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Negative impacts of intensive agricultural practices on environment and ecosystem: A review

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Abstract
Intensive agricultural practices, driven by the need to maximize crop yields and meet global food demands, have profound negative impacts on the environment and ecosystems. These practices often involve excessive use of chemical fertilizers, pesticides, monocropping, and large-scale irrigation systems. Such activities degrade soil quality, reduce biodiversity, and contribute to water pollution through runoff laden with agrochemicals. The over extraction of water for irrigation strains freshwater resources, while deforestation and land conversion for agricultural purposes lead to habitat destruction and greenhouse gas emissions. Additionally, monocropping increases vulnerability to pests and diseases, necessitating further pesticide use, which disrupts natural ecosystems and harms non-target species, including pollinators. There is pressing need for sustainable agricultural methods to mitigate environmental degradation and preserve ecosystem health while ensuring food security. Sustainable agricultural practices like conservation agriculture, minimum disturbance of soil, organic farming, use of indigenous technical knowledge (ITKs), climate smart agriculture etc. can minimize the greenhouse gas (GHG) emissions from the agriculture and allied activities and can transform sector into less carbon intensive, thereby minimizing the global warming and pace of climate change.

Keywords: ITKs, GHG, sustainable agriculture, climate smart agriculture

Introduction

Agriculture plays a vital role in the Indian economy. It is well known that agriculture also has major implications on the environment and ecosystem because modern intensive agricultural practices deplete the natural resources, exploit the soil fertility etc (Fig1). Intensification of agriculture over a past decade is the root cause of environment and ecosystem loss. Intensive agriculture needs higher inputs than regular agriculture practices which has both positive and negative effects on the ecosystem and biodiversity (Fig 2). Indian agriculture sector emits 408 MMT of CO2 equivalent (Verma *et al*., 2024) [40]. Agriculture contributes around 18% - 20% to the global GHG emissions. GHGs like CO_2, N_2O and CH_4 are the primary greenhouse gases (GHGs) emitted from the agricultural fields. Rice cultivation is second highest source (17.5%) of methane emissions in Indian agriculture after enteric fermentation (54.6%) and agricultural nitrous oxide emissions from application of nitrogenous fertilizer (19%) together accounts to 91% GHG emissions (Kaur *et al*., 2024) [13]. Oxygen deficient fields of paddy leads to the anaerobic decomposition of organic matter which leads to the methane emissions (Yuan *et al*., 2023). Further nitrous oxide is a another major GHG emitted from the agricultural fields. Main reason behind this is synthetic fertilizers and soil management practices (Ramzan *et al*., 2020) [26]. Emissions gap report released by UNEP (United Nations Environment Programme) mentioned that, the world is not on track to reach the Paris Agreement goals and global temperatures can reach 2.8°C by the end of the century (Olhoff *et al*., 2020) [23]. In 2017, with the adoption of the ‘Koronivia Joint Work on Agriculture’ (KJWA) which provides a road map to address issues related to agriculture in a holistic manner and recognizes the unique potential of agriculture in tackling climate change at COP23. In COP 26 which is recently held in Glasgow, Scotland also mentioned about soil and nutrient management practices and the optimal use of nutrients lie at the core of climate-resilient agriculture and improving sustainable production and animal health can contribute to reducing greenhouse gas emissions.

While enhancing sinks on pasture and grazing lands. India needs to focus on the reduction of GHG emissions from agricultural fields because agriculture is India's main occupation and largely practiced in rural and semi urban areas where awareness about sustainable practices in agriculture needs to be created (Gulati *et al.*, 2022) [9]. Soil degradation due to modern agricultural practices poses a significant threat to long-term agricultural sustainability. It is essential to adopt more sustainable farming practices, such as no-till farming, agro ecology, agroforestry, crop rotation, organic farming, and the use of cover crops, to restore soil health and maintain productivity. Integrated approaches that focus on soil conservation, biodiversity, and the reduction of chemical inputs are key to mitigating the impacts of soil degradation. While modern agriculture has been linked to some environmental challenges, many recent innovations and sustainable practices are helping to mitigate these impacts and, in some cases, even improve ecosystem health. Through practices such as no-till farming, agroforestry, integrated pest management, precision irrigation, and carbon sequestration, modern agriculture can contribute positively to environmental conservation, climate change mitigation, and biodiversity protection. These advancements show that it is possible to increase food production while improving or maintaining ecosystem integrity, which is essential for a sustainable future.

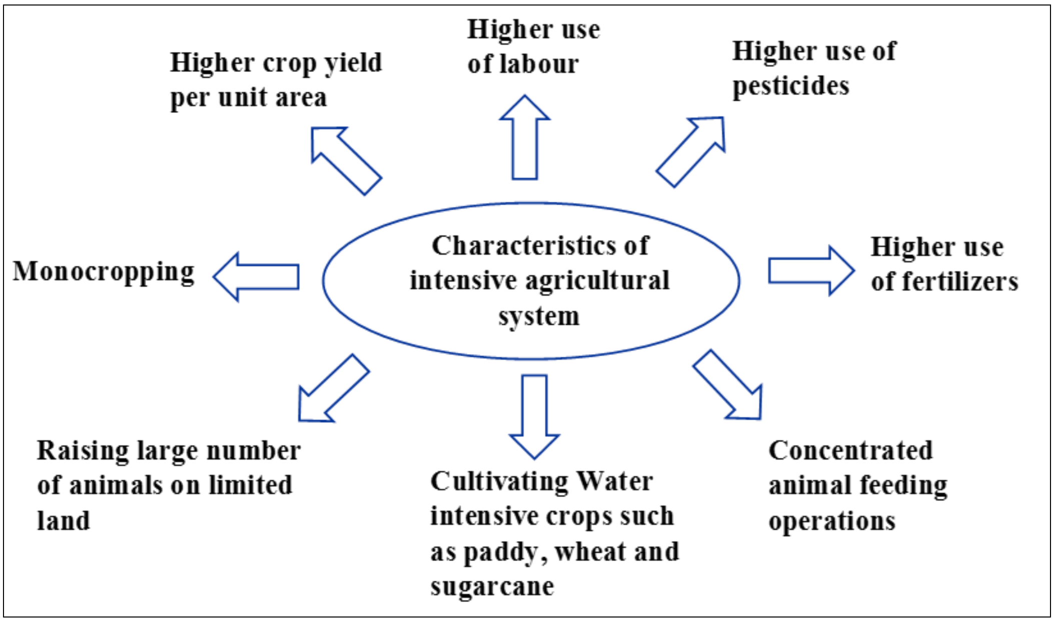

Fig 1: Characteristics of intensive agricultural practices

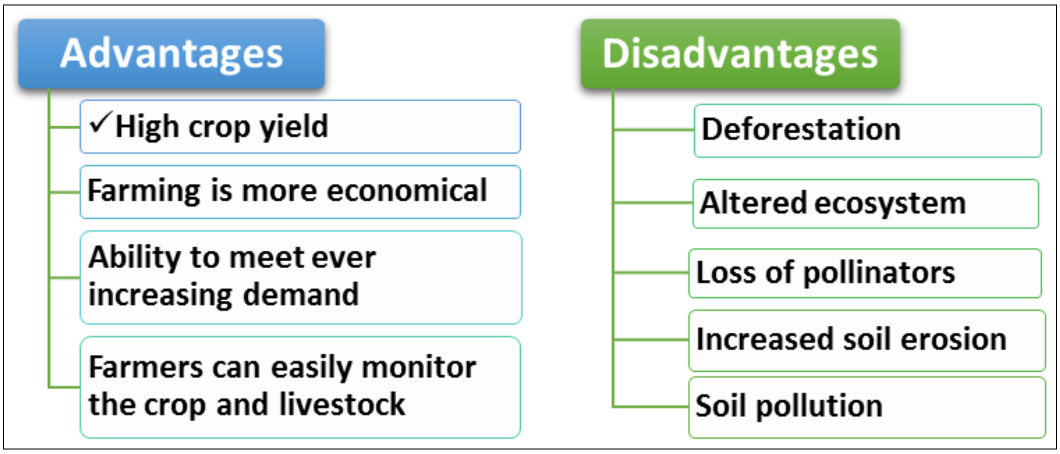

Fig 2: Advantages and disadvantages of modern agricultural system

Negative impacts of modern agricultural practices on ecosystem and environment

1. Soil degradation

Intensive tillage, monoculture cropping, and poor land management practices leave soil vulnerable to erosion by wind and water. Soil erosion removes the topsoil, which is rich in nutrients, organic matter and microorganisms necessary for healthy plant growth (Musa *et al.*, 2024) [19]. This leads to reduced agricultural productivity and can create long-term challenges for re-establishing fertile soil (Goud *et al.*, 2022) [8]. In areas where livestock are allowed to graze without proper land management like overgrazing can lead to soil compaction, erosion, and loss of vegetation cover. Overgrazing can strip the land of vegetation, expose soil to erosion, and degrade the soil's ability to retain moisture and nutrients, exacerbating desertification and reducing pasture productivity (Blanco *et al.*, 2023) [4]. The use of heavy machinery in modern agriculture, such as tractors and harvesters, often compacts the soil. Soil compaction reduces pore space in the soil, limiting the movement of water, air, and nutrients. This makes it more difficult for roots to penetrate the soil and increases the risk of waterlogging or drought stress, both of which reduce crop yields (Pais *et al.*, 2022) [25]. Practices like continuous monoculture, overuse of synthetic fertilizers, and insufficient organic matter additions deplete the soil's organic content. Soil organic carbon depletion leads to poorer soil fertility, lower microbial activity, and a decrease in the soil's ability to retain water, making it more prone to erosion and less productive (Musa *et al*., 2024) [19]. Excessive irrigation, especially in arid and semi-arid regions, can lead to the accumulation of salts in the soil. Salt build up affects soil structure, reduces water infiltration, and ultimately harms plant roots (Paz *et al*., 2023) [24]. The widespread use of chemical pesticides and herbicides in modern agriculture can harm soil organisms that are essential for crop growth (Tudi *et al*., 2021) [39]. A reduction in soil biodiversity can impair nutrient cycling, soil structure, and the ability of the soil to support healthy plant growth. Growing the same crop on the same land year after year (monoculture) without crop rotation or diversification can deplete specific nutrients in the soil and encourage pest and disease build-up (Belete *et al*., 2023) [3]. This leads to soil nutrient imbalances, increased soilborne diseases, and pests. Additionally, monocultures tend to reduce soil microbial diversity, which is crucial for maintaining a healthy, resilient soil ecosystem.

2. Water pollution and exploitation of water resources

Additionally, the excess nutrients from fertilizers can contribute to environmental pollution e.g., eutrophication of water bodies (Tiwari *et al*., 2022) [37]. Eutrophication depletes oxygen levels in the water (hypoxia), leading to dead zones where most aquatic life cannot survive. It also harms biodiversity by favouring fast-growing algae over other organisms, including fish and plants. Some algae produce toxins that can be harmful to aquatic life and even humans (Neves *et al*., 2021) [21]. Pesticides contaminate water sources through runoff during excess rainfall and excessive irrigation etc. further degrading ecosystems (Akhtar *et al*., 2021) [2]. Pesticides pollution can also smother fish eggs and aquatic habitats, and clog water treatment systems (Malik *et al*., 2020) [16]. Excessive water withdrawal can reduce the flow of rivers, harm aquatic habitats, and impact the availability of water for other uses like drinking, industrial use, etc. In extreme cases, it can lead to the drying up of rivers and lakes, causing the loss of aquatic species and the deterioration of ecosystems. Manure from livestock can be a source of pollution if it enters nearby water bodies through runoff or poor waste management practices (Wang *et al*., 2021) [42]. Overuse of fertilizers causes nitrate contamination of groundwater due to nutrient leaching and also Agrochemicals seep into aquifers, posing risks to drinking water and ecosystems (Srivastav *et al*., 2020) [35].

3. Loss of biodiversity

Agricultural expansion is a primary driver of habitat destruction**.** Natural ecosystems such as forests, wetlands, grasslands, and savannas are cleared to make way for crops or livestock. As habitats are destroyed, species lose their natural homes, leading to population declines and sometimes extinction (Sandor *et al*., 2022) [33]. The conversion of natural landscapes into large-scale agricultural operations reduces the diversity of plant, animal, and microbial species in the soil. Widespread pesticide use kills non-target organisms, including pollinators, soil microbes, and beneficial insects (Ankit *et al*., 2020) [1]. Reduced biodiversity means the loss of ecosystem services that healthy soils provide, such as nutrient cycling, pest control, and disease resistance. This makes agricultural systems more vulnerable to pests, diseases, and environmental stress (Saha *et al*., 2020) [1]. The movement of plants, animals, and soil for agricultural purposes can introduce invasive species into local ecosystems, including aquatic environments (Mayfield *et al*., 2021) [17].

4. GHG emission

Agricultural practices, such as deforestation, can contribute to climate change by releasing greenhouse gases. This, in turn, affects rainfall patterns and the availability of freshwater resources for both agriculture and aquatic ecosystems (Xing *et al*., 2024). Forests act as carbon sinks, so their destruction both releases carbon and reduces the capacity of the Earth to absorb future emissions. The use of fossil fuels in agricultural machinery, irrigation systems, and transport of crops is a direct source of CO_2 emissions. Soil disturbance accelerates the oxidation of soil organic carbon, turning a soil carbon sink into a carbon source (Yang *et al*., 2020) [46]. The manufacturing of fertilizers, particularly through processes like the Haber-Bosch method, releases large amounts of CO_2 into the atmosphere. While this is an indirect agricultural source, it is a significant part of the overall carbon footprint of agriculture (Rosa *et al*., 2022) [30].

Table 1: Three main GHGs emitted from the agricultural practices

GHG Emissions	Agricultural Practices
Carbon Dioxide (CO_2)	Deforestation For Farmland Expansion
	Use of fossil fuels in machinery and transportation
	Production and application of synthetic fertilizers
	Intensive tillage practices
	Crop residue burning (Punjab- Haryana region)
Methane (CH_4)	Enteric fermentation in livestock (e.g., cattle)
	Rice under anaerobic conditions
	Improper management of manure (e.g., slurry storage)
	Improper residue management
Nitrous Oxide (N_2O)	Over application of nitrogen-based fertilizers
	Decomposition of crop residues
	Inefficient management of animal manure

5. Climate change and extreme weather

Modern agriculture is both a contributor to and a victim of climate change. Practices like deforestation, burning of fossil fuels for machinery, and synthetic fertilizer use contribute to greenhouse gas emissions. Climate change leads to increased frequency and severity of extreme weather events, such as droughts, floods, and heatwaves, which further stress soils and reduce agricultural productivity. Crops are unable to thrive under drought conditions, leading to reduced yields, lower quality of produce and in some cases, crop failure. Some crops, like corn, wheat, and rice, are particularly vulnerable to water stress (Liliane *et al*., 2020) [15]. In areas with heavy rains or inadequate drainage systems, waterlogging can occur, where excessive water saturates the soil, depriving plants of oxygen and stunting crop growth. This is particularly damaging to crops like rice and maize**,** which require well-drained soils (Islam *et al*., 2022) [12].

Solutions to conserve environment and ecosystem

Maintaining high level of crop- genetic biodiversity both at the farm level as well as in seed banks. Planned diversity maintained with associated diversity in crop sequences and association suitable with pollinators (Howlett *et al*., 2021) [11]. Use of crop residues as a mulch cover and growing cover crops (Webber *et al*., 2022) [43]. Following integrated pest and disease management practices and use of indigenous technical knowledge (ITKs) in farming system (Tripura *et al*., 2024) [38]. Following integrated nutrient management (INM) and integrated pest management (IPM) practices (Lata *et al*., 2023) [14]. Production of good quality produce by practicing organic farming and less intensive agricultural practices (Soni *et al*., 2022) [34]. Adoption of zero tillage, minimum tillage and reduced tillage (Ogieriakhi *et al*., 2022) [22]. Not discharging the agricultural field runoff to freshwater ecosystem (Rideout *et al*., 2022) [29]. Proper management of wetlands i.e. alternate wet and dry method of irrigation, direct seeding of rice, SRI method of cultivation, use of leaf colour chart and split application of nitrogen fertilizers (Mishra *et al*., 2022) [34]. Good animal husbandry practices: balanced nutrition, good composting and manuring practices (Rayne *et al*., 2020). Avoiding shifting cultivation in northeast and hilly regions and promoting agroforestry (Nath *et al*., 2020) [20]. Proper management of grazing lands (Teague *et al*., 2020) [36]. Integrated Water Management has to be followed like combining surface water and groundwater use can balance agricultural demands and environmental sustainability (Sabale *et al*., 2023) [31].

Conclusion

Intensive agricultural practices, while essential for meeting the growing global food demand, have significant negative impacts on the environment and ecosystems. These include soil degradation, water pollution from agrochemicals, loss of biodiversity, deforestation, and greenhouse gas emissions contributing to climate change. Additionally, the heavy reliance on synthetic inputs and monocropping can undermine the long-term sustainability of agricultural systems. Transitioning towards more sustainable and regenerative farming methods is critical to balance productivity with environmental conservation, ensuring the health of ecosystems for future generations.

Consent

All authors declared that no competing interests exists.

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