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Learning from Past Research for a Green Future: Harnessing Organic and Genetically Enhanced Trees to Reduce Construction-Induced CO_2 Emissions †

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Abstract: In today's world, GHG emissions, especially CO_2, drive rapid global warming. Construction significantly contributes to this by emitting CO_2. Plants have long been recognized for their role in mitigating climate change through CO_2 absorption, enhancing both climate control and environmental beauty. Thus, the aim of this paper is to assess plants' CO_2 absorption potential, focusing on recent articles from reputable journals in the past decade. First, we delve into the primary causes of global warming. Next, we explore the philosophy of CO_2 emissions in construction, from inception to completion. Finally, CO_2 emission control through plantation is examined, exploring the potential of organic and genetically modified plants for real-world applications.

Keywords: construction; global warming; carbon dioxide; plantation

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1. Introduction

Greenhouse gases, commonly known as GHGs, unquestionably serve as the primary catalysts for global warming, effectively synonymous with this pressing environmental concern. These GHGs encompass four key constituents: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. Among this quartet, CO_2 emerges as the most influential contributor, responsible for a substantial 70–75% of the global warming effect [1]. The remaining 25–30% is ascribed to the other trio of GHGs: methane, making a 16–20% contribution; nitrous oxide, contributing around 6–10%; and fluorinated gases, with a contribution of roughly 1–3% [2–4]. Consequently, it becomes patently clear that exerting control over CO_2 emissions assumes a pivotal role in the endeavor to mitigate global warming. CO_2 emission reduction offers the potential to significantly diminish the extent of global warming and its far-reaching repercussions for the planet.

The construction industry, with its vast reach, is a significant driver of global warming, emitting greenhouse gases, primarily CO_2, during both the construction phase (cradle-to-gate) and the entire building life cycle (gate-to-key) [5]. The construction industry plays a substantial role in exacerbating global temperatures and CO_2 emissions, from inception to demolition [6]. The objective of this paper is to analyze the industry's carbon footprint comprehensively, offering an in-depth assessment of its contributions to the climate crisis by scrutinizing emissions both upstream and downstream [7]. It underscores the urgent need for adopting sustainable practices to mitigate environmental consequences.

In the midst of the construction industry's persistent and significant contribution to global warming, marked by the continuous release of GHGs, notably CO_2, throughout both the cradle-to-gate and gate-to-key phases, an innovative approach warrants attention [8]. This review paper embarks on a transformative journey, shedding light on the remarkable potential of tree plantation as a dynamic strategy for climate control [9]. However, the intrigue does not stop there; it guides the pioneering realm of genetic modification, contemplating the feasibility of enhancing tree species with specialized genes to augment CO_2 absorption. As it ventures into the scientific frontier, it will delve into the potential and ethical considerations of genetically engineered trees as a catalyst for swift climate change mitigation [10]. Trees, both organic and genetically modified, excel at absorbing CO_2 emissions, offering adaptable solutions for combatting global warming [11–13]. This exploration has the potential to redefine the course of the battle against global warming.

Rapid urbanization presents significant climate concerns [5]. In response, tree planting emerges as a viable remedy. The global construction industry is a key contributor to global warming, primarily through greenhouse gas emissions, especially carbon dioxide (CO_2) [7]. Tree planting offers a comprehensive strategy to mitigate emissions from construction activities [10]. This review analyzes reputable journal articles from the past decade. It first assesses the causes of and contributors to global warming. Then, it explores the CO_2 emissions from construction industry via the 'cradle-to-key phase'. Finally, it discusses the essential aspects of tree planting, including organic and genetically modified varieties, emphasizing the adaptability and environmental benefits. After studying plantation strategies, it recommends tree combinations based on the existing literature.

2. Global Warming, Its Major Cause, and Contributor

Global warming is an escalating global crisis driven primarily by the accumulation of greenhouse gases (GHGs) in the Earth's atmosphere. Among these gases, carbon dioxide (CO_2) plays a pivotal role due to its abundant emission sources [1]. The construction industry, characterized by its intensive use of energy and materials, is a significant contributor to CO_2 emissions [7]. The energy-intensive processes involved in construction, such as cement production and the transportation of materials, release substantial amounts of CO_2. Moreover, the carbon footprint of buildings themselves, especially large-scale commercial and residential structures [4], substantially contributes to CO_2 emissions over the lifecycle of the buildings, including heating, cooling, and maintenance.

Deforestation worsens global warming by releasing stored carbon, disrupting the natural carbon cycle. Forests function as carbon sinks, capturing and storing CO_2. When trees are cut or burned, as in deforestation, stored carbon is released, intensifying GHG concentrations [9]. Deforestation results from land demand for agriculture, urbanization, and resource extraction and is closely linked to construction needs [8]. CO_2 emissions from deforestation and construction are compounded, underscoring the urgent need for sustainable construction and forest conservation to mitigate climate impacts.

3. CO_2 Emissions from the Construction Industry via the Cradle-to-Key Phase

The worldwide construction sector, largely fueled by carbon dioxide (CO_2) emissions, plays a pivotal role in aggravating global warming [7,8]. This comprehensive analysis delves into the intricate factors contributing to its impact on rising temperatures. CO_2 emissions emanate from various stages in the life cycle, spanning planning, material extraction ("cradle to gate"), and operational phases ("gate to key") [8]. These emissions intensify due to energy-intensive procedures and the transportation of materials, exacerbating the consequences of climate change [14,15]. Recognizing this intricacy underscores the immediate need to adopt sustainable practices, mitigating the sector's ecological footprint and addressing the imperative for a more environmentally conscious approach.

The construction industry faces significant carbon emission challenges, spanning material production, transportation, construction, operation, and disposal, highlighting a need for managing embodied carbon in buildings to mitigate global warming [16]. There is a lack of comprehensive, material-specific emission calculations, despite extensive research on building life cycle energy and emissions [17]. Assessing emissions during construction is critical [18]. Sustainable design and materials are pivotal for reducing embodied carbon and environmental impact, given the sector's substantial contribution to global warming, being responsible for about 27% of annual CO_2 emissions [19,20]. During the construction phase, steel, concrete, aluminum, and bricks are the prime contributors to CO_2 emissions (Figure 1). The concept of a building's carbon footprint quantifies CO_2 emissions throughout its life cycle [19]. Sustainable development balances environment and resource conservation.

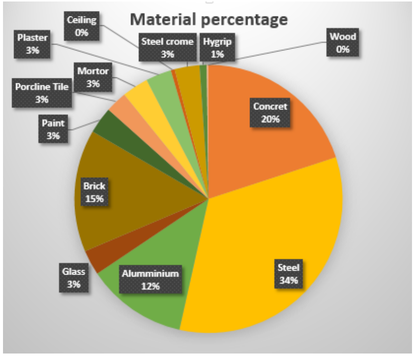

Figure 1. Major contributors of CO_2 emissions during construction [4].

The construction industry's "gate to key" phase is pivotal in combating greenhouse gas emissions, especially carbon dioxide (CO_2) [21]. This phase, from building occupancy to demolition, significantly contributes to climate change. Operational buildings, reliant on fossil fuels for heating, cooling, and lighting, extend their CO_2 emissions beyond construction [22,23], emphasizing the need to rethink design, materials, and energy-efficient technologies to mitigate the industry's lasting impact on global warming. Examining this phase highlights CO_2 emissions' resilience in constructed environments, as buildings are designed for long-term use [24]. Demolition and disposal add further emissions, reinforcing the industry's prolonged role in global warming [25]. Understanding and addressing CO_2 emissions in this phase are crucial for a sustainably built environment and a reduction in the industry's lasting climate impact.

4. Harnessing Trees to Reduce CO_2 Emissions from the Construction Industry

In-depth research underscores the construction industry's significant contribution to global warming, emphasizing innovative solutions like tree plantation [8]. Solutions like green construction and alternative materials are cost-effective for CO_2 reduction and may not always prioritize sustainability. Tree planting offers an affordable, aesthetically pleasing, and accessible climate solution. Trees, via photosynthesis, capture CO_2, aiding the fight against climate change while also regulating temperatures, improving air quality, and enhancing urban aesthetics [9]. Genetic modification has been explored to enhance CO_2 absorption in trees, potentially accelerating their climate impact [18]. This biotechnological approach raises ecological, genetic diversity, and ethical concerns, demanding careful consideration for harmonious coexistence with the environment [19]. Integrating genetic modification with tree planting offers a promising opportunity for climate control, necessitating further research and ethical guidelines.

Organic trees like Sukh Chain, Jamun, Kachnar, Drek, Mulberry, and Shisham are essential natural carbon sinks, aiding in carbon dioxide (CO_2) emission mitigation from buildings through photosynthesis [8]. Strategically planting these trees near structures can significantly reduce their carbon footprint (Table 1), with this group capable of absorbing 105 kg of CO_2 daily [26–32]. These trees continue to absorb CO_2 throughout a building's lifespan, enhancing air quality and fostering a harmonious ecosystem that counters the structure's environmental impact [32,33]. This enduring relationship highlights the importance of integrating nature into the built environment for climate change mitigation.

Table 1. Fastest growing plants.

Plants *	Sukh Chain	Jamun	Kachnar	Drek	Mulberry	Shisham
Scientific name	*Pongamia pinnata*	*Syzygium cumini*	*Bauhinia variegata*	*Melia azedarach*	*Morus* spp.	*Dalbergia sissoo*
Nutritional Requirements	Well-drained soil, organic mulching	Well-drained, fertile soil, organic matter	Well-drained soil, organic matter, phosphorus	Various soils, nitrogen, phosphorus	Well-drained soil, organic matter, nitrogen	Well-drained soil, nitrogen
Growth Rate	10 cm/day	10 cm/day	1–5 cm/day	10 cm/day	10 cm/day	10 cm/day
Water Requirements	Mature trees are drought-tolerant	Mature trees are drought-tolerant	Regular Watering	Regular watering	Requires moist soil	Regular watering
Temperature Tolerance	10 °C (50 °F) to 40 °C (104 °F)	15 °C (59 °F) to 40 °C (104 °F)	15 °C (59 °F) to 35 °C (95 °F)	10°C (50 °F) to 40°C (104 °F)	10 °C (50 °F) to 35 °C (95 °F)	15 °C (59 °F) to 40 °C (104 °F)
Height	10 to 25 m (33 to 82 feet)	15 to 30 m (49 to 98 feet)	6 to 12 m (20 to 39 feet)	6 to 12 m (20 to 39 feet)	5 to 15 m (16 to 49 feet)	15 to 25 m (49 to 82 feet)
Environmental Factors	Temperature, sunlight, water availability	Wet and dry season, sunlight	Wet and dry season, sunlight	Various conditions	Sunlight, soil conditions	Sun exposure
CO_2 Absorbance	5 to 15 kg/day	5 to 20 kg/day	5 to 15 kg/day	5 to 15 kg/day	5 to 20 kg/day	5 to 20 kg/day
References	[28]	[29]	[30]	[31]	[32]	[28]

* For Rawalpindi, Pakistan region only.

Genetically modified (GM) trees, engineered for improved CO_2 absorption, offer a dynamic approach to address building emissions [34]. Unlike natural species such as Sukh Chain, Jamun, Kachnar, Drek, Mulberry, and Shisham, GM trees show potential for rapid CO_2 sequestration [19]. Research confirms their CO_2-absorbing abilities, despite ongoing debates on feasibility and ethics [35]. Planting GM trees around a CO_2-emitting building during the cradle-to-gate phase significantly reduces the required tree count within five years. This innovation accelerates carbon absorption, aiding climate change mitigation. However, careful urban integration and ethical, ecological, and regulatory considerations are crucial [28,29]. GM trees hold promise in reshaping the fight against global warming, demonstrating the potential of science and biotechnology for a sustainable future. Both natural and GM trees offer adaptable solutions, each with unique strengths and considerations in absorbing CO_2 emissions from buildings to combat global warming.

5. Conclusions

This review examines tree planting's effectiveness in reducing construction CO_2 emissions using recent articles from reputable journals. Based on literature research the conclusions are as follows:

- GHG emissions, primarily CO_2 from the construction industry, significantly contribute to global warming and are tied to deforestation for urban development.
- The construction industry significantly contributes to global warming by emitting tons of CO_2 from the material used in construction. The percentage of CO_2 emissions of materials vary with respect to quantity. However, steel is the prime contributor, emitting the highest percentage of CO_2 into the environment.
- Integrating organic trees offers the potential to reduce CO_2 emissions from the construction industry. Sukh-chain and Jamun are temperature tolerant and the fastest growing trees native to certain areas and can play a huge role in CO_2 absorbance. The genetic modification of these trees with the CO_2 absorbing gene at high rate can increase their absorbance rate by up to 5%, but it requires ethical and ecological scrutiny, demanding additional research and ethical guidelines for effective climate change mitigation.

The above findings indicate a promising path to investigate the profound effects of CO_2 emissions from the construction industry. Increased awareness can facilitate the successful implementation of tree planting initiatives, spanning from small- to large-scale applications in practical contexts. However, genetically modified plants will require ethical concerns to be addressed and extensive research to be implemented at small-scale and large-scale levels.

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