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An Overview of Anthropogenic Changes in Land Use and Land Cover, with Specific Attention to Climate Change and Unsustainable Agriculture

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The worldwide need for food and the alterations in bioenergy demands associated with shifts in land use and land cover changes (LULCC) have given rise to environmental apprehensions, including global warming and climate change. There is substantial evidence indicating that we are currently witnessing human-induced transformations that could potentially result in a sixth mass extinction event. This study seeks to explore the connections between land use and land cover change (LULCC), forests, biodiversity, the carbon cycle, hydrology, climate, and various biogeochemical feedback mechanisms. These interrelationships play a crucial role in shaping future

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environmental outcomes and influencing climate change. Additionally, the review critically assesses existing research on the correlation between LULCC and climate, along with associated processes. The paper delves into ongoing investigations surrounding LULCC, its ecological repercussions, and its influence on the regulatory mechanisms of terrestrial ecosystems, ecosystem services, atmospheric chemistry, and the climate. It underscores the importance of developing land-use strategies rooted in a scientific evaluation of LULCC to promote sustainability and wider economic development, with a particular emphasis on addressing climate change. Global agreements and protocols also call for land use strategies that consider the implications of environmental degradation.

Keywords: Agroforestry; biodiversity; economic development; ecosystem services; sustainability.

1. INTRODUCTION

The article underlying this review provides detailed estimates of the repercussions of anthropogenic LULCC on the environment, biodiversity and climate change. The major problem is that the LULCC for food security and agriculture turns into a curse on its productivity, consumption, prices, and commerce, and also evaluates the overheads of acclimation. Anthropogenic activities are changing the both climate and ecosystems of the biosphere in ways that could be harmful and disruptive to people. Alterations in LULC can likewise impact the climate due to biophysical influences on factors such as surface albedo, evapotranspiration, and roughness of the terrain [1]. Since the last 20 years, there has been a considerable advancement in climate research, and as a result, we now have a robust comprehension of the physical effects of greenhouse gas emissions [2]. In the 1980s and early 1990s, when climate models were initially applied, the year 2100 was considered to be a sufficiently far threshold for climatic variables. Furthermore, that threshold is currently only a human life apart, and alternatives to easily decarbonize in pursuance of the Paris Agreement are limited [3].

The global appetite for food and bioenergy production is a direct driver of Land Use and Land Cover Change (LULCC), which subsequently exerts influences on the natural environment, ecosystems, and biodiversity, as noted by Taylor and Rising [4]. Moreover, LULCC contributes to the degradation of natural resources, a decline in ecosystem services, the diminishment of species diversity, and the exacerbation of extreme climatic conditions. These consequences, in turn, have far-reaching effects on humanity, especially impacting the well-being of impoverished and vulnerable populations heavily reliant on natural resources for their sustenance. In contemporary times, the assessment of LULC alterations plays a pivotal role in formulating sustainable land use strategies. This is because the accessible data reveals evolving landscape patterns over time, establishing a connection between resource availability and human needs and requirements. Many communities depend on agriculture and natural resources, highlighting the significance of recognizing the environmental and agricultural sectors as essential providers of people's basic requirements. Land practices and their management also result in diverse LULC patterns, which can either have adverse or advantageous impacts on other ecosystems. The objective of this review is to explore the connections between LULCC, the carbon cycle, hydrology, climate, and various biogeochemical feedback mechanisms. These connections play a crucial role in influencing future environmental consequences and climate change.

2. METHODOLOGY

The data sources concerning anthropogenic changes in land use and land cover, with a particular focus on climate change and unsustainable agriculture, were compiled from various published studies, encompassing research papers, review articles, books, and reports related to land use and land cover. The gathered information from multiple databases has been summarized and synthetically presented in this article addressing land use and land cover changes.

3. LAND USE AND LAND COVER CHANGE (LULCC): A CHALLENGE WITH SUSTAINABILITY

The Intergovernmental Panel on Climate Change [5] came to the unequivocal conclusion that the twentieth century's rise in temperature was caused by anthropogenic factors including emissions and LULCC. It is directly influenced by global food and bioenergy demand, which has an adverse effect on the ecology, ecosystem, and biodiversity [4]. LULCC also results in the degradation of natural resources, a reduction in ecosystem services, the extinction of species, and extreme weather, all of which have an impact on individuals, specifically the poor and marginalized communities or populations that depend on environmental assets for basic subsistence. The human race, settlement growth, changes in agricultural production systems, energy demand, deforestation, farming modernization, transformation of natural landscapes, and excessive use of environmental assets are the primary causes of land use change [6]. It is often evident that human induced LULCC caused a wide range of natural events, including those that affect the environment, the climate, and the extinction of species [7].

The primary causes of LULCC are either underlying or immediate (direct or indirect) factors. The primary (Direct) influencing elements also have secondary (Indirect) effects. The natural vegetation and exchanges among the terrestrial ecosystem and environment evolved drastically over prior years of land use-caused climatic changes. The current endeavour is to comprehend connections between the LULCC, agriculture, climate, biodiversity and other biogeochemical feedbacks that may be crucial in regulating the consequences of climate crises and future environmental repercussions.

4. COHERENCE OF CLIMATE CHANGES AND LAND USE AND LAND COVER (LULC)

Shifts in land use cause environmental consequences through emission levels, land/air correlations, hydrogeology, interactions with earth's surface energy, habitat destruction, and species reconfiguration [8] (Jiang *et al*., 2021).

Land use change is a significant factor in climate variability, which ultimately led to LULCC (Fig. 1). Asian Summer Monsoon (ASM), one of the most well-known climatic systems, is related to various climate change models over land and water. The human habitation, agriculture, and cultural advancements in the ancient Indian civilization began weakening/strengthening the Indian summer monsoon. A paucity of water, unpredictable rainfall, and rising temperatures as a result of the delayed monsoon owing to climate crises influence agricultural activities. As degradation and habitat loss alter the planet's energy balance and have an impact on the pattern of winds across land and water, changing the distribution of natural forests nationally or internationally will hasten climate change [9]. In the Himalayan foothills of northeast India, forests that were transformed to intermittent farming resulted in micro and macro climate change, greater deterioration of soil carbon forms and general soil quality [10]. According to reports, between 1980 and 2000, the tropics lost more than 55% of its virgin forest land to agriculture, and another 28% of its virgin forest land was disturbed [11].

5. LULC CHANGES AND LAND–ATMOSPHERE RELATIONSHIPS

Forest Loss and Intensification of Agriculture: Over the past few decades, the impact of changing forestland to farmland on domestic, state and global climate has received extensive documentation. In India, Srivastava *et al*. [12] and Kushwaha *et al*. [13] both found significant deforestation throughout the northeastern region. The regional climate is impacted by the diversity in agricultural patterns. Similar events have been tracked and reported in Odisha, where an increase in Rabi crop output as a substitute for Kharif crops contributed to temperature rise of 0.3 °C from 1981 to 2010 and 2010, with large temperature stresses (0.9 °C) reported between [14]. Broadly speaking, the North Peninsula of India receives less rainfall as a consequence of farming intensification methods.

Development Projects: Due to the increasing human need for sustenance, textiles, and housing, human activities have significantly disrupted the Earth's land surface. This has resulted in the conversion of vast natural landscapes into areas primarily controlled by humans, including farmland, pastureland, and urbanized regions with impermeable surfaces. [15]. LULCC often arises from engineering initiatives [16], which can entail modifications to infrastructure, such as the development of hydroelectric dams [17]. These changes can have significant effects on both biodiversity [18] and the well-being of indigenous communities [19]. In recent times, the rapid proliferation of hydroelectric dams in the world, both those in planning stages and under construction, has sparked significant social and environmental apprehensions. On the one hand, hydropower is water-use-flexible, clean, effective, and inexhaustible. Conversely, scientists have contended that dams may instigate changes in hydrology and climate, impact local wildlife and vegetation through forest and land inundation, as well as alter land utilization, potentially necessitating population displacement, which can result in forest fragmentation and loss. A study conducted by Velastegui-Montoya *et al*. [16] in the Amazon basin was aimed at generating "clean" energy to meet regional energy demands and integrate Brazil into the global economic market. However, it is essential to acknowledge that such megaprojects have the potential to disrupt natural ecosystems. The findings indicate that the initial period of analysis witnessed the highest deforestation rates, primarily attributable to the submersion of land by reservoirs and human activities like logging, road development, and the conversion of forests into extensive agribusiness areas. In conclusion, it underscores the importance of developing land use policies through rigorous scientific analysis of LULCC, aiming to attain sustainability objectives and foster broader socioeconomic progress, with a particular emphasis on addressing climate change.

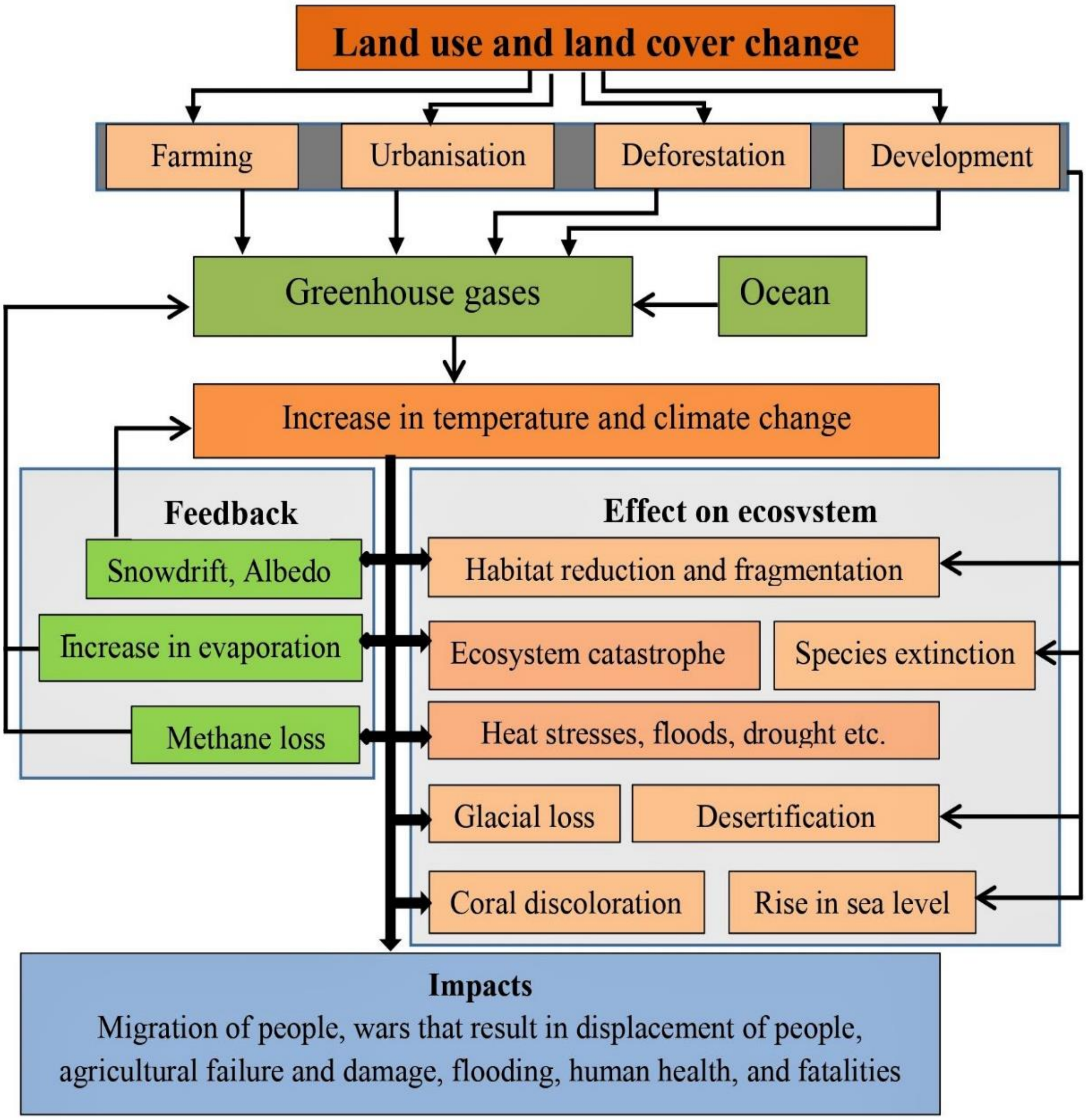

Fig. 1. Drivers and Feedback: Consequences of LULCC on Climate and Civilization

Urbanisation and Land-Atmosphere Interactions: Numerous landscape-level factors, such as hydrology, energy balance, and microclimate, are altered by urbanisation. A study was conducted by Chen *et al*. [20] in Tianjin (China) to access long-term urban evapotranspiration and its trends using Landsat satellite. According to the analysis, urban surface water evaporation, heat transfer flux, and Bowen ratio display a considerable rise while urban evapotranspiration, topsoil evaporation, and vegetative water loss show a marked decline in trend. Metropolitan heat stress is measured by a quantity called the heat index and is caused by both widespread warming in urban areas and high humidity.

Alteration in Atmospheric Constituents Caused by LULCC: LULCC influences the local atmosphere by emitting gases and aerosols directly. Former research showed that land use is a significant global source of anthropogenic carbon dioxide (CO_2) emissions. A substantial source of atmospheric CO_2 is the agricultural industry. Over a Himalayan watershed, the shifting of woodland to farmland led to the annual discharge of 7.7 Mega grams of Carbon per hectare [21]. Regionally significant atmospheric aerosol loading was another aspect of urbanisation. From the perspective of precipitation, it was found that Aerosols were found to have the potential to catalyse further the urbanization-induced increase in downstream rainfall intensity across the Gangetic Basin.

6. LULCC: IMPACTS ON BIODIVERSITY

The very first "Big Five" extinction events occurred during the late Ordovician period (440 million years ago) followed by the Devonian period (374 million years ago), the Permian period (250 million years ago), the Jurassic period (200 million years ago), and the Cretaceous period (145 million years ago). The "Anthropocene extinction," the 6th major extinction underway may be caused by grave environmental challenges to human civilization. Besides the density, structure, biodiversity, and woodland matrix features, partitioning of the habitats—which is caused by LULCC is regarded as the most crucial metric for assessing changes and perturbation of species diversity at the ecosystem level. The world's natural habitats are rapidly disappearing as they are used for mankind and transformed to pave the way for other land use types including agribusiness, urbanisation, construction, and industrial installations. Therefore, it is believed that habitat loss poses the greatest hazard to species. Natural systems are significantly affected by long-term changes in the temperature and habitats, which leads to habitat destruction. Commercial farming of latex, palm oil, and coffee has taken the place of the biologically diverse tropical forests. As potential solutions, the idea of rejuvenating farming and the regrowth of clear land to trap Carbon dioxide from the air is being discussed. It is advised under the UN Decade of Rehabilitation to create forest nature conservation plans that are suitable for current land practices, such as agroforestry, particularly in nations with sizable rural farm holdings [22].

7. IMPACTS OF CLIMATE CHANGE

7.1 The Biological Effects on Yields

Analysis was conducted by Nelson *et al.* [23] in Food Policy Report: Analysis relied on two climate derivatives or models: The National Centre for Atmospheric Research (NCAR) model from the US and the Commonwealth Scientific and Industrial Research Organization (CSIRO) model from Australia.: The National Centre for Atmospheric Research, US (NCAR) model and the Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO) model.

Direct effects on yield: For the majority of crops grown in developing nations without CO_2 fertilisation, yield decreases predominantly. Irrigated grain crops (wheat and rice) are particularly heavily damaged. In general, wealthy country harvests are less impacted than those in underdeveloped nations. Climate change boosts yields in industrialised countries for a few crops. Some crops thrive in China because sites where present temperatures are at the lower end of the plant's ideal range are favoured by greater future temperatures.

***Indirect Benefits*:** The amount of water that is available for irrigated crops will fluctuate due to climate change. The CSIRO model predicts significant yield losses for irrigated rice, wheat, and maize in East Asia and the Pacific. Such scenarios would result in severe drops in South Asia's irrigated crop yields. Both models result in lower corn yields in Sub-Saharan Africa, but the CSIRO effects are particularly significant. As a result, to the low level of irrigated agriculture in Latin America and the Caribbean, yields are unlikely to be affected.

7.2 Impacts on Crops

- The warming trend will influence multiple crops differently depending on the optimum range of temperature for their reproductive cycles.
- Crop productivity may be affected by elevated carbon dioxide levels. Based on specific preclinical studies, higher carbon dioxide readings may encourage crop growth. Other variables like pollution, shortage of water and minerals, and temperature fluctuations might prevent these potential yield improvements.
- In areas where summer temperatures are continuing to rise and soils are drying out, managing drought could become difficult.

7.3 Impacts on Livestock

- Because of global warming, higher temperatures are predicted to occur more frequently and could pose a major threat to animals.
- Pasture and forage reserves could be in jeopardy from a drought. The supply of premium feedstuffs accessible to grazing animals is diminished by drought.
- The rise in the frequency of diseases and parasites that infect animals may be due to climatic variability. Some pathogens and parasitic infections may be able to survive because of hotter and drier winters and an earlier spring.

7.4 International Impacts

At the global, provincial, and state or local levels, anthropogenic global warming has the worst consequence on food supply. Food security is expected to be influenced by environmental issues, which in turn hinder the accessibility to food [24]. For instance, declining crop production can be brought on by sudden rises in temperature, variations in weather patterns, shifts in extreme events, and/or declines in groundwater resources.

The implications of climatic variability on food supplies, however, might be amplified by other pressures like population expansion. Compared to the United States and other developed countries, the possibilities for adaptation, such as modifying agricultural management, ranching methods, or irrigation systems, are more constrained in developing economies.

8. RECOMMENDATIONS

The outcome of this article highlights the important policies and legislative recommendations, which are discussed below.

1. Through global declarations endorsed by all Signatory Nations, accorded substantial consideration to climatic and catastrophic resilience while acknowledging the consequence of land use on the environment and climate-induced crises.
2. The 2030 Agenda for Sustainable Development is one of the specific theories which can guide the legislative framework on land development in connection to disaster reduction and climate change mitigation.
3. Effective land use design and development are encouraged by Sustainable Development Goal (SDG) 11, which emphasises urban areas and communities more livable, secure, adaptive, and efficient. To meet the aims of SDG 11, socioeconomic and ecological problems are presented by the connections between landuse and climatic variability
4. In underdeveloped nations where agribusiness is strongly dependent on environmental variables, the application of spatial intelligence, as well as other new and industrialized innovations, is essential for creating optimal land use that provides catastrophic and climatic adaptability.
5. Agroforestry, effective and integrated land management, maintaining and recovering environments, lowering farm animals, water efficiency, financial sectors, transit, global relations, and our fundamental consumer economy must all be integrated into a new system of food production.
6. Create and operate effective policies and initiatives for global development.
7. Revitalise federal research and extension initiatives.
8. Funding for climate adaptation initiatives should be increased by at least $7 billion annually.

9. CONCLUSION

The enforcement of the nationally determined contributions (NDCs) declared before COP26 would cause an increase in global GHG emissions of 1.5°C in 2030 [25,26]. Worldwide demand for food and bioenergy brought on by land transformation has prompted concerns about the ecosystem, rising temperatures, and ecological degradation. The article highlights recent findings on LULCC, its effects on the environment, and its effects on the terrestrial biosphere's regulatory systems, ecosystem services, climate, and agriculture production (Quality and quantity). To accomplish sustainability targets and general improvement of living standards with a view on climate change, the value of adjusting land use policies on research-based study of LULCC should be emphasized. Land use strategy, which considers climate change issues, is also required under the obligations of international accords and protocols.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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