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Towards Sustainable Development: Harnessing the Role of Trees for Environmental Conservation and Economic Growth

Naresh Raj K[1], Vidhya Lakshmi Sivakumar[2], Pamila Ramesh[3], Sathya Priya A[4], Anand Raju[5]

[1]Chief information officer, Sri Sai Ram Engineering College, Chennai, TN, India
[2]Department of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, TN, India.
[3]Department of Civil Engineering, Sri Sai Ram Engineering College, TN, India
[4]Department of Physics, Sri Sai Ram Engineering College, Chennai, TN, India
[5]Department of Civil Engineering, Saveetha School of Engineering, SIMATS, Chennai, TN, India.

This review aims to explore the role of trees within the world's ecosystem and address the challenges and dangers associated with managing their biodiversity. Additionally, it critically evaluates the economic value that trees bring to the construction industry. The study seeks to develop a counter strategy for preserving the relative importance of trees within the ecosystem while also balancing economic benefits. Trees outside forests (TOFs) represent a crucial natural resource, contributing significantly to national biomass and carbon stocks. In recent decades, there has been an increased awareness of the significance and importance of TOFs. The review underscores the importance and various applications of trees in ecosystem development. It emphasizes the necessity of consistent monitoring of trees both inside and outside forests as a key aspect of sustainable land management.

Keywords: Tree Biodiversity, Ecosystem Services, Sustainable Land Management

1. Introduction

The preservation of future generations grapples with pressing issues such as global warming and the extinction of species, igniting discussions among scientists and policymakers worldwide [1]. Addressing these challenges involves sustainable practices like agroforestry, community forests, village woodlots, roadside plantations, urban green spaces, and other forms of tree cultivation outside traditional forest areas [2]. Trees outside forests, commonly

known as Trees Outside Forests (TOFs), refer to woody vegetation growing outside officially designated forest lands. Their ecological significance spans ecosystem services and economic benefits, including support for agriculture, food security enhancement, and income generation through goods and services provision. Trees hold vital roles in society, fulfilling essential functions for both individuals and the environment [3] .Through the attraction of both public and private investments, agribusiness incentives in tropical forests have the potential to boost employment, reduce carbon emissions, and advance sustainable resource use[1]. Because baobab tree populations are highly sensitive to changes in land use, this species is in danger of extinction and urgent action is needed to manage and protect it[2]. Numerous studies indicate that trees and green spaces in urban areas can enhance mental and physical well-being (Sustainable Development Goal 3 is good health and well-being), improve children's concentration and academic performance, boost real estate values, and provide other benefits. The intricate interplay between biodiversity, carbon, forests, and human populations underscores a complex scenario [4]. There are no other threats to growth, sustainability, or the environment like the global warming caused by green house gas emissions, particularly carbon dioxide[3]. The extraction of non-renewable minerals is widely seen as fundamentally unsustainable[4]. In terms of both ecology and economics, soil erosion is a major problem[5].

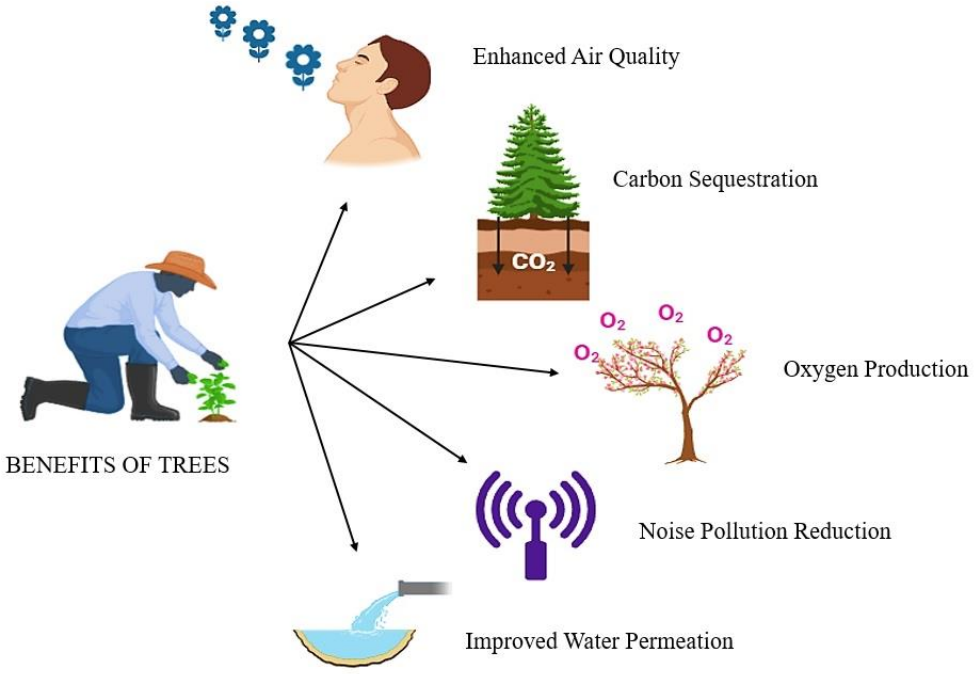

Fig.1 Benefits of trees

Tackling global deforestation and forest degradation promises significant benefits, not only in mitigating climate change but also in preserving biodiversity, addressing global climate challenges, and fostering swift and sustainable rural development [5] A deeper understanding of tree-tree interactions and their impact on key ecosystem functions through increased tree species richness is imperative [6]. Easing the process of ecosystem management is facilitated

by the evaluation of the availability of ecosystem services[30]. Renewable energy's incorporation into the grid has a major impact on the advancement of sustainable development[31]. Woodland species are essential to the welfare of local populations, rendering them an essential element of agroforestry systems[32]. The socioeconomic status and historical degree of development of a society are correlated with its natural systems[33]. It is true that historical homes are influenced by cultural memory and vice versa[34]. Sowing trees that can withstand dry conditions in order to boost biodiversity. Immersed in nature and bordered by exotic trees, Casa Jelinek sits next to the flower bed's formal parterre garden[35]. Stabilizing and improving water conservation capacity can be achieved by the planting of drought-tolerant trees, commercial forestry, and ecological activities such as afforestation and wetland restoration[36]. The majority of the medicinal requirements were met by trees in the periphery villages, demonstrating the critical role that trees play in addressing the health needs of these populations[37].

The loss of biodiversity poses a substantial impact, rivalling or exceeding the effects of herbivorous behavior, fire, dryness, nitrogen deposition, elevated CO_2 levels, and other environmental stressors [7] [ref4, @]. On top of that, TOFs are crucial for carbon sequestration and biodiversity preservation. Trees hold immense value for humanity, influencing various aspects of human life including economic, industrial, environmental, aesthetic, spiritual, and medicinal realms [8] (Panshin & Zeeuw, 1980). Trees directly or indirectly support human life by providing resources for sustenance, survival, and economic prosperity. Large, perennial (long-lived) woody plants that attain a maturity height of at least 20 feet (6 meters) are classified as "trees". Typically, they possess a single primary stem, referred to as a "trunk", which is further divided into a multitude of branches, limbs, and foliage, resulting in a dense canopy [9-11](Seth, 2001; Schubert, 1979; Trotter, 1960). Trees whether directly or indirectly, offer a multitude of advantages and enhance the quality of life for city dwellers. Their roles encompass the absorption of carbon dioxide, release of oxygen, filtration of air contaminants, mitigation of urban heat islands, noise attenuation, enhancement of water permeation into the soil, and reduction of runoff. Furthermore, trees contribute to vital ecosystem services, food security, environmental sustainability, and public health [12-13] (ref 26,27). Green financing, which supports varied projects that meet criteria, helps sustain global economic growth[38]. It is crucial to manage and preserve the natural habitats of multipurpose tree species since they are susceptible to the effects of climate change and human expansion[39]. Homestead agroforestry has stimulated the economy in spite of the prevalence of intensive monoculture agriculture[40].

Every tree exerts a notable influence on the built environment. As industrial operations continue to advance at a rapid pace, there is growing worldwide concern over the excessive discharge of metallic elements into the surrounding environment. Approximately 500 plant species known for their ability to accumulate heavy metals have been identified, predominantly in regions linked to metal extraction, showcasing a natural resilience to elevated concentrations of metallic elements; however, the majority of these species are classified as herbaceous plants [14] (ref 33). Afforestation of degraded land demonstrated a fourfold increase in organic carbon improvement [15] (ref 34). The accumulation of litter from various tree species enhances resource heterogeneity [16] (ref 35), thereby fostering soil fauna enrichment and activating nutrient cycling processes [17] (ref 36). This review explores the

vital role of trees in the ecosystem and the challenges of managing their biodiversity. It also assesses the economic value trees provide to the construction industry and seeks strategies to maintain their ecological importance while balancing economic benefits. TOFs are recognized as significant contributors to national biomass and carbon stocks, underscoring the need for ongoing monitoring to ensure sustainable land management.

2. Significance of trees in economy:

Experts, practitioners, and interested parties continue to discuss the construction of massive tree plantings [18] (ref 8). Trees situated in urban environments significantly impact air quality and various environmental issues [19] (ref 9). The exposure of individuals to air pollution can be influenced by the presence of trees, as they reduce emissions, delay the development of secondary pollutants, and filter out airborne particles.

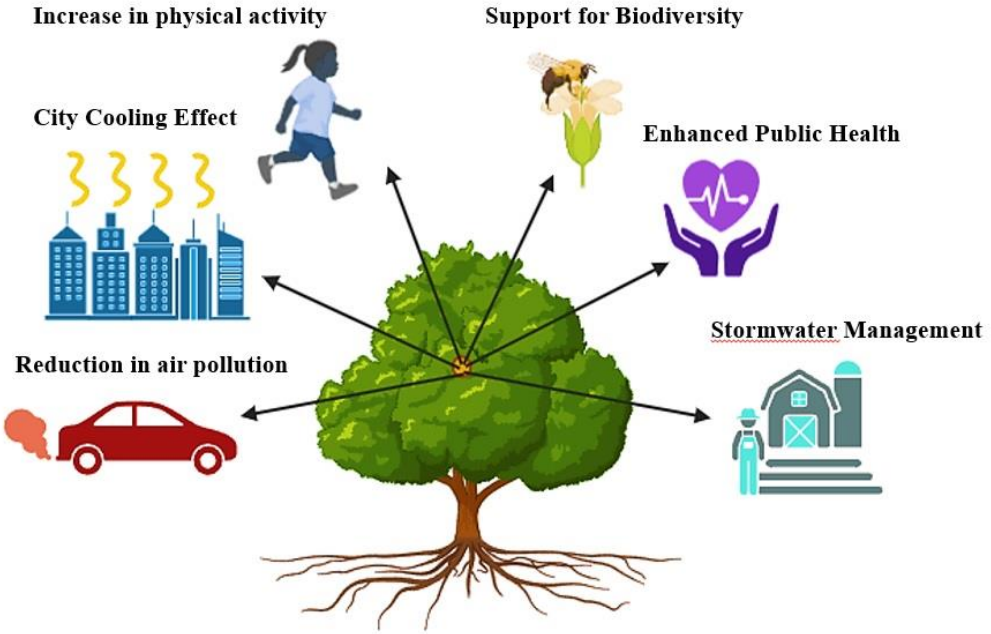

Fig.2 Positive impacts of Trees in Cities

Additionally, trees provide supplementary benefits such as increasing property value, intercepting stormwater runoff, and conserving energy needed for cooling structures during warmer seasons. Each tree's economic value was evaluated based on its ability to intercept stormwater in urban areas, boost property value, reduce energy consumption by enhancing cooling, mitigate air pollution through the removal or prevention of harmful substances, and capture and store carbon dioxide [20] (ref 10). Here, T represents Timber, which stands as the primary and most significant use of trees. R signifies the Restoration of topsoil during erosion, a vital function of trees that aids in regenerating arable land for vegetation. The roots of trees rejuvenate, reclaim, and revitalize the eroded and depleted soil, thereby safeguarding against desertification, soil nutrient loss, and moisture depletion. E denotes Ecosystem, where the role

of trees profoundly impacts the quality of human life worldwide. 'Photosynthesises facilitates the conversion of CO2 in the air into O2, essential for human and all other living organisms' respiration. Trees serve as oxygen reservoirs purging air pollutants, moderating temperature, supporting diverse life forms, preserving biodiversity, and conserving energy [21] (Keerthika A and Chavan S. B, 2022).

E stands for Economy, as trees offer a perpetual natural resource supporting human livelihoods through timber, fodder, fragrances, medicines, fuel, fibres, fruits, and more, with timber being the primary economic asset. S symbolizes the Sustenance of life on Earth, as trees play a crucial role in sustaining life across the planet through their environmental influence. Timber is regarded as a sustainable material owing to its minimal treatment needs and low energy consumption across its lifecycle, spanning from production to disposal. The increase in tree coverage has notably contributed to preserving nearly 93% of pollinators crucial for crop production, often found in their original forest habitat [22] (ref 7). In addition to ensuring the economic sustainability of rural communities, native tree species are essential to sustainable agriculture because they conserve biodiversity and ecosystem services[41].

3. Sustainable Development through Trees

The research highlights socio-economic and sustainable developments crucial for mitigating climate change. Recognizing the socio-economic importance of trees and their impact on ecosystems is essential. To facilitate this, the UK government should offer financial incentives for carbon sequestration and planned forestry. Economic planning of forests is necessary to reduce emissions and increase forest cover to align with European standards. Urban land demands often limit space for forestry, posing challenges. Policy decisions and practices will significantly impact forests' capacity to mitigate climate change and lower greenhouse gas emissions. Silvo-pastoral systems are frequently mentioned when discussing sustainable production alternatives, as they enhance productivity, provide critical ecosystem services, and benefit the environment[42].

4. Classification Challenges of Trees Outside Forests

Trees Outside Forests (TOF) present classification challenges due to their diverse functions and arrangements [23]. The Food and Agriculture Organization (FAO) recognizes three primary types of TOF: those found on agricultural, urban, and non-urban non-agricultural land[24]. Parks, roadside greenery, arboreal elements, parking spaces, and horticulture are all constituents of urban tree and open space features.

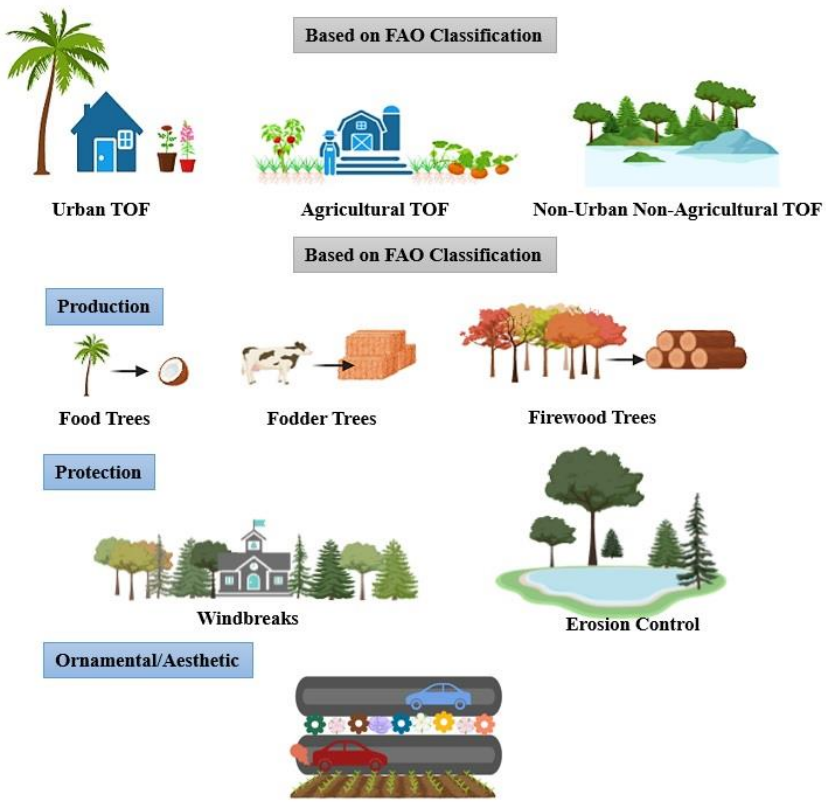

Fig.3 Classification of trees outside forest

Agricultural TOF includes trees and shrubs within agricultural areas, covering agroforestry systems, tree crop plantations, and orchards. TOF on natural lands, such as grasslands, mountain tree lines, and peatlands, fall outside urban and agricultural classifications. On land that is not utilized for agricultural or municipal development, TOF is comprised of trees and shrubs that are located outside of forests.

Spatial arrangement further categorizes TOF into isolated, scattered, grouped, or linear formations. Functionally, TOF are classified based on their purpose, including production, protection (windbreaks, erosion control), and ornamental and aesthetic uses. Origin-based classification distinguishes between planted trees and remnants of former forests. Instances of former forest remnants are reported in Latin America, where virgin forests have been harvested. The most pleasant effect, according to farmers was improved soil fertility. Soil microbes and organic matter may have been enhanced by the root system or litter fall of Piper Chaba and related trees[43].

5. Applications of trees

5.1. Climate change control

On land that is not utilized for agricultural or municipal development, TOF is comprised of

trees and shrubs that are located outside of forests. As emphasized by Greenfield Boyce (2015) [25], trees play a crucial role in erosion mitigation and climate regulation. Strategic ecosystem face three main threats: geological processes, climate change and human activities[45]. They actively absorb carbon dioxide from the atmosphere and store significant amounts of carbon within their structures. Despite the abundance of tree resources in nearly every country, they have often been overshadowed by forests. However, the environmental and social advantages of Trees Outside Forests (TOF) have been increasingly widely acknowledged in recent years [26]. Placing greater emphasis on Terrestrial Organic Carbon (TOC) could enhance efforts to achieve net-zero goals by encompassing expansive terrains across Africa, Asia, and Latin America. Adaptation methods, livelihoods, and income production resilience in the face of climate change threats can all be positively impacted by these landscapes' abilities to sequester carbon from the air. The industrial revolution increased green house gas emissions from energy production, manufacturing, and transportation, causing global warming and sea level rise[46]. Numerous native trees and plants may be found in the forest, such as the Tineo violet, Sicilian snapdragon, Boccone fennel, Busambra cornflower and Boccone Perlina as known as ciombollino[47]. Greening urban areas significantly contributes to tackling climate change and mitigating the effects of the heat island phenomenon in constructed environments [27] (ref 23) by modifying temperatures. [28-29] (ref 24,25). While every tree holds importance in the urban setting, deciduous trees are recognized for their capacity to absorb gases, whereas coniferous trees aid in decreasing air pollution.

A substantial number of native trees have the potential to provide ecological benefits, as indicated by a growing body of research connecting widespread tree planting projects to various essential measures for mitigating climate change. These encompass carbon sequestration, mitigation of urban heat islands, reduction of diverse environmental contaminants in the atmosphere, economic benefits, and improvements in both physical and mental well-being [30-31](ref 29,31). There are two primary ways in which trees either retain air pollutants or reduce their dispersion: first, they take in hazardous substances via their leaves; second, when some poisons break down, trees metabolize them, turning them into non-toxic molecules internally [32] (ref 32).

Reducing heat is a critical ecosystem service offered by trees, particularly amid climate change challenges. Studies on urban heat islands are largely shaped by land surface temperature measurements taken during specific times, typically in the morning [33] (ref 36). Firstly, tree canopies may block shortwave radiation from the sun by intercepting it and directing it away from the ground. This process ultimately reduces convection, thus assisting in mitigating the heat island effect. Monitoring urbanization and land degradation is essential to advancing sustainable development and environmental care[24].

The process of evapotranspiration is highly significant, as tree canopies not only absorb solar radiation but also draw energy from the surrounding environment, leading to a rise in latent heat fluxes rather than sensible ones. When combined with the oasis effect and clothesline effect, even a single tree has the potential to regulate the local micro-climate [34] (ref 37). Research indicates that a healthy, properly cultivated tree transpires approximately 100 gallons (380 litres) of water daily, equivalent to the cooling effect generated by five one-ton air conditioners operating for 20 hours each day. Thus, trees contribute to stabilizing climatic variations and regulating temperature [35] (ref 38).

5.2. The Role of Trees in Cleansing the Environment

Industrial operations often lead to the accumulation of waste materials across landscapes, resulting in elevated pollution levels in various elements of surrounding ecosystems, including soil, water, and air. Unlike natural ecosystems, artificial structures like ash and mine tailings storage facilities or industrial landfills are significantly isolated from natural or agricultural environments due to their specific design and layout [36] (ref 28).

Photosynthesis, a metabolic physiological process performed by trees, generates energy for their normal functioning, during which atmospheric CO2 (carbon dioxide) is converted into O2 (oxygen) as a byproduct. Therefore, trees serve as "oxygen reservoirs," crucial for the survival of all life forms on Earth. Recognized as the planet's essential respiratory organs, trees possess an extraordinary capability to release oxygen through photosynthesis. The deterioration of air quality in densely populated areas increasingly impacts human well-being.

Planting trees in urban settings is particularly effective as it directly absorbs CO2 through photosynthesis. Furthermore, trees offer shade and wind shielding, thereby reducing the need for fossil fuels for heating and cooling in residential structures. Urban tree planting can result in an overall reduction in carbon emissions of up to 18 kg of CO2 per tree annually. This benefit is comparable to that provided by 3 to 5 forest trees of similar size and condition [37] (ref 30).

5.3. Tree-Influenced Building Construction

The sustainability of a building structure should encompass environmental stability, user-friendliness, and durability [38] [5]. Wood plays a paramount role as a crucial construction material, prized for its strength, eco-friendliness, ease of handling, and convenience in construction processes. Throughout history, trees and their by-products have served as indispensable resources for human populations worldwide for thousands of years. Scholars and governments globally have extensively focused on issues related to sustainable buildings and materials [39] [6]. Consequently, several green policies have been introduced to address these concerns, notably emphasizing the promotion of wooden building structures as environmentally friendly and energy-efficient choices. By integrating sustainable materials into building design and construction, not only can environmental harm be mitigated, but it also fosters a more circular economy by minimizing waste and reliance on finite resources [40] [12]. Prioritizing sustainable materials in construction projects is crucial for policymakers, architects, builders, and consumers to effectively mitigate the environmental impact of buildings. Environmental management is significantly enhanced by indigenous knowledge[48].

5.4. Managing Soil Erosion

Robust forests are crucial for the local water cycle, as they contribute to the generation of regional rainfall. However, deforestation or degradation can disrupt this role, leading to altered precipitation patterns and river flows, which in turn increase soil erosion. Without trees to stabilize fertile soil, erosion can sweep land into rivers. Agricultural crops often replace trees but are less effective in soil retention. In fact, many of these crops, such as coffee, cotton, palm oil, soybean, and wheat, can exacerbate soil erosion. Scientists estimate that approximately one-third of the world's arable land has been lost to soil erosion and other forms of degradation

since 1960. Erosion may wash land into rivers if trees aren't there to support rich soil. Housing and jobs help many communities stay stable. Forests manage and provide fresh water to many people. They offer food security with fuel, cooking supplies, and agricultural aid. Survival depends on woodlands for many people worldwide. Aboriginal peoples and local communities control at least 15.5% of the world's forest area, which makes them essential stewards of the planet's remaining natural ecosystems. However, deforestation disrupts the lives of these communities, often resulting in devastating consequences such as social conflict and migration. The loss of indigenous peoples' lands affects their access to essential resources for survival.

This study holds significance as it seeks to address environmental concerns amid increasing exploitation of natural resources under the guise of globalization. Little attention has been given to examining how the construction industry in various regions is impacting the role of trees in ecosystems. Additionally, this study holds commercial importance as it aims to propose solutions for sustainable timber production in the construction industry without compromising forest cover. It also aims to identify strategies for planned forestry management to discourage illegal deforestation in rainforests. This study gains importance as it aims to uncover the commercial aspects of timber that are environmentally friendly. This study stands out because it provides a concise overview of recent findings and contributions from a variety of fields that enhance our knowledge of the ecological role trees play in ecosystems across the world.

5.5. Tree-Based Carbon Solutions

Trees can serve as a substitute for fossil fuels and petroleum-based products, thereby impacting greenhouse gas emissions. Moreover, prioritizing wood in construction ensures carbon storage within the wooden structures. This leads to a reduction of 36.7 MtCO2 and a corresponding decrease of 20 Mt of carbon (equivalent to 73.4 MtCO2) in carbon-intensive construction materials. Hence, it's recommended to employ productive/multipurpose forestry to enhance carbon fixation for wood products and expand Greenland's acreage simultaneously. Increased tree planting offers a more environmentally friendly alternative to petroleum products. However, the legal system must ensure plywood used in construction is sourced from legitimate or Forest Stewardship Council-certified sources. Rainforests should remain untouched by commercial timber usage.

In addition to the aforementioned points, promoting agroforestry practices can further contribute to carbon sequestration and sustainable land management. Agroforestry integrates trees into agricultural systems, offering multiple benefits such as increased soil fertility, biodiversity conservation, and climate resilience. By incorporating trees into agricultural landscapes, we can enhance carbon storage in both aboveground biomass and soil organic matter, thus mitigating greenhouse gas emissions. Agroforestry also provides additional economic opportunities for farmers while promoting environmental sustainability.

5.6. Balancing the ‘trees’ for ecosystem management and economic benefits for sustaining Life

Forest policies for inclusive and sustainable development are crucial to meeting the aims of the 2030 agenda and Sustainable Development Goals, and it is recognized that social and

economic responsibilities are interdependent. Forested watersheds serve as the origin of 75% of the globe's reachable freshwater. Community-based forestry has been formulated as a method to alleviate poverty in numerous nations, as well as to foster rural development via forest strategies and initiatives (UNFFS 2021) [41] (Ref 58). In addition to promoting increased rates of afforestation, the plans primary objective is the preservation of inland freshwater habitats, wetlands and animals[50].

Trees do sustain the life every bit on Earth through its influence on environment. For sustaining the wildlife, trees form the first chain of the food-cycle where the wildlife (Herbivores) propagates on the vegetative growth as provided by the trees, while the Carnivores feed on Herbivores and soon (Seth, 2001)[42]. The trees are also an unending natural resource of economic sustenance for the human life as these provide timber, fodder, fragrance, medicines, drugs, fuel, fibres, fruits etc. with 'timber' forming the most prominent economic resource (European Sustainability Group, 2007). [43]

Trees play a crucial role in helping nations fulfil the UN Sustainable Development 0Goals by offering food, resources, and economic benefits. These objectives encompass(Table 1): Goal 1 - Eradicating poverty in all its forms worldwide; Goal 2 - Combating hunger, achieving food security, enhancing nutrition, and promoting sustainable agriculture; Achieving universal access to modern, cheap, dependable, and sustainable energy is the seventh goal. Eighth Goal: Promoting long-term, equitable, and inclusive economic growth; ensuring everyone has access to good jobs; Goal 10 - Mitigating inequality within and among nations; and Goal 12 - Ensuring patterns of consumption and production that are sustainable (ref 59)[44]

Table 1: Mapping of Benefits of Trees with Sustainable Development Goals

Sl.No	Benefits of Trees	Corresponding SDG goals	Justification
1	Trees offer economic benefits and contribute to lower energy bills while providing various resources like food to communities	SDG 1: No Poverty	Trees can provide income opportunities through the sale of timber, fruits, and other forest products, helping to alleviate poverty in communities reliant on forest resources.
		SDG 2: Zero Hunger	Trees bear fruits and nuts, which can serve as a source of food for communities, contributing to food security and nutrition.
		SDG 7: Affordable and Clean Energy	Trees provide natural shade, reducing the need for air conditioning in buildings during hot seasons, thus lowering energy consumption and promoting energy efficiency.
		SDG 8: Decent Work and Economic Growth and SDG 12: Responsible Consumption and Production	The forestry sector provides employment opportunities, from forestry management to timber processing, contributing to economic growth and job creation.
		SDG 10: Reduced Inequality	Access to forest resources can help reduce inequalities by providing marginalized communities with opportunities for income generation and resource access.

2	Trees foster both physical and mental well-being among urban residents, nurturing community bonds and contributing to lower crime rates. Trees are vital components of terrestrial ecosystems and contribute to biodiversity conservation in urban areas. They provide habitat and food sources for various plant and animal species, including birds, insects, and small mammals. Communties may help safeguard ecosystems both inside and outside of cities by protecting and increasing urban tree cover, which in turn supports biodiversity conservation initiatives.	SDG 3: Good Health and Well-being	Trees contribute to better physical health by purifying the air, reducing pollution, and providing shade, which can mitigate the impact of urban heat islands. Cleaner air and cooler temperatures lead to reduced respiratory illnesses and heat-related health issues. In addition, studies have shown that city dwellers who have access to parks and other green spaces report lower stress and better mental health.
		SDG 11: Sustainable Cities and Communities	Urban greenery, including trees, promotes sustainable urban development by enhancing the livability of cities. Trees contribute to the creation of vibrant and inclusive public spaces that encourage social interaction, physical activity, and recreation. They also improve the aesthetics of urban areas, making them more attractive places to live and visit.
		SDG 15: Life on Land	Trees are vital components of terrestrial ecosystems and contribute to biodiversity conservation in urban areas. They provide habitat and food sources for various plant and animal species, including birds, insects, and small mammals. By preserving and expanding urban tree cover, communities can support biodiversity conservation efforts and contribute to the protection ofecosystems both within and outside of cities.
		SDG 16: Peace, Justice, and Strong Institutions	Trees create safer and more secure urban environments by providing natural surveillance, reducing opportunities for criminal activity, and fostering a sense of ownership and stewardship among residents. Strengthening community bonds through shared experiences in green spaces can also contribute to the promotion of peace, social cohesion, and inclusive governance.

6. Conclusion

The pivotal role of trees within ecosystems is widely acknowledged. Trees are essential for sustaining life on Earth, as they engage in various bio-physiological activities such as reducing greenhouse gas emissions, converting CO_2, regulating temperatures, and sequestering atmospheric CO_2. Additionally, trees serve as substitutes for petroleum products through their wood derivatives, leading to a significant reduction in global carbon emissions Trees contribute significantly to the transport, electricity, and power sectors through biomass resources. Biomass is identified as the most cost-effective renewable energy source by the

Renewable Energy Department, without increasing carbon footprints. Furthermore, trees are projected to yield approximately 2 million tonnes of wood fuel annually, resulting in 1 $MtCO_2$ abatement per year. Moreover, existing wood stocks in the UK have the potential to annually reduce CO_2 emissions by 7.3 Mt, thereby decreasing reliance on fossil fuels, particularly petroleum products.

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