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Editorial

Modeling Forest Response to Climate Change

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In an era marked by unprecedented climate shifts, understanding the intricate responses of forest ecosystems to these changes is of paramount importance. The research presented in this Special Issue delves deeply into various dimensions of forest dynamics under the influence of climate change, offering critical insights that can guide effective conservation and management strategies.

Vegetation seasonality, a crucial component of ecological systems, is under significant stress due to global warming. Nooni et al.'s study [1] highlights how Normalized Difference Vegetation Index (NDVI) trends in Equatorial Africa (EQA) have been influenced by changes in precipitation and temperature over the past four decades. The research reveals that while forest and cropland areas have experienced declining NDVI trends, shrubland and grassland areas have tended to increase, suggesting that there is a complex interplay between climate factors and vegetation types. This nuanced understanding is essential for ecological conservation and resource management in the face of ongoing climate change.

Similarly, the capacity of forests to act as carbon sinks is under threat. In their study, Morichetti et al. [2] examine carbon fluxes within forest ecosystems using the 3D-CMCC-FEM model. Their analysis of five contrasting European forest sites under current and future climate scenarios demonstrates the model's robust ability to estimate net ecosystem exchange (NEE). The study predicts a consistent reduction in the carbon sink capabilities of forests due to climate change and forest aging. Despite an increase in the number of days that evergreen forests act as carbon sinks, their overall annual capacity is projected to decrease. Similarly, deciduous forests maintain stable carbon sink days but also show a reduction in their annual capacity. This highlights the need for the implantation of adaptive forest management practices that mitigate the anticipated decline in carbon sequestration.

The same model was employed by Vangi et al. [3] by simulating carbon stocks and wood production across different forest ages and climate scenarios. Their findings indicate a pronounced decline in biomass for older coniferous stands, such as spruce, under warming conditions; meanwhile, beech forests may sustain or even enhance their carbon storage capacity. Scots pine forests display intermediate behavior, with a stable stock capacity but decreasing annual increment. These insights highlight the variable resilience of different forest types to climate change, necessitating tailored management approaches and, most importantly, underscoring the differential impacts of climate change on coniferous and broadleaf forests; in addition, they highlight the necessity of species-specific management practices.

An important component of the carbon cycle and its dynamics is soil respiration; therefore, its influence on the carbon cycle was explored by Kivalov et al. [4]. The authors developed empirical models to better understand soil respiration in different forest ecosystems. Their research highlights the importance of soil's organic carbon and water-holding capacity in predicting soil respiration, providing a foundation for the enhanced

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modeling of the carbon cycle in terrestrial ecosystems. Moving to a management-oriented perspective, several studies investigated how management practices, namely restoration, plantation and thinning techniques, can alleviate forest ecosystems from the future pressure of environmental stressors.

The restoration and conservation of native forests also emerge as critical themes in Yong et al.'s study [5]. The authors employ a joint species distribution model to analyze the distribution of tree species in China's Jilin Province. The study identifies climate, site, and soil as the key environmental factors influencing tree species niches, with the model demonstrating strong explanatory power. Their work emphasizes the importance of environmental factors—climate, site, and soil—in shaping tree species niches, thus providing a robust framework for forest restoration and proactive forest management.

The impact of climate change on economically significant timber trees is a crucial aspect of timber-based bioeconomies. In their work, Feng et al. [6] focus on *Cunninghamia lanceolata* by using the MaxEnt model to project its distribution under future climate scenarios. Their research identifies the key environmental variables affecting its growth and suggests that suitable habitats will shift to higher latitudes as the climate warms. This predictive modeling is crucial for the planning of future planting strategies and conservation efforts to ensure the survival of this valuable species.

Innovative methodologies also play a pivotal role in forest management. In their study, Liu et al. [7] integrate remote sensing, deep learning, and statistical modeling to monitor forest changes and carbon storage dynamics in China. Their approach demonstrates high accuracy in mapping forest types and quantifying carbon storage, offering a valuable tool in local forest management and the achievement of carbon neutrality.

On the same level, predictive models of species distribution under various climate scenarios offer critical insights into conservation planning. For instance, rare and endangered species such as *Magnolia wufengensis* 'Jiaolian' are projected to experience significant habitat shifts due to climate change, as reported by Shi et al. [8]. According to their study, the suitable habitats for such species will move to higher elevations and latitudes, highlighting the need for dynamic conservation strategies that can adapt to these changes. Understanding these shifts is crucial for the protection and sustainable management of biodiversity.

Thinning practices, which are an essential technique in sylviculture and the optimization of its management, were examined by Qin et al. [9] through a hybrid modeling approach; this combined the 3-PG process model and a long short-term memory neural network. Their study offers practical guidelines for thinning practices that enhance forest growth and carbon sequestration, demonstrating the significance of adaptive management in response to climate and anthropogenic pressures.

The conservation of endemic ornamental species was explored by Shi et al. [10] who reported that, under more severe scenarios of climate change, the populations of *Helleborus tibetanus* Franchet, are at high risk of destruction. These insights are critical for the conservation and sustainable utilization of this species in China.

Similarly, Korznikov et al. [11] employed Random Forest models to explore changes in the distribution of Jezo spruce (*Picea jezoensis* (Siebold and Zucc.) Carrière) in Northeast Asia under climate change scenarios. For this species, however, the key refugia are predicted to remain suitable; hence, the establishment of artificial stands in these future climate-acceptable regions may be vital for preserving genetic diversity.

The potential ability of forest plantations to mitigate climate change was also explored by Altamirano-Fernandez et al. [12], who developed a mathematical model to optimize carbon capture in forest plantations. Their work underscores the importance of strategic planning in reforestation, thinning, and fire prevention to maximize carbon sequestration and combat global warming.

Climate change impacts the productivity of sites differently across tree species and regions. For example, in Ontario, Canada, the effects of climate on site productivity vary among jack pine, black spruce, red pine, and white spruce plantations [13]. Sharma reports that while jack pine shows positive climate effects in western Ontario, black spruce, red pine, and white spruce exhibit negative impacts, especially under high-emission scenarios. These findings highlight the need for localized management strategies that account for species-specific and regional climate responses in order to sustain forest productivity.

In conclusion, the collective research presented in this Special Issue underscores the multifaceted responses of forest ecosystems to climate change by means of both statistical and process-based models. Through modeling techniques and comprehensive analyses, these studies provide critical insights and practical solutions regarding the management and conservation of forests in a warming world. The knowledge gained from these investigations is vital for informing policy and guiding actions that will help sustain forest ecosystems and their invaluable services for future generations.

Conflicts of Interest: The authors declare no conflicts of interest.

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