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Research Article

Explore the Effect of Afforestation on Climate Change in The City -Case Study the Kingdom of Bahrain

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ABSTRACT

This research aims to explore the effect of afforestation on climate change in the city. It provides comprehensive overview of the Glasgow climate pact, a landmark outcome of COP26, marks significant progress in global climate action. Adopted in November 2021, the pact formulates a strong strategy to confront Earth's warming challenges. The pact also acknowledges the top importance of adaptation, sustainable land use, and transitioning to cleaner energy sources. Cities worldwide confront escalating climate challenges, from the increasing urban heat island effect to more frequent extreme weather events and rising sea levels. Also, underscore the critical need for adaptation and resilience strategies to protect urban areas from evolving climate dynamics. Bahrain, like many nations, contributes to climate change through fossil fuel reliance and industrial activities. Localized efforts are crucial for global climate initiatives and sustainable practices. In addition, this research explores Bahrain's commitment to achieve net-zero carbon emissions by 2060, emphasizing the significance of decarbonization, efficiency programs, and afforestation. Post-COP26, Bahrain's National Plan for Afforestation shows ambitious targets for expanding mangrove areas and tree coverage. Moreover, it discusses the afforestation strategy's potential impact on greenhouse gas mitigation, along with broader implications for soil quality and environmental changes. The path to resilient cities amid climate change necessitates embracing cutting-edge technologies, smart urban planning, circular economy principles, and international collaboration. Finaly, the research offers theoretical and policy suggestions for policymakers and decision-makers to draw upon their quest to achieve a green sustainable city in Bahrain.

Keywords: Glasgow climate pact, afforestation, climate change, Kingdome of Bahrain.

INTRODUCTION

Highlight Nations and politicians around the world have been trying to address the effects of climate change. International cooperation on this topic has been greatly aided by the United Nations climate change conferences, also referred to as the conference of the parties (COP). The 2021 COP26 conference in Glasgow was a turning point in the global struggle to address climate change. The Glasgow climate pact, a comprehensive framework that lays out practical solutions and sets aggressive targets to limit global warming, cut greenhouse gas emissions, and improve climate resilience. Countries are being pushed to take more aggressive measures to address the causes and impacts of climate change as the urgency of climate action increases. With an emphasis on the Glasgow climate pact, this research highlights the major accomplishments of COP26 and looks at how Bahrain, a small but important country in the Gulf, is supporting international climate efforts with its own bold plans and promises. Bahrain seeks to meet global climate goals while overcoming the obstacles presented by its own geographic and environmental conditions through programs like afforestation. This research will explore afforestation initiatives, their effects on Bahrain, and the part afforestation plays in the nation's plan to mitigate climate change.

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IMPACT OF CLIMATE CHANGE ON THE CITY

United Nations Climate Change Conference (COP 26):

Thirty years ago, world leaders convened to jointly confront climate change. Countries were invited by the United Nations to sign a climate convention pledging their commitment to cut greenhouse gas emissions. Ever since the signatory nations to the agreement have convened annually to deliberate on advancements and obstacles. Leaders from every nation gathered for the United Nations climate change conference, or COP26, to discuss ways to intensify international action in response to climate emergencies. Taking action to address climate change is imperative. The Glasgow climate pact, emerging from the 26th United Nations climate change conference of the parties (COP26), stands as a focal achievement in the global action to fight climate change [1]. Formally adopted in November 2021, this pact outlines a comprehensive strategy to handle the challenges proposed by a warming Earth. The following points offer briefing on each issue in promoting a sustainable and resilient future.

1. The commitment to restrict global warming to 1.5 degrees Celsius above pre-industrial levels is emphasized in the Glasgow climate pact [1].
2. The pact underscores the necessity for countries to enhance their Nationally Determined Contributions (NDCs), which represent individual nations' commitments to reducing greenhouse gas emissions [2].
3. A crucial element of the pact involves the commitment by developed nations to mobilize $100 billion annually in climate finance to aid developing countries in their climate mitigation and adaptation efforts [3]
4. The pact recognizes the significance of implementing measures for adaptation and resilience, particularly in vulnerable communities facing the impacts of climate change [4].
5. The pact includes pledges to combat deforestation and promote sustainable land use, such as the protection and restoration of forests [5].
6. The encouragement to expedite the reduction of unabated coal power highlights a commitment to transitioning toward cleaner and sustainable energy sources [6].
7. The acknowledgment of loss and damage associated with climate change impacts addresses situations where adaptation measures may prove insufficient [4].
8. The emphasis on technology transfer and capacity building aims to reduce the technological disparity between developed and developing nations [2].

As a result, of the COP26 pack, nations are being pressured to adopt increasingly aggressive policies to address the causes and effects of climate change.

Bahrain Share Causing the Climate Change:

The Cities face escalating climate challenges with the urban heat island effect intensifying, extreme weather events increasing in frequency, and rising sea levels threatening coastal areas [7],[8],[9]. Adaptation and resilience strategies are imperative to safeguard urban environments from these changing climate dynamics. Firstly, climate change contributes to the enhanced intensity of the urban heat island effect, resulting in elevated temperatures within cities compared to their surrounding rural areas [7]. This increase establishes challenges related to heat for urban populations and infrastructure. Secondly, climate change correlates with an increased occurrence and difficulty of extreme weather events, including heatwaves, storms, and floods. These events present substantial risks to urban infrastructure, human health, and overall city resilience [8]. Thirdly, elevated global temperatures contribute to the melting of ice caps leading to a rise in sea levels. Coastal cities are consequently at risk of heightened flooding, placing both infrastructure and communities in vulnerable situations [9]. Bahrain is one of the six Gulf Cooperation Council (GCC) countries, with a total area of 8,269 Km2 and a land area of 786.8 Km2 and a population of 1,577,059. The country is a high-income, oil-producing and developing country, and similar to other nations, it plays a contributing role in climate change through various mechanisms. The country heavily relies on fossil fuels, oil and gas, for its

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energy needs, leading to substantial greenhouse gas emissions, including carbon dioxide (CO_2). Industrial activities, such as oil refining and manufacturing, further contribute to air pollution and climate change, releasing greenhouse gases into the atmosphere. Additionally, Bahrain's rapid urbanization and extensive infrastructure development result in heightened energy consumption and emissions, with urban expansion, construction, and transportation demands collectively shaping the nation's carbon footprint. Although Bahrain's individual impact on global emissions may be comparatively modest, (around 0.1%) [10], but it is among the highest per capita CO_2 emissions in the world (19.9 metric tons of CO_2 per capita in comparison with the global average of 4.4 metric tons) [11]. Therefore, addressing these localized factors are essential for the country's commitment to global climate initiatives and sustainable practices.

Bahrain National Plan for Afforestation:

Global warming is a new challenge for human civilization because of industrialization, excessive fossil fuel consumption, and agricultural activities, the effects of climate change are widespread, yet they take different forms, unfortunately small and developing nations frequently find themselves at the forefront [12]. The Glasgow climate pact, emerging from the 26th United Nations climate change conference of the parties (COP26), had a primary goal to adopt more aggressive targets to cut greenhouse gas emissions by 2030 and talk about ways to prepare for the effects of climate change that will inevitably occur. Bolster financing for combating climate change, especially for developing countries. In 2021, during the COP26 His Royal Highness Prince Salman Al Khalifa the prime minister of Bahrain has announced that Bahrain is dedicated to achieving net zero carbon emissions by 2060 and has established several challenging short-term targets to guarantee that Bahrain moves forward without any delays. Through decarbonization and efficiency programs, in addition to doubling Bahrain's tree coverage, quadrupling the area covered by mangroves, leveraging renewable energy and investing in technology for carbon capture, Bahrain will cut emissions by thirty percent by 2035 [13]. The Bahrain committed to meeting the global climate targets with great ambition, pledging to achieve net zero emissions by 2060 and a 30% reduction in emissions by 2035, through leveraging renewable energy efficiency, investing in technology for carbon capture, and quadrupling the coverage of mangroves and doubling tree coverage. It has been highlighted that afforestation has been promoted recently as one of the primary ways to stop disastrous climate [12], it has a natural way to mitigate the effect of climate change [13].

The mitigation plan of afforestation in Bahrain includes that doubling the number of trees from 1.8 million to 3.6 million by 2035, in recognition of the important role trees play in reducing the effects of climate change [14]. As part of the national afforestation plan, Bahrain has limited the afforestation to twenty-one species of trees, these trees are suitable to arid environment and are characterized by the ability to withstand the environmental constraints and challenges of water security and salinity of soil, as well as the extreme hot climate. Furthermore, the main components of the afforestation national plan are fast-growing tree species to help in achieving the ambitious greenhouse gas (GHG) mitigation targets [15]. The trees species were divided into two groups of recommended trees species to be planted north of Bahrain and other species to be planted south of Bahrain which it is characterized with desert environment. As example of trees planted north are Moringa, Cassia Senna, Hibiscus, Neem, Bauhinia, and Jatropha. Whereas, on the southern part the proposed species are sider, Tamarisk, Arabian Acacia, Conocarpus, and Camphor.

Impact of Afforestation on Climate Change:

Under strict mitigation scenarios, afforestation has significant trade-offs with other policy domains when used as a climate change mitigation strategy. Afforestation is preferred over other more costly initiatives like electrification of industry, decarbonization of transportation, and widespread deployment of renewable energy sources due to its relative affordability [12]. Furthermore, afforestation is one of the most widespread methods for removing carbon dioxide from the atmosphere, however, it is limited by the availability of suitable land and enough water resources [16]. According to the Supreme Council of Environment in Bahrain mangrove plantation has high ecological benefits, such as enhancing biodiversity, protecting shorelines, enhancing diversity, and facilitating habitat complexity [17]. Whereas for the afforestation of trees the benefit includes the positive influence of soil quality, carbon (C) stocks,

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long-term sustainability, greenhouse gas (GHG; mainly CO2, CH4, and N2O) fluxes and environmental changes. It has been highlighted that this shift may take place in reaction to modifications in the political, social, economic, or environmental context. Many people agree that afforestation improves soil quality and makes it easier for heavily anthropic soil to return to its original function [18]. Additionally, afforestation aids in restoring the water cycle and combat the growing problems of desertification, soil erosion, and floods [16].

METHODOLOGY

The Ministry of Municipalities Affairs and Agriculture was challenged with the Bahrain national plan for afforestation, and a response to this strategic climate change initiative, in 2023 the Ministry of Municipalities Affairs and Agriculture collaborated with the United Nations Human Settlements Program (UN-Habitat) to develop the strategy for Bahrain national plan and the framework to build a greener and more sustainable Bahrain [19]. One of the main purposes of this collaboration is to develop landscape design guidelines that address mainly the ecological sustainability and resilience of landscape, strategies to provide relief from urban heat, focus on preservation, and enhancement of existing urban landscapes. The collaboration facilitated Bahrain to transit towards climate-resilient urban systems with the enhancement of the environmental qualities. The work was divided into two phases, context analysis phase which focused on the current situation in Bahrain in respect to afforestation and the main challenges, whereas phase two focused on developing the framework for afforestation strategy and the guidelines for landscaping including conservation and enhancement of existing urban landscape. The main stakeholders in developing the project were Municipalities Affairs, Urban Planning and Development Authority, Ministry of Works, National Space Science Agency, citizens, landscape contractors, and local nurseries.

Context Analysis Phase:

This phase consisted of the identification of the stakeholders and all the factors that are considered to have influence in the afforestation context. This was conducted through field visits to parks, roads, nurseries across Bahrain, interviews with stakeholders, international and local experts, and observations. The data collection during this phase resulted in identifying mainly the challenges facing the implementation of the national plan for afforestation, related to infrastructure, design, ecosystem management and resilience.

Strategy Framework Phase:

During this phase the data collected in the previous phase was used to develop the methodology for the Bahrain national afforestation plan including the recommendations to develop the strategy for Bahrain national plan for afforestation. In this phase landscape guidelines have been developed, which included the challenges facing the afforestation national plan, complete design guidelines for softscape and hardscape, in addition to maintenance and care guidelines as well as planting palette suitable for Bahrain's arid climate. Several workshops were held to share the proposals and the initiatives with the stakeholders such as government agencies, private sector, and environment sector. Ultimately the developed document should serve as a strategy and a roadmap for the realizing Bahrain national afforestation objectives.

CHLLENGES FOR DEVELOPING THE NATIONAL PLAN STRATEGY FOR AFFORESTATION

Since the announcement of Bahrain national plan for afforestation in 2022, and the initiation of the implementation plan number of challenges rose which affected the progress in the targets, the primary challenge is the luck of strategy for afforestation national plan, this is required to unify all efforts toward one unified objective which is sustainable and green city that priorities the wellbeing of people as well as the environment.

The National Targets for Afforestation (2022-2024):

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Since the announcement of the afforestation strategy in 2022, Ministry of Municipalities Affairs and Agriculture was the main actor to achieve the targets of the strategy afforestation and mangrove. The national plan for afforestation has two main objectives, first to increase the number of mangrove trees from 400,000 trees to 1.6 million trees by 2035, in other words to quadruple the present of mangrove, and to double the number of trees from 1,8 million to 3,6 million [20]. The set annual minimum target for the green cover is 150,000 tees, and the planted trees till end of 2024 are 431,434, "Fig. 1" shows the annual planted trees per year, whereas "Fig. 2" highlights the percentage of main species planted during the implementation of afforestation. As for 2022 the afforestation target was to plant 140,000 trees in Bahrain and 161,000 trees in 2023. Whereas in 2024 the target was 170,000 trees but 111,000 trees were planted.

In 2025 the afforestation target has been set to plant 180,000 trees by the Ministry of Municipalities Affairs and Agriculture, which is considered to be excessively ambitious due to the challenges facing the afforestation implementation plan, which is mainly the availability of irrigation water network.

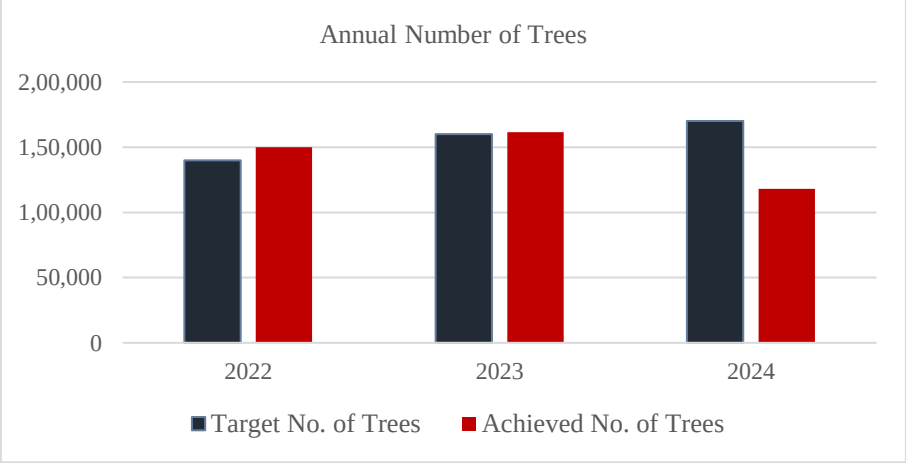

Figure 1. Number of trees planted (UN-Habitat, 2024)

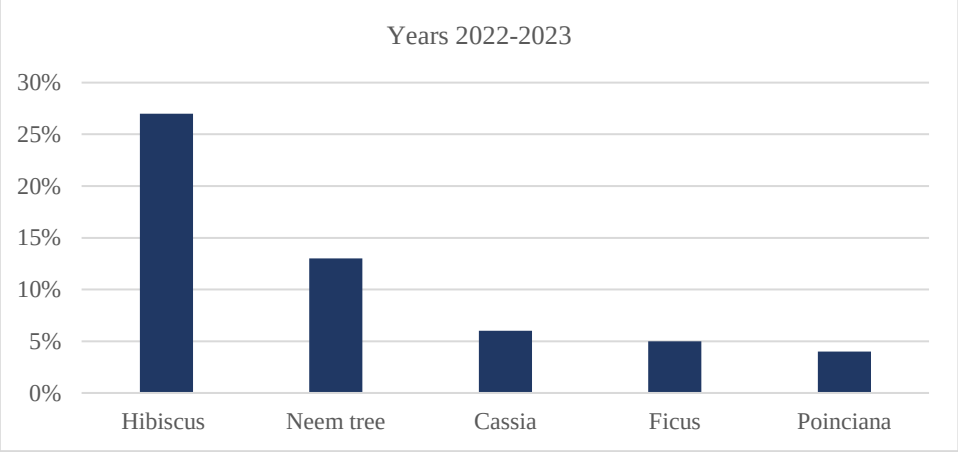

Figure 2. The percentage of main species planted (UN-Habitat, 2024)

Challenges of the National Plan for Afforestation:

The implementation of the national plan for afforestation is facing serious challenges that prevent achieving the targets set by the strategy, the main challenge is the scarcity of water which leads to Bahrain's dependency on sewage treated water for afforestation in public urban areas. Bahrain has number of sewage treatment plants that produces sufficient quantities of sewage treated water of approximately 212,070 meter3/day from Muharraq station, Salman

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Town station, and Tubli station [21]. Unfortunately, due to the limitation of sewage treated water network, the supplied sewage treated water does not satisfy the number of planted trees, in other words networks do not reach newly proposed afforestation areas, especially the southern area of Bahrain which is less urbanized and has the potential of accommodating large trees coverage. According to Ministry of Works sewage treated water reports, the total average water discharges from Muharraq sewage treatment plant and Madinat Salman sewage treatment plant to the sea is approximately 90,000 meter3/day [21], this quantity is enough to irrigate 1,8 million trees and this is due to the capacity limitation of the network, "Fig. 3" illustrates the quantities of sewage treated water discharged to the sea. Another challenge facing the afforestation strategy would be infrastructure and maintenance which includes the lack of automated irrigation systems, the poor soil condition primary sandy, and high need for proper maintenance [19].

Resilience against climate and the need to enhance the ecosystem services for afforestation in Bahrain is one of the main issues that needs to be addressed by introducing resilient and sustainable solutions to afforestation in Bahrain. Another critical challenge would be maintaining the aesthetic of the urban fabric, because of the huge acceleration in planting trees to meet the annual targets of the national afforestation plan, the result was the inconsistency in city landscapes and negative impact on esthetics of the city. Moreover, it caused irrigation problems, drainage issues, failed plantings, and inadequate infrastructure. Another challenge which needs to be addressed is the substantial funding required for achieving the afforestation plan which includes, funding the development of government nurseries, plantation and implementation landscape contracts, expanding the irrigation networks, automation and upgrading of irrigation networks, maintenance and caring budgets, upgrading the existing infrastructure, and introducing technologies for urban planning.

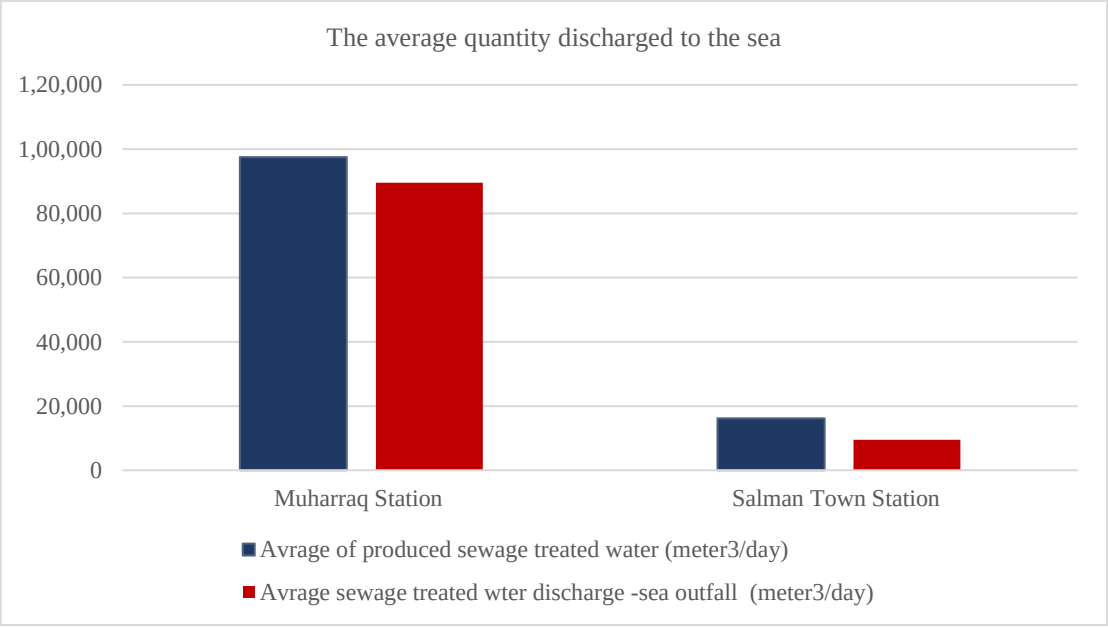

Figure 3. The average quantities of sewage treated water discharged to the sea (Ministry of Works, 2024).

DISCUSSION

In the context of climate change, several overarching themes of urban resilience have emerged. For example, expanding the use of renewable energy sources like solar and wind energy could help build cities that are more resilient to natural disasters and climate change [22]. As well as the reuse and recycling, solid waste separation to reduce the amount of waste dumped in landfills, and numerous other tactics have drawn a lot of attention lately. To endure the consequences of climate change, metropolitan areas need to be more adaptive, through nation's national development frameworks and policy initiatives. Bahrain has been following the similar themes by introducing the

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waste management strategy, expanding the use of renewable energy, primarily solar energy, and introducing afforestation national strategy.

The Bahrain national plan for afforestation with its objectives and targets needs to have a clear strategy framework to be achievable, and to progress in achieving the strategic objectives all relevant stakeholders need to be part in drawing the implementation roadmap for the afforestation national plan. It should be highlighted that the implemented afforestation during the years 2022-2024 shows the plantation in Bahrain is concentrated in urbanized zones in the north and center area of Bahrain, 70% of the planted trees has been planted in roads, institutions, and parks, this draws the attention to explore the option of afforestation in non-urbanized area on the south of Bahrain, but first the issue of water availability needs to be addressed by expanding the irrigation network of sewage treated water to the south of Bahrain. In order to Achieve the national afforestation plan Bahrain has to develop frameworks and policy initiatives towards green sustainable city, which should focus on:

- Accelerating afforestation with the development of national strategy for afforestation, including a master plan for the afforestation to accommodate the remaining 1,37 million trees, develop comprehensive and sustainable green infrastructure management strategy, enhance monitoring and impact assessments, and increase public engagement in greening initiatives [14],[20].
- Employing smart urban planning and technology, such as data analytics, the Internet of Things (IoT), and real-time monitoring, to optimize operations, boost energy efficiency, and improve disaster response [24],[25].
- Embracing cutting-edge technologies and smart solutions to enhance city operations [23]. As well as employing data analytics, sensors, and real-time monitoring systems to manage and respond effectively to climate-related challenges.
- Incorporating circular economy principles and sustainable practices in infrastructure development and resource utilization to minimize environmental impact [26],[27].
- Accelerating the integration of renewable energy sources like solar and wind into the urban energy mix, coupled with energy storage solutions, to enhance energy resilience [28],[29].
- Fostering international collaboration and knowledge exchange through city networks, partnerships, and platforms to share best practices, innovations, and lessons learned in climate resilience [30],[31].
- Enhancing the monitoring and impact assessment by evaluating the success afforestation projects and maintaining an up-to-date dashboard for monitoring the progress of the strategy. As well as developing an integrated urban afforestation monitoring and management system [20].
- Creating a sustainable funding model, focusing on public-private partnership for the long plan.
- Formulating nursery and sourcing strategies for trees and focusing on establishing partnership with suppliers [20].
- Diversifying range of trees species in order to enhance the biodiversity and resilience to heat, also focus on species that provide multiple benefits such as shade, and air purification.

CONCLUSION

The aim of this research was to explore the effect of afforestation on climate change in the city and identify Bahrain's commitment to achieve net-zero carbon emission through the Bahrain national afforestation plan. This research contributes to the fields of green sustainable cities, and the adaptation of afforestation as a mitigation measure facing climate change. In an effort to reach its national and international commitments, Bahrain worked hard to expedite climate change mitigation measures. Despite this, Bahrain's national plan afforest trees and mangroves is fraught with difficulties, long-term forestry initiatives are yielding encouraging outcomes for carbon stocks and other

biological and environmental processes. List of recommendations for policy makers of both sectors public and private were listed in the discussion. The main recommendations of this research would be to establish the strategy for Bahrain national plan for afforestation including the development of a framework for afforestation master plan to accommodate the objectives, enhance the monitoring impact assessment, and increase the greening initiatives engagement of public. Moreover, it is essential to employ urban planning technologies to optimize operations, boost energy efficiency, and improve disaster response.

One of the primary limitations of this research is the limited number of publications that examine climate change mitigation and low- or zero-carbon pathways in Bahrain, especially in the domain of afforestation mitigation plans. Despite a large amount of global literature, before implementing mitigation technologies, initiatives, and pathways, it is necessary to determine how effective they are at lowering CO2 emissions. Future studies can concentrate on examining the viability and sustainability of Bahrain's carbon neutrality initiatives from social, economic, and environmental viewpoints.

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