depletion. Systemic insecticides are also affecting the reproductive behavior of invertebrates, amphibians and birds (Chagnon *et al.,* 2015; EASAC 2015). Many times, the impact of pesticides is seen far away from the site of application (Martin *et al.,* 2011). Continued use of these herbicides and pesticides causes resistance in genetically modified crops (GM crops), thus forcing an increase in application rate (Tanentzap *et al.,* 2015). All these findings indicate the loss of biodiversity around the farm areas (Donald *et al.,* 2006). It also affects the global economy due to the loss of natural pollinators as seen in China. In several parts of China, crops are pollinated manually by farmers due to the loss of pollinating insects (Gallai *et al.,* 2009). Food security without harming the environment can be ensured by the application of agrochemicals in place of synthetic chemicals. Modern agriculture practices not only cause biodiversity loss but also cause climate change. Land area used for livestock production releases greenhouse gases. A major fraction of this emission, 14.5% is contributed by human activities (Gerber *et al.,* 2013). Biodiversity on earth encompasses around 8.7 million unique species of flora and fauna and countless varieties of bacteria (Sweetlove, 2011). Each of these species is unique on its own due to its specific role in ecosystem functioning and maintaining natural balance. Biodiversity is also a driving force of agriculture to provide germplasm to maintain and protect the food supply under any kind of biotic and abiotic threat. However, industrial agriculture has shrunk this wealth of nature due to the favoring of a few varieties of plants and animals. On one hand, wheat and rice responded very well to the inputs of chemical fertilizers, while on the other hand, they caused environmental degradation and biodiversity loss. All these impacts of current agricultural practices force policymakers to adopt sustainable agriculture programs incorporating other plant varieties in breeding programs and using agrochemicals to improve yield.

Biodiversity: Wealth of Nature

The term biodiversity includes all the forms of living beings that differ at the gene level, inhabiting various ecosystems and performing different roles in ecological niches. Several definitions are given to explain the term biodiversity. Environmental protection and sustainable development necessitate the conservation of biodiversity from all sources, aquatic, terrestrial and other complex habitats. Biodiversity was defined as the diversity within the species and among the species. It can also be defined as the diversity within the habitat, among the habitats and in the landscape. Different scientists had different interpretations of what defines biodiversity. There is no single definition to describe the term biodiversity that could incorporate all the dimensions of biodiversity. Taxonomist

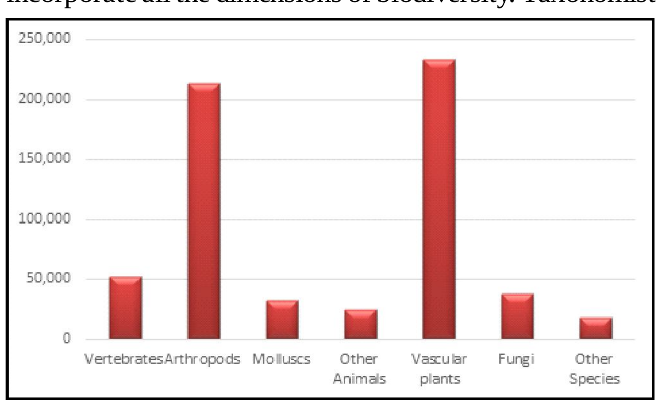

Fig. 1: Global Species Distribution (Dasgupta *et al.,* 2024).

relates the term biodiversity with the number of listed species. Millions of species have been identified due to the collective efforts of scientists and the percentage contribution of various groups in Global biodiversity varies considerably (Fig. 1). Geneticist relates biodiversity with allelic diversity that exists among the varieties. According to plant sociologist, biodiversity is concerned not only with the recorded number of species but also their distribution on the landscape.

Biodiversity starts with the unique genetic makeup of every living thing on earth. Different genes encode different traits, thus helping the organism to survive in its environment by providing certain advantages such as disease resistance and abiotic resistance. Genetic diversity is the vital factor that keeps the species evolving under continuous environmental changes happening in nature. The distribution of plants and animals is not even on Earth. Certain parts of the earth inhabit a large number of native species that are not found anywhere else. These areas are designated as biodiversity hot spots. 36 regions across the globe have been tagged as biodiversity hot spots (Mittermeier *et al.,* 1999; Myers *et al.,* 2000; Habel *et al.,* 2019). Biodiversity hotspots are the areas of species richness and high level of endemism and also, they harbor genetic resources in the form of wild relatives of major crops. These genetic resources are regarded as raw materials in several breeding programs operated for crop improvement. Agrobiodiversity hot spots include the center of origin of major crops and their wild cultivars. Both types of hotspot realms are not only indicators of species richness but also serve several benefits to humankind in terms of medicines and nutrition (Pironon *et al.,* 2020). The concept of agrobiodiversity conservation proves to be a double-edged sword in terms of providing edible food in the local agroecosystem as well as preservation of germplasm that can serve mankind to meet future challenges. Biodiversity confers a positive approach to proper functioning of multifunctional ecosystems. India comes in one of the world's 17 mega biodiverse countries having one of the eight identified Vavilov's centers of origins (MoEFCC 2014; Ramakrishnappa, 2003). Indian biodiversity encompasses around 8% of the total world's biodiversity with nearly 49000 species of plants. India is identified with four hot spots, namely the eastern Himalayas, the Western Ghats, the Andaman and Nicobar Islands and the Indo Burma Region. These hotspots are the home of species richness and high levels of endemism. India is the home of rich faunal diversity accounting for 25000 fishes, 197 amphibians, 408 reptiles, 1200 bird species and 350 mammalian species.

Africa is the home of rich biodiversity distributed along a great latitudinal range extending from 37°N to 35°S. The diverse African ecosystems include terrestrial, aquatic islands, coastal, tropical dense forests, grassland, bushland, montane and Afro-alpine. This continent borders the Mediterranean Sea in the North, covering the vast region of the Sahara Desert, which extends into a biodiverse region and culminates into the Kalahari and Namib Deserts in the south (Stephenson *et al.,* 2017). Great Rift Valley is the source of many rivers and streams due to the various spectacular gorges. This region also harbors the African Great Lakes that hold the world's 25% fresh water and more than 90% freshwater of the African Region. With all these diverse ecosystems Africa supports various habitat that in turn supports enormous species. Africa is considered an exclusive reservoir of world biodiversity having 8 of the world's 36 hot spots (Archer, 2018). The continent's rich geographic diversity is exemplary in a way, displaying high functional diversity by connecting both terrestrial and aquatic ecosystems. The continent shows a high level of plant endemism in its Mediterranean habitats (Burgess *et al.,* 2006). Vertebrate endemism is seen in tropical and aquatic ecosystems, especially in the African Great Lakes (Vernaz *et al.,* 2021).

Biodiversity Loss: Once gone is gone forever

Biodiversity loss may be defined as the reduction in the variety of life forms at the genetic level, species level and ecosystem level. Constantly changing environmental conditions exert pressure on species to undergo changes that make them well-suited to existence. These changes and adaptations led to the evolution of new species and the extinctions of those that failed to do so. In this way, the number of species and the population fluctuate over time. However, the current rate of biodiversity loss due to human activities has never been recorded in the history of the planet, with a record of approximately one million species at risk (Ceballos *et al.,* 2020). The current trend in biodiversity loss has several consequences. One is seen in terms of the loss of genetic diversity with the declining population of species. The second consequence is seen as ecosystem degradation by affecting inter-relationships among biotic components. The third consequence is seen at the level of community structure due to the loss of entire species as a result of habitat destruction, pollution and overexploitation. Loss of ecosystem diversity has a profound effect, as sometimes it could lead to the loss of keystone species that control the overall functioning of that ecosystem (Cardinale *et al.,* 2012). Biodiversity loss is a matter of great concern that is not limited to one nation. Developing countries are worst hit due to biodiversity loss as a major fraction of their economy comes from natural resources. Proper measures should be taken to rejuvenate it by international funding and cooperation in developing mitigating strategies and implementation.

According to biodiversity experts around 30% of species have been threatened or on the verge of extinction. The estimated percentage of endangered species in various groups is shown in Fig. 2. This irreversible loss has a profound effect on ecosystem functioning and global economies. The rate of extinction has been overwhelmingly very high in tropical habitats (terrestrial as well as aquatic) in the past few decades. A recent estimate indicated the loss of 10% of insect species due to habitat destruction by using agrochemicals in intensive agriculture. Insects are vital components of the ecosystem, while working as pollinating agents, in the recycling of nutrients and as pest control. A third of the insect population is threatened due to the synergistic effect of climate change and agriculture practices (Sanchez-Bayo and Wyckhuys, 2019; Outhwaite *et al.*, 2022; Dainese *et al.*, 2019). According to the Global Report on Biodiversity and Ecosystem Services presented by IPBES in 2019, 85% of species are at risk of extinction due to several factors such as terrestrial land use, the introduction of alien species, overexploitation of organisms, agriculture expansion by deforestation, heavy use of agrochemicals, climate change, etc. The report further highlights that biodiversity loss is mainly driven by changes in land and sea use by humans (IPBES, 2019). Biodiversity loss will severely impact global food security as losing invertebrate biodiversity that has a profound influence on the food web as a major biotic component and the agricultural productivity that further ensures food availability (Samways, 2020). Climate change contributes to rising ocean temperature that causes displacement of species towards the poles. Polar habitats are shrinking, species diversity is declining, and these issues are worsened by species displacement. Rising temperature also causes the melting of permafrost and imposes threats to various ice-inhabiting biota (Halpern, 2015). The biodiversity of aquatic ecosystems is greatly affected by the process of eutrophication due to the discharge of nitrogen-laden material into water bodies. These materials cause excessive growth of algal forms in aquatic ecosystems that subsequently affect the marine ecosystem due to oxygen depletion. These environmental changes not only affect aquatic ecosystems but also terrestrial ecosystems, as seen in the decline in the productivity of grassland due to the constant use of fertilizers and eutrophication. This finding confirms the interaction between biodiversity, environmental changes and the functioning of various ecosystems (Hautier *et al*., 2014). Marine biodiversity is further affected by the harvesting of materials from the ocean floor, which leads to instability in marine life due to the destruction of marine habitat. Overfishing and unintentional capturing of various species during fishing exercises drastically affected the whole marine ecosystem. Rising temperatures and changes in rainfall patterns are turning fertile lands into deserts, resulting in the reduction of plant species. The reduced plant species result in the loss of animal species that depend on them. These transformed lands impose a threat to food security due to the loss of agricultural land (D'Odorico, 2013). Non-native species are often introduced into new environments by human activities through trading and tourism, causing biodiversity loss by affecting native species. Research analysis concluded that most of the plant invaders are from the family Poaceae. The invasion of non-native species to new ecosystems is often seen through marine routes due to ballast water that is taken onboard by ships for stability. This water contains thousands of marine creatures that are taken away during transport to different destinations and get introduced into new habitats with the release of it (Manchester and Bullock, 2000). Further, these non-native species compete with native species for various resources and sometimes make native species decline in number or, in extreme cases, cause them to become extinct. These changes can further lead to ecosystem imbalance due to alterations in the food web. Urbanization is further contributing to biodiversity loss due to the conversion of natural landscapes such as forests, grasslands and wetlands into human-inhabiting regions. These natural landscapes are home to diverse fauna and flora that are adversely affected by habitat destruction and fragmentation. These

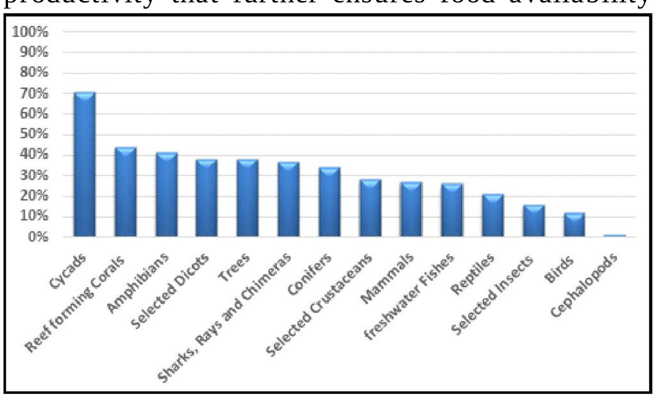

Fig. 2: Estimate of the percentage of threatened species under each group (IUCN Red List of Threatened Species, 2024). Selected Dicots (Cacti and Protea Family), Selected Crustaceans (Lobsters, Freshwater Crabs, Freshwater Crayfishes, Freshwater Shrimps), Selected Insects (Dragonflies and Damselflies), Cephalopods (Nautiluses, Octopuses, Squids).

human developments disrupt the migration pattern of species due to the fragmentation of large landscapes into small pockets that lead to the isolation of species and further loss of biodiversity. Species richness has been reduced to 21% in aquatic habitats and 27% in terrestrial habitats. Avian diversity is affected most adversely by facing a 41% decline in species richness.

The fifteenth conference of parties (COP15, Montreal Canada in 2022) designed a global biodiversity framework taking four major goals to protect and enrich nature. These four goals include the following perspective: 1. Reduction of human-driven extinction of threatened species by tenfold by 2050; 2. Sustainable use of natural resources; 3. Gains from the genetic resources should be shared equally without any disparity; 4. The framework should be accessible to all the parties by ensuring the resources. Various direct and indirect drivers of biodiversity loss are suggested by different conservationists such as habitat change and loss, climate change, pollution, invasive species, overexploitation, demographic, economic, technological, governance, wars and epidemics (Cafaro *et al.,* 2022; Achieng *et al.,* 2022) and are depicted in Fig. 3. Africa, poorest and second most populous continent is facing unprecedented environmental challenges. According to an estimate, the African population will be quadrupled by 2100 (UNWP 2015). Around 6.6 million km^2 land area, which is nearly twice the size of India, has been degraded (Archer *et al.,* 2018).

Agriculture: The Main Driver of Biodiversity Loss

Agriculture is the main source to provide global food security, but this practice is often responsible for causing changes in the environment around it. However, agriculture relies on natural processes, but focuses only on productivity, causing widespread loss of wild species.

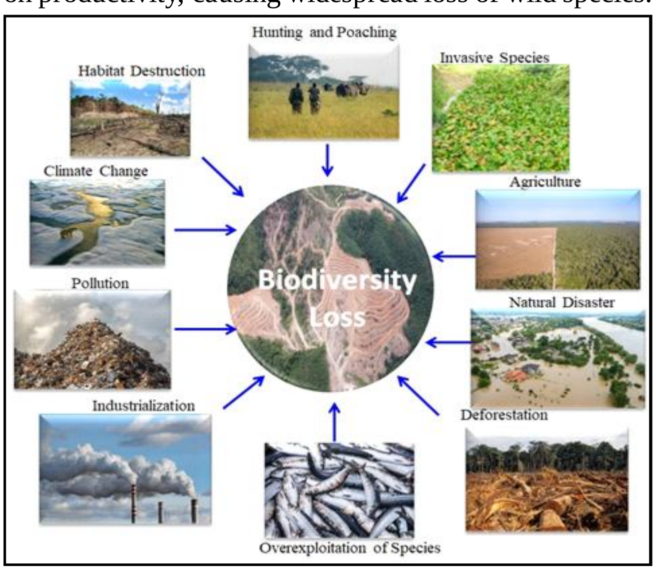

Fig. 3: Various Causes of Biodiversity Loss.

Excessive use of agrochemicals, to increase the yield, pollutes the environment to the extent that it causes many species to become vulnerable. Expanding the world population requires space not only for their living but also for their livelihood to grow fruits, vegetables, animals, and grains. Fertile land is a limited resource and rich in wildlife in the form of forests and grasslands. However, agriculture expansion has converted these lands into farms at the cost of biodiversity loss (Fig. 4). The process of converting wild areas into agricultural land is known as extensification (Foodprint, 2024). Agriculture extensification in the US has converted 170 million acres of prairies into farmland. This land supported the species equally those of the tropical forest. Indigenous people maintained the rich biodiversity in this area with managed fires. However, modern human settlements pushed the native people out of their land by converting the area into farmland. This once biodiverse area with deep root grasses has now reduced to one percent seen in narrow strips along rail tracks (National Park Service, 2022). Amazon rainforest solely accounts for 25% of total terrestrial diversity. (World Bank 2019). Agriculture expansion is solely responsible for 80% of deforestation globally (Kissinger 2012). Global cropland area reached 1,244 Mha in 2019 with a total annual net primary productivity of 5.5 Pg C/Year (Potapov, 2020). The largest expansion was seen in Africa with 53.2 Mha. Australia and New Zealand exhibit moderate cropland expansion. Global per capita cropland area has decreased from 0.18 ha per person in 2003 to 0.16 ha per person in 2019. South West Asia faces the largest decrease in this context (by 19%, 0.08 ha per person). However, Australia and New Zealand reverse the pattern showing an increase in per capita cropland area i.e. 1.34 ha per person. Nearly 17% of the total estimated cropland area is newly established from 2003-2019. 11% fraction of this comprised of dryland conversion through irrigation

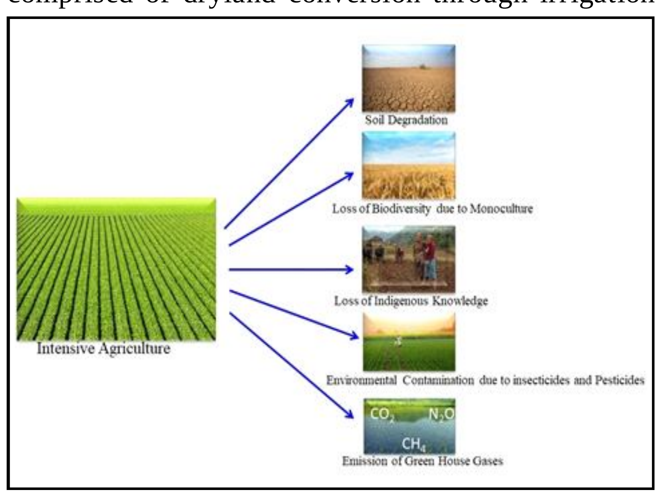

Fig. 4: Negative Impacts of Intensive Agricultural Practices.

Table 1: Data related to Estimated Global Cropland Area in 2019 (Potapov *et al.,* 2021).

Sr.	Continent/ Country	Area under cropland (percent of global cropland area)
1	Eurasia	55%
2	Africa	17%
3	North and Central America	16%
4	South America	9%
5	Australia and New Zealand	3%

practices. Data given in Table 1 give an overview of the global increase in cropland area. In Africa, the cropland area expansion was done by clearing the large area of natural vegetation, not including the dryland area (79% of total cropland gain area) followed by Southeast Asia and South America (Potapov *et al.,* 2017; Zalles *et al.,* 2021).

In slash-and-burn agriculture practices, farmers cut down small forest areas and burn them to make land clear for farming. After a few seasons of cultivation, they used to move to another area to repeat the same practice. These practices were once considered a major cause of loss of biodiversity. However, current intensified agricultural practices do more harm to biodiversity as compared to old slash-and-burn practices. Economic gain is more to farmers by growing oil crops and soy in comparison to afforestation and conservation of forests. This fact is causing the conversion of around 10000 miles of forest area (nearly the size of the UK) into agricultural land per year (Busch and Gallon, 2017; Harvey, 2019). Asia continent is considered one of the richest places on the earth in terms of living forms containing seven biodiversity hot spots. In addition to this, Asia is harboring half of the human population of the world, which is continuously increasing. Protected Areas (PAs) are being converted into agricultural land for food production. According to current estimates, the Asia continent will experience the highest rate of habitat loss due to the fragmentation of PAs by 2050 in comparison to other continents (Molotoks *et al.,* 2018). Agriculture expansion is a threat to 24,000 species out of 28,000 red-list species documented by the International Union of Conservation of Nature. These species are at risk of extinction due to habitat destruction, which makes these species deprived of food and shelter (Ritchie and Roser, 2019). Excessive use of synthetic fertilizers releases greenhouse gases such as NOx and ammonia that cause air pollution and global climate change (Fig. 2). Excess atmospheric nitrogen gets deposited in the rain, making the soil acidic. All these changes make the environment unsuitable for many species. Some reports claim that excessive nitrogen deposition is the third largest threat to biodiversity loss after land use change and climate change (Xiankai *et al.,* 2008). In India, the agriculture sector is the main contributor to employment, accounting for 47% covering 54.6% of the total population. India ranks second after China in agricultural land area, i.e. 159 million hectares. India is among the largest producers of rice, wheat, groundnut, vegetables, fruits, sugarcane, etc. India is experiencing heavy biodiversity loss due to agriculture extensification, due to the clearing of forest areas. Grasslands, wetlands, and other habitats are also being converted into agricultural lands, making several species homeless due to their habitat destruction and fragmentation (Ministry of Environment and Forest, 2014). The green revolution in the 1960s made spectacular changes in the production of grains, but it also boosted the use of chemical fertilizer with the high-yielding grain varieties of wheat and rice. This increased yield has had a major toll on the ecosystem, causing soil and water pollution, and increased salt concentration in underground water (Rahman, 2015). These agricultural practices also aid in the emission of greenhouse gases, further contributing to global warming. India ranks second after China in the emission of greenhouse gases (FAO 2015). The agriculture sector thrives on water availability. Rain-fed agriculture is mostly dependent on irrigation. High-yielding varieties require heavy irrigation leading to groundwater depletion. In India, the agriculture sector accounts for 80% of total groundwater withdrawal. It is estimated that by 2020, the Indian agriculture sector will face a 21% decline in water availability. It is projected that 15%-40% of rice cultivating rain-fed areas will become unsuitable for cropping by 2050 due to climate change and water shortage (Buker, 2017). Therefore, agricultural expansion and over-exploitation of resources to sustain this agricultural expansion harms not only biodiversity but also agriculture itself. Biodiversity serves humankind and the economy in many ways, such as pollination, and nutrient recycling. However, unprecedented loss in biodiversity has been seen over the last 500 years. Over 300 species of vertebrates have become extinct now and many more are facing the threat of extinction due to agriculture (EU 2016). Data obtained from the countryside species-area relationship (SAR) study done over 800 global areas indicated that several species of mammals, reptiles, birds, and amphibians have been lost due to the conversion of various habitats into agricultural land (Chaudhary and Kastner, 2016). The cultivation of three major cereal crops, wheat, rice, and maize, altogether contribute to the loss of 2,200 species globally. The farming of other crops such as sugarcane, coconut, rubber, coffee, palm oil and cassava also exerts a negative impact by causing 23% global biodiversity loss. Some parts of India, such as the Garhwal Himalayan Region, have experienced heavy loss in forest cover and fragmentation due to the key driver agriculture. Batar *et al.*, (2017) findings concluded that agricultural land has increased from 3.76% to 8.02% from the year 1976 to 2014 (Batar *et al.*, 2017). Punjab, the Indian state, is known for agricultural advancement and intensive rice-wheat cultivation. Rice cultivation in Punjab requires major water input that is not naturally fulfilled by rainfall patterns. Thus, irrigation is the most common alternative to support rice cultivation. Excessive irrigation practices in Punjab have resulted in groundwater depletion and shortage due to over-exploitation of groundwater (Misra, 2014). Mono-cropping systems (growing only one type of crop on a vast land area) are rather simple and provide continuous feed to farmers, but they are biodiversity deserts. Furthermore, intensive chemical application to maintain the monoculture harms the biodiversity in neighboring land areas too. Overuse of herbicides to maintain crops disturbs plant diversity not only in the area of application but also around the areas also. Disturbed plant diversity affects the animal diversity feeding on plants in those areas. Significant reduction in plant diversity has been reported with the widespread application of herbicide glyphosate in the United States. The application of glyphosate for the removal of milkweed plants has significantly reduced the useful insects like monarch butterflies that feed upon milkweed (Gonthier *et al.*, 2014; Schutte *et al.*, 2017). In comparison to herbicides, the effect of insecticides is more pronounced as they directly target other animals. This affects the pollination in other crops as seen in the case of the insecticide neonicotinoids. Application of these insecticides hampers hymenopterans by affecting their rate of reproduction. Runoff herbicides and insecticides in water bodies exert toxic effects on various species of fishes, amphibians, birds, etc., surviving in these (Ali *et al.*, 2011; Whitehorn *et al.*, 2012). Routine plowing by farmers also disturbs soil communities, which play a significant role in recycling dead plant materials and making the soil fertile. Significant reduction in bacterial and fungal diversity has been reported after the application of herbicides and inorganic fertilizers. Highly disturbed soil is unable to hold carbon dioxide and thus easily loses carbon to the atmosphere and water bodies. The widespread use of herbicides and pesticides in agricultural land is killing the soil (Oertel *et al.*, 2016). Nature has provided us with a food basket with several edible plant species. Nonetheless, the majority of the world population relies on a few plant and animal species for their need of food and fiber. Conservation of large gene pools is important in terms of providing disease resistance and other abiotic resistance to the global food crops, which are likely to face the consequences of climate change and sudden outbursts of any disease. But the industrial agriculture has caused genetic erosion. Genetic erosion may lead to the loss of entire species or narrow the gene pool within the species due to the loss of certain variants. Genetic erosion within the species is well documented in the case of rice. Rice once accounted for 40000 varieties in India, which has been reduced to 30000 now (Van de Wouw *et al.*, 2009). The introduction of new species in non-native areas and their cultivation, also replaces several domesticated species grown in the area, for example, the introduction of corn in North America. Hybrid seed production in the twentieth century accelerated the process of replacement of domestic plant species. A few companies hold the control over the selling of these hybrid seeds, thus leaving the farmers with limited choices for growing crops, thus reducing the diversity further (Willingham and Green, 2019).

Sustainable Agriculture: Food Security without compromising biodiversity

Agriculture undoubtedly ensures food security on the one hand, but reduces biodiversity on the other hand. However, by combining traditional knowledge with scientific research programs, food security can be ensured without taking a toll on biodiversity. This new frontier of agriculture is known as agroecology, which deals with the building of healthy soil and water while cropping (Garnett *et al.*, 2013). This regenerative agriculture makes a chemical-free productive agroecosystem. One of the key steps towards this is the growing of a few more crops in monoculture agriculture fields, such as the growing of beans and lentils with the main crops (intercropping) that add nitrogen into the soil. This practice also reduces greenhouse gas emissions as seen with the use of chemical fertilizers, hence helping in reducing global warming (Jensen *et al.*, 2011). Another approach to building a healthy agro-ecosystem is termed agroforestry. In this approach, woody plants are grown with the main crop. These may include fruit trees or shrubs. This kind of agriculture management helps in carbon building in the soil and prevents soil erosion. A projected estimate indicated that agroforestry will help in the removal of 2 billion tons of carbon dioxide from the atmosphere in the next 50 years (Jose, 2009). Livestock grazing not only removes residues of harvested crops but also adds natural fertilizer to maintain soil fertility. Controlled grazing also boosts the growth of grass crops as they plowed the farm naturally with their hooves. High-yielding varieties of Wheat and rice that are grown year after year make the soil depleted of nutrients. This kind of biased farming system has made several other nutritive crops such as millet, beans, and root crops disappear from the farming scene. This trend fostered the monocropping system on land areas once occupied by diverse crop varieties (Pingali, 2019). Millets are some of the oldest cultivated crops. Millet farming was very prevalent in prehistoric times. In China and Korea, people used to grow millet instead of rice (Tarannum, 2006). In India, archeological records suggest that the people were cultivating millets about 2500 BC. The Harappans used to make chapati out of these coarse grains. They are unique in the way that they can be grown throughout the year whereas wheat and paddy crops are seasonal. These crops are resilient to climate change, thus ensuring food security to the people living in any region. These grains can be grown in adverse environmental conditions in the dry to subhumid drought-prone ecosystem as cultivation requires minimal input of water. Contrary to this, most of the food crops require a lot of water. Millet cultivation is considered a savior of biodiversity as they do not need the application of herbicides and pesticides. Millet's farming is the most suitable approach to sustain agrobiodiversity. Millets are highly nutritious in comparison to major cereals as they contain high protein content, vitamins, minerals, and insoluble fibers. Millets were designated as nutritious millets by Prof M S Swaminathan due to their superior properties. Millets are the best fit in the new age answer to the new age crisis. They are not only conserving biodiversity but also providing food security in challenging environmental conditions where most of the major food crops fail to do so.

Conclusion

Agriculture plays a key role in ensuring food security for the people of developing countries. Agriculture products are also the source of national income and thus play an important role in rising GDP. In India, agriculture plays a major role in the economy and employs nearly half of the population. Expanded agriculture sector to meet the food demands of the escalating human population inevitably harms biodiversity and the environment. Suitable measures should be taken to mitigate the negative impact of intensive agriculture. Industrial agriculture practices are converting fertile lands to deserts due to overexploitation of natural resources. Revitalizing the underutilized crops such as millets, legumes, agroforestry, intercropping, organic farming, careful livestock grazing, and involvement of indigenous communities are certain measures that should be taken into account for sustainable agriculture. Amalgamations of all these approaches are not only capable of sustaining biodiversity but also food security.

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