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Environmental Protection Through Sustainable Land Management

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Abstract

Sustainable land planning and successful land use change methods are essential as the world faces rising environmental challenges. This study examines the transformative potential of biomimicry and biophilia in addressing these challenges and the potential of bio-collaboration, bio-utilization, bio-inspiration, biophilic design, and biomimicry in creating a sustainable environment. The argument is that such integration can potentially create creative ways to lessen the effects of human activity on the environment by utilizing the knowledge of nature and combining biological system concepts. This study argues that by incorporating the above environmental factors into land planning practices, a holistic and sustainable approach can be achieved, fostering peaceful coexistence between human activities and the natural environment. This will also improve the resilience of urban and rural environments while offering practical solutions for a climate change-conscious world. As the main theoretical contribution, this study synthesizes a theoretical framework in the form of a conceptual structure for understanding, analyzing, and interpreting sustainability by adopting an ecosystem theoretical framework for achieving sustainable land management.

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Keywords

Biophilic design; Biomimicry; Sustainable Design Strategy; Bio-Collaboration; Biodiversity; Land use Management; Sustainable Land Management; Environmental Protection; Global Climate.

1. Introduction

In recent years, many studies have discussed environmental destruction to draw the attention of designers to key points in industrial design and urban structure design to use sustainable materials obtained from nature that are suitable for humans, animals, and biodiversity species. This study argues that such integration has the potential to integrate nature into the construction and use of sustainable and natural buildings.

In the current study, we argue that to solve the problem of climate change band an integration of biophilia and biomimicry designs is an appropriate design directive.

By proposing an integrated theoretical model as a design strategy, the present study explores causal relationships among various biophilic and biomimicry elements to demonstrate potential changes in land system change (LSC) and land use planning (LUP). The proposed theoretical model demonstrates how the elements in ecosystems, that is, LSC, sustainable land management (SLM), and biodiversity, can potentially be used in nature-inspired designs to achieve sustainability goals of land use.

By adopting a semi-systematic literature review relevant extant literature was reviewed to explore elements of the proposed synthesized theoretical model. The proposed model is expected to provide a theoretical foundation for future research in land management and related disciplines and inform environmental policymakers and practitioners of sustainability. The goal of the developed model is to better understand and appreciate the potential benefits of an integrated solution for overcoming some of the existing environmental sustainability challenges. In particular, the study focuses on the positive influence of biomimicry and biophilia design on nature and organisms, human and animal health, work productivity, and living conditions.

In biomimicry design natural materials and associated natural biological mechanisms are often sources of inspiration due to their unique properties and their ability to withstand impact and energy. The argument is that these natural biological mechanisms and structures should be used in a way to develop different technologies that do not harm nature and biodiversity and preserve the principles of earth and environmental sustainability (Katiyar et al., 2021).

The remaining parts of the paper are structured as follows: Section 1 provides an introductory background of the study. Section 2 is allocated to a discussion on the literature review and research design that highlights the major research process and a summary of findings synthesized from the reviews. In section 3 we introduced the proposed theoretical model of the study in two parts: part 1 is an ontological model demonstrating high-level assumptions and perspective adopted by the authors when developing the model, and part 2 is the model itself. The remaining parts of the paper are allocated to deeper discussions on various parts of the proposed model, as well as justifications for the inclusion of various concepts and relationships within the model.

2. Literature Review

The main argument of the current study is that to achieve a partial solution to the climate change problem and to achieve sustainable land system management, four interconnected approaches of biophilia, biomimicry, biotechnology, and science (Zhao et al., 2022) should be integrated with future designs. More specifically, the study attempts to develop a theoretical model that explains the interplay between biophilia and biomimicry that can positively affect land system change.

Knowledge production within the field of environmental planning and protection research is accelerating at a tremendous speed while at the same time, it remains fragmented and interdisciplinary. This makes it hard to keep up with state-of-the-art research. To partially overcome this challenge the Current study adopts a systematic literature review method as its overarching research method (Snyder, 2019), (Tranfield D, Denyer D & Smart P 2003).

This method is suitable for topics conceptualized differently by various groups of researchers within diverse disciplines, yet reviewing every relevant article is not simply achievable or appropriate. Based on this review method we reviewed how research within a selected field has progressed over time or how a topic has developed across research traditions for a better understanding of all potentially relevant research traditions that have implications for the studied topic and to synthesize the findings (Wong et al.,2013).

The interplay between biophilia (the innate human connection to nature) and biomimicry (design inspired by natural systems) can affect land system change positively, and this is done by promoting sustainable and regenerative practices. Biophilia design on the other hand can enhance our appreciation for natural landscapes and can encourage conservation and restoration efforts. Biomimicry enables designing land use systems that mimic nature's efficiency and resilience, and this in turn will lead to more sustainable and harmonious land management practices. Together, they promote ecological balance and sustainable land use, mitigating environmental degradation and supporting healthier ecosystems.

To develop the proposed theoretical model the current study adopts a semi-systematic review of the current literature as the main data collection method of the study. Selected data are then analyzed through a thematic analysis process (Smith & Stirling, 2021) and interpreted by the authors based on their expertise and experiences. The goal of the review is to synthesize the above theoretical model from the current literature.

At the initial phase of the review, many codes were initially provided, and more codes were explored. These codes were classified into a set of major and relevant themes of the study as shown in Table 1. The causal relationships among the themes are then identified and integrated to form the proposed theoretical model of the study.

The semi-systematic review of the literature enabled the integration of various concepts and relationships from five interrelated areas including Biodiversity, Genetic Diversity, Functional Diversity, Sustainable Land Management, and Bio-collaboration. As the last step of the research design, findings were analyzed and interpreted and the proposed model was constructed.

Table 1: Literature Mapping for the Proposed EPC Model

Concept	Definition	Benefits	Scope	Relationship with this study
Biophilic Design	1. *Biophilic design* focuses on human adaptations to the natural world that over evolutionary time have advanced people's health, fitness, and well-being; 2. *Biophilic design* encourages an emotional attachment to particular settings and places; 3. *Biophilic design* promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human and natural communities; and, 4. *Biophilic design* encourages mutual reinforcing, interconnected, and integrated architectural Solutions (Paul Downton et. al., 2017).	- various positive effects on microclimate, energy balance, also on social and physiological issues. - promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human Benyus, J.M. (1997) Sunder M, V., & Ganesh, L. S. (2021) (Radha, 2022).	1-Innovation 2-Connect to nature 3-Future design	Social change Sustainable materials SLM G.D. F.D.
Biomimicry	1. *Biophilic design* focuses on human adaptations to the natural world that over evolutionary time have advanced people's health, fitness, and well-being; 2. *Biophilic design* encourages an emotional attachment to particular settings and places; 3. *Biophilic design* promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human and natural communities; and, 4. *Biophilic design* encourages mutual reinforcing, interconnected, and integrated architectural Solutions (Paul Downton et. al., 2017).	- Nature is one main source of inspiration. - Innovation inspired by nature. - Biomimicry is a new tool that can provide the panacea for all (sustainable) design challenges. Benyus, J.M. (1997) (Pathak, 2019).	- Well-being - Innovation - Connect to nature and Biophilia	Social change Sustainable materials SLM F.D. G.D.

Land system	Land systems represent the terrestrial component of the Earth system and encompass all processes and activities related to the human use of land, including socioeconomic, technological, and organizational investments and arrangements, as well as the benefits gained from land and the unintended social and ecological system that addresses theory, concepts, models, and applications relevant to environmental and societal problems (Rounsevell et al., 2012) and www.ncbi.nlm.nih.gov)	1-Central to understanding relationships among people and their environment 2- Helps understand the dynamics of land cover and land use in the human-environment relationship. 3-Land registration has led to better access to formal credit, higher investments in land, and higher output and income (Deininger & Feder, 2009). Buchanan, M., Miguez, F., & Herzog, H. (2021)	-Biodiversity -Connect to nature - Biophilia -Biomimicry -SLM -Social change - Social Diversity	-Environment change - SLM - Social change -resilience and adaptation -Bio collaboration
G.D (Genetic Diversity)	It is the biological variation that occurs within species. It makes it possible for species to adapt when the environment changes. (Carvalho et al., 2019).	contributes to the achievement of individual sustainable development goals (Goleman et al., 2019).	-land system change - Connect to nature - Biophilia -Biomimicry	- Resilience and adaptation - SLM -Connect to nature - Biodiversity -Bio collaboration
F.D (Functional Diversity)	- As a component of biodiversity, it covers the range of functional traits of microorganisms prevailing in an ecosystem. -Is of high ecological importance; influences several aspects of ecosystem functioning e.g., ecosystem dynamics, stability, nutrient availability, etc. (Goswami et al., 2017)	-Incorporated into conservation and restoration decision-making, especially for those efforts attempting to reconstruct or preserve healthy, functioning, ecosystems (Cadotte, Barscadden & Mirotchnick, 2011).	-Land system change -Connect to nature - Biophilia -Biomimicry	- Resilience and adaptation - SLM -connect to nature - Biodiversity -Bio collaboration
B.D (Biodiversity)	- Refers to the variety of life on Earth at all its levels, from genes to ecosystems, and can encompass the evolutionary, ecological, and cultural processes that sustain life (Magurran et al., 2018).	- Well-being - Provides food, fiber, and medicine, furnishing ecosystem services e.g., water and air purification nutrient cycling, and carbon uptake	- Connect to nature - Biophilia - Biomimicry - Well-being - SLM	- Environment change - Connect to nature - F. D. - G.D.

		- Contributing to technological innovations from biotechnology to robotics to material science (Wong & Kay, 2019); (Kumar et al., 2022).		- Resilience & Adaptation - SLM - Biophilia - Biomimicry -Bio collaboration - Biomaterials - Biotechnology
SLM (Sustainable Land Management)	- Offers solutions beyond technology, including aspects of social participation and policy dialogue. - Land degradation is a central challenge to sustainable development (Chayaamor-Heil & Vitalis, 2021)	- Increase food production without degrading soil and water resources. -Improves agronomic practices e.g., organic fertilization, minimum soil disturbance, and incorporation of residues, terraces, water harvesting and conservation, and agroforestry (Branca et al., 2013).	- Biophilia - Biomimicry - Biodiversity - Connect to nature - Innovation - Bio collaboration	-F. D. -G.D. - Resilience & Adaptation - Biodiversity -Biophilia -Biomimicry -Bio collaboration - Bio-materials - Biotechnology

3. Proposed Environmental Protection Model (EPM)

This research proposes a theoretical model of a collaborative biological process inspired by the structure, function, process, and mechanism of living organisms in nature, that is compatible with the environment and the goal of enhancing sustainability. The research perspective that guided the proposed theoretical model is the *ecosystem thinking perspective* that addresses the scale and diversity of complicated environmental challenges (Likens & Franklin, 2009) and is shown in Figure 1. The adopted perspective explains the underlying ontological assumption of the researchers that asserts that the design and performance of any environmental ecosystem is only understood and improved by collaboration among various elements of the ecosystem.

The above research perspective along with the results from a review of relevant literature guided the current study towards the development of the proposed theoretical model. The latter consists of a set of concepts and relationships (both causal and associative) among the concepts mentioned earlier and is shown in Figure 2. In this model, biomimicry is regarded as a sustainability environmental design and this in turn is based on the generally accepted argument that sustainable targets can be achieved by applying a biomimetic classification system from a biological and ecological point of view (e.g., Blok, 2023).

The underlying ontological assumption of the study is shown in Figure 1 and the proposed EPM is shown in Figure 2. Figure 1 explicates the assumptions held by the authors for the development of the proposed EPM.

These assumptions are related to the land system change and current critical environmental challenges. This Figure shows the foundational assumptions that envision a holistic approach where human activities coexist harmoniously with the environment based on symbiotic principles.

Figure 1 emphasizes a long-term perspective, adaptability to change, and a synergy between scientific advancements and ecological principles. In Figure 1 components of the proposed EPM are shown at a lower level of detail. These components include land system changes, metamorphosis, biodiversity, nature, genetic diversity, global climate, and biotechnology. It highlights a proactive land management strategy that minimizes negative impacts on ecosystems caused by human activities. It also recognizes the interconnectedness of ecosystems and aims to preserve and restore natural habitats, ensuring the survival of diverse species and their genetic variability.

In Figure 1, *metamorphosis* represents the transformation of landscapes over time. The EPM implies that these landscape changes must be based on adaptive planning while safeguarding ecosystem functions. Biodiversity conservation is a key pillar of the proposed model for the protection of ecosystems through the establishment of nature reserves, corridors, and sustainable resource management. Genetic diversity is acknowledged as fundamental to ecosystem resilience and is promoted through habitat preservation and restoration. The model also addresses the role of global climate systems and supports strategies to mitigate climate change impacts. This involves carbon sequestration, reforestation, and sustainable energy practices. Biotechnology is integrated into the model as a tool for sustainable development. It emphasizes responsible biotech applications that enhance crop yields, disease resistance, and ecosystem health without compromising natural systems.

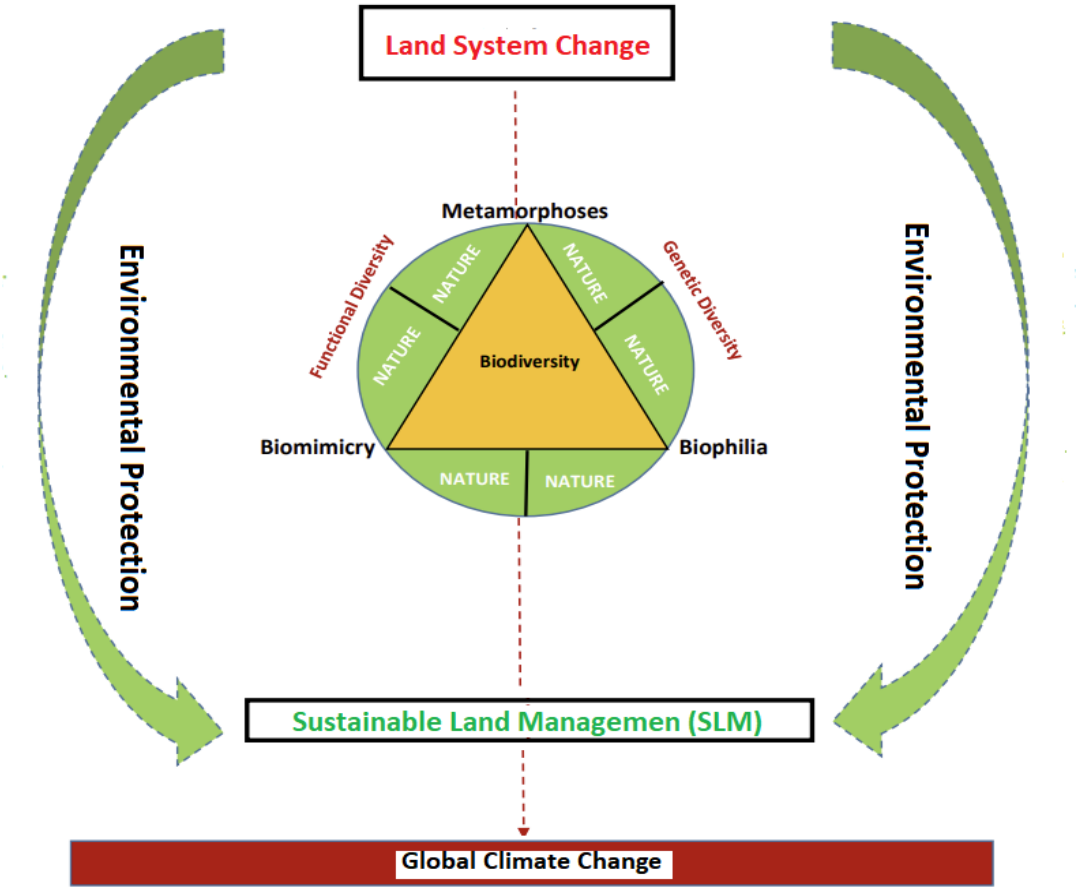

Figure 1: Ecosystem thinking perspective showing underlying ontological Assumptions of proposed EPM

Figure 2 represents the theoretical foundation of the EPM and is inspired by the ontological assumptions mentioned in Figure 1. EPM demonstrates details of causal relationships among various elements of Figure 1. It follows the *interactionist research paradigm* (Zhao, Chen & Zhang, 2022) by showing relationships between man and nature (biophilia) and innovation inspired by nature (biomimicry) working together to achieve the goal of global environmental protection and sustainability. More specifically, EPM demonstrates the impact of climate change on biodiversity by highlighting factors that cause such impact. Indiscriminate human use of land is the main driver of the loss of biodiversity which may occur in the form of food production processes where land is converted for agriculture and some animals and plant species may lose their habitat and face extinction, building dams regardless of their potential damage to ecosystems and environmental protection and other factors.

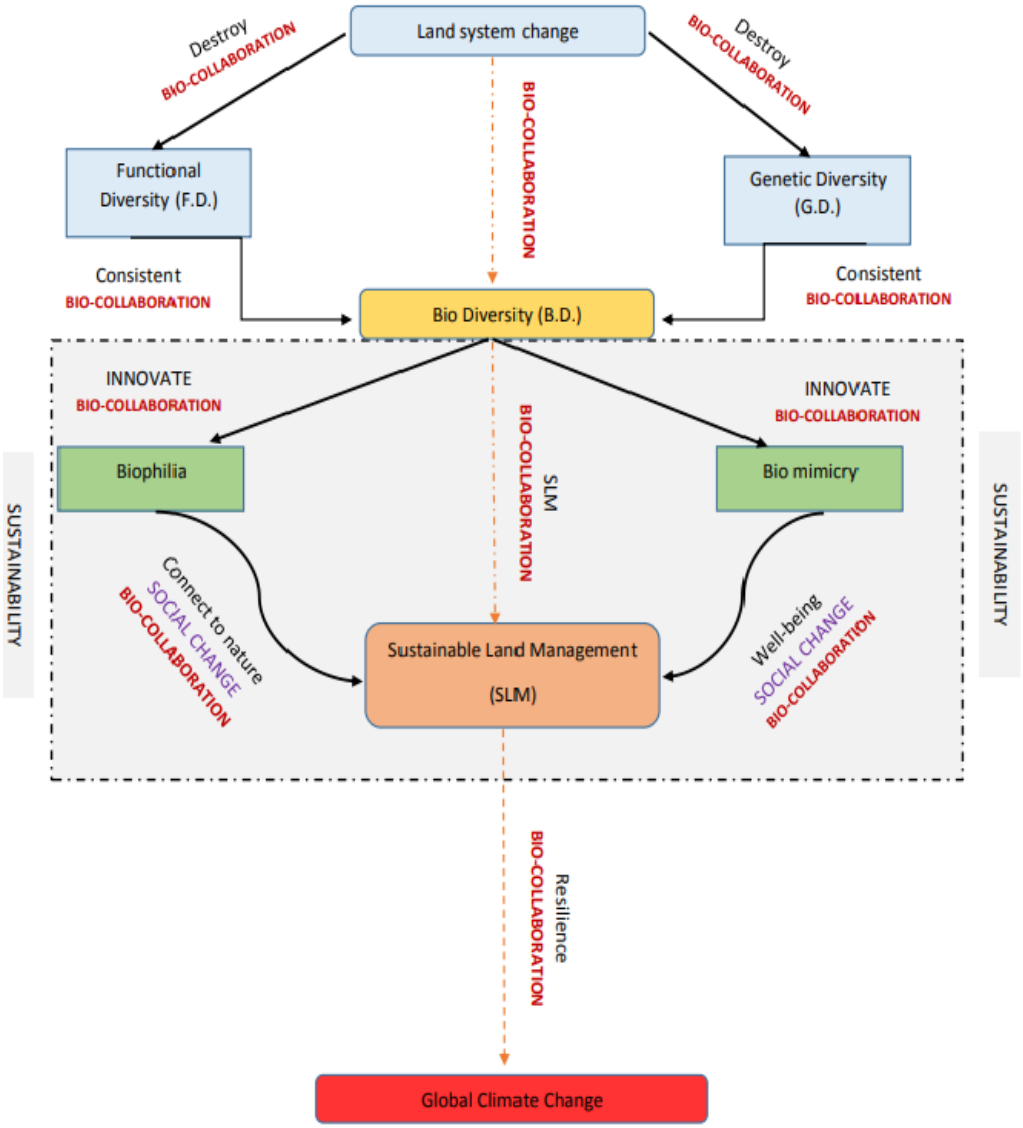

Figure 2: Proposed Environmental Protection Model (EPM)

In the following sections, various elements of the proposed EPM of Figure 2 are explained along with evidence-based justifications for their inclusion in the EPM.

4. Synergy of Biophilia, Biomimicry and Land System Management

The middle part of Figure 2 demonstrates the above relationship that constitutes the core argument behind the EPM. Land system management is the practice of managing land in a way that sustains its ecological functions and benefits people. This can involve various practices, such as conservation, restoration, and sustainable agriculture. Land system management can help to protect natural resources, reduce pollution, and mitigate climate change Louis Vitalis & Natasha Chayaamor-Heil (2021). The three elements of biophilia, biomimicry, and land system management have gained significant attention in recent years for their transformative impact on the interactions between humans and the environment in managing land systems (World Economic Forum 2022; Watchman, Demers & Potvin, 2021).

Biological designs are natural systems and structures that have evolved over millions of years to be incredibly efficient and effective. Studying these designs will teach us how to create designs that are more sustainable and resilient (Science Daily, 2020). The current study argues that the above three approaches together can help create a more sustainable future. For example, we can use biological designs to develop new materials that are stronger, lighter, and more durable than traditional materials. We can use biophilic design to create buildings and cities that are more liveable and healthier for people. And we can use biomimicry to develop new technologies that can help us reduce human adverse impacts on the environment.

Recent studies (e.g., Buchanan et al., 2021; Dickinson et al., 2016) demonstrate that biophilia, biomimicry, and land system management, each coming from a different discipline, foster collaboration among ecologists, architects, urban planners, and agriculturists. The current study extends the above argument by claiming that one major strength of the current study is its inter-disciplinary nature that represents an inter-subjective community of researchers where researchers in the three fields leave their fundamental differences aside to solve the problem of sustainability; this in turn encourages adoption of pragmatic approaches to research, mixed-method research, and adoption of abductive reasoning in future studies, all in the direction of problem-solving rather than focussing on the differences among the above three designs.

The integration of biophilia and biomimicry into land system management offers innovative strategies for sustainable agriculture, urban planning, and ecosystem restoration (Berg, 2020; Dickinson et al., 2016). Researchers have explored how biophilic urban design can lead to more resilient and liveable cities (Ness & Hurlbert, 2015). Similarly, biomimicry can inform land management practices such as using natural ecosystems as models for regenerative agriculture. Despite the growing body of literature supporting biophilia and biomimicry, their integration into land system management remains limited (Berg, 2020); and the current study attempts to partially fill this gap. The synergy of biophilia, biomimicry, and band system management are further explained in the following subsections.

4.1. Bio-Collaboration as Enabler of Integration and Sustainability:

Throughout the EPM model in Figure 2, bio-collaboration is the enabling factor for enabling various activities expected from the EPM to be realized. The central argument here is that while industrial biotechnology has the potential to promote sustainable development, it still operates within industrial and traditional paradigms, suppressing economic growth and patterns of societal interest. Biomimicry introduces elements and materials from nature that are not based on what we can extract from them and their ecosystem, but their use is based on their biological and genetic relationships. In biophilic and biomimetic designs, biological collaboration with microorganisms and plants in nature is necessary at all levels to reintegrate biological systems with nature to achieve a sustainable performance for new technologies (Hoyos, 2010). The current study recommends the use of natural materials instead of non-degradable biochemical materials, and this can be achieved by using biomimicry in designs and activities to replace degradable materials. Grazuleviciut-Vileniske, Daugelaite & Viliunas (2022) suggest the use of innovative biophilic and biomimicry technologies to maintain favorable conditions for human well-being and health.

4.2. Sustainable Land Management System:

Sustainability extends beyond the actual structural components of buildings and the natural world. It entails comprehending and fostering the complex interactions among ecosystems, processes, and behaviors (KC & Gautam, 2021). Sustainable practices must support biodiversity, protect natural resources, and lessen climate change by realizing the interconnection of all elements. In the current study, achieving sustainability is the primary goal integrating aspects of biomimicry and biophilic designs. The four main facets of sustainability include environmental, political, social, and economic facets. The current study regards these principles as the criteria for evaluating the proposed EPM for achieving sustainability.

Environment is the cornerstone of sustainability and consists of natural resources, ecosystems, and the delicate balance of life on our planet. Humans can establish a peaceful coexistence with the environment by engaging with nature and built environments. Buildings' ecological footprints are reduced while becoming more ecologically integrated using green architecture and sustainable design techniques including green areas, natural lighting, and renewable energy sources (Jabareen, 2018).

The political facets of sustainability include governance frameworks, guidelines, and laws that guarantee ethical decision-making and equitable resource allocation. Ecologically responsible policies can encourage sustainable development by incorporating sustainability principles and the integration of biomimicry and biophilia designs into political structures. Examples include encouraging the use of renewable energy sources, promoting eco-friendly building techniques, and enforcing environmental laws to protect natural areas (Dehghani & Panahi, 2019).

In terms of social facets of sustainability, the latter cannot be attained without taking social considerations into account. The current study argues that the integration of biomimicry and biophilia designs will improve the general

quality of life through socially sustainable architecture that creates buildings that offer a secure, healthy, and inclusive environment (Smith & Stirling, 2021). Community gardens, public parks, and easily accessible infrastructure are characteristics that can be incorporated to enhance social contact, build a sense of belonging, and advance physical and mental health.

The economic factor of sustainability acknowledges the need for long-term economic development, which also seeks to minimize adverse effects on the environment and society. The efficient use of integrated biomimicry and biophilia into design and resources will create new green jobs and stimulate local economies by incorporating sustainability into the economic system. Green building techniques, for instance, boost property value while simultaneously consuming less energy, which positively impacts the economy (Sharifi & Yamagata, 2016).

4.3. Land System Change and Global Climate Change:

Biomimetic methods can increase productivity while reducing harmful environmental effects. Designing agroforestry systems after the structure of forests is a good example of increasing soil fertility, preserving water, and boosting biodiversity (Piquer-Rodríguez et al., SSRN 4063496). An example would be termite mounds' self-cooling systems that were used by builders to create energy-efficient structures that do not require as much air conditioning (Mazza, 2018). Or, the creation of more streamlined wind turbines by investigating the aerodynamics of bird wings to maximize energy production (Yuan et al., 2017). Biomimetic methods can also restore the ecosystem. For instance, restoring water filtration and flood control capabilities in harmed ecosystems can be facilitated by imitating the hydrological patterns of wetlands (Mitsch & Gosselink, 2015).

Biophilia design on the other hand is also a major factor for enhancing environmental conservation by encouraging greater respect and comprehension of the natural world. According to Saatchi, Oh & Oh (2023) biophilic experiences such as outdoor immersion learning and nature-based education, strengthen people's emotional connections to the environment. This emotional connection in turn can encourage people to support campaigns to safeguard ecosystems and biodiversity and promote conservation efforts. Another related positive impact is on human health and well-being. Being in nature has been connected to several health advantages such as lower stress levels, enhanced mental health, and increased physical activity (Frumkin, 2001). As a result, healthier and more sustainable communities can be built by prioritizing biophilic design in urban planning such as including green areas and natural features (Frumkin, 2001).

4.4. Biodiversity

Climate change and industrial and human waste play an important role in reducing biodiversity. These pollutions affect the climate of marine ecosystems, in the lack of freshwater around the world. This causes the loss of species, the increase of unknown diseases, the mass death of plants and animals, and as a result, the first extinctions caused by climate. Climate change has not only harmed biodiversity, plants, animals, water, and soil, but in the oceans, the increase in temperature also threatens the irreversible destruction of marine ecosystems.

Functional Diversity: The importance of functional diversity and ecosystem functioning has been emphasized by many researchers. This functional type is a part of biodiversity that covers a range of functions of microorganisms in an ecosystem. Functional diversity is defined as a measure of the functional traits of an organism that influences one or more aspects of ecosystem functions (Goswami et al, 2017). This functional diversity is of high ecological importance, which can affect several aspects of ecosystem functioning for a sustainable ecosystem. Furthermore, functional diversity plays an important role in the productivity of biomimicry. Functional diversity has a major effect on the productivity of ecosystem sustainability sustainable land system management and global climate change; and this effect could influence ecosystem dynamics, stability, productivity, nutrient balance, and other aspects of ecosystem functioning.

5. Conclusion

Sustainable land planning and successful land use change methods are essential as the world faces rising environmental challenges. This study provides a theoretical foundation for integrating various environmental design elements for environmental sustainability. More specifically, the study highlighted the transformative potential of

biomimicry and biophilia in addressing the above sustainability challenges and the potential of bio-collaboration, bio-utilization, bio-inspiration, biophilic design, and biomimicry in creating a sustainable environment. As the main theoretical contribution of this study, a semi-systematic critical review of the literature was conducted that resulted in the development of an integrated model called EPM (Environmental Protection Model) supplemented by the associated ontological model that portrays world views adopted by the authors for the development of the EPM.

The EPM incorporated various design methods into land planning practices to achieve a holistic and sustainable approach for fostering peaceful coexistence between human activities and the natural environment and improving the resilience of urban and rural environments while offering practical solutions for a climate change-conscious world. Various components of the EPM that is, that is, concepts and relationships, were analyzed and their inclusion in the model was justified.

For future studies, the authors plan to: (i) EPM through the collection and analysis of various empirical evidence and relevant studies to enhance the rigor of the proposed theoretical framework, and (ii) apply the model in various real-life scenarios.

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Ethics approval

Not applicable.

Conflict of interest

The authors declare that there is no competing interest.

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