Chapter 8
Spatial Trend Analysis of Vegetation Dynamics and Their Responses to Climate Change on Black Sea Coasts, Romania From 2000 to 2021

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ABSTRACT

Based on the normalized difference vegetation index (NDVI) time series of moderate-resolution imaging spectroradiometer products, meteorological observations, and spatial trend analysis, the authors analyze how climate change and vegetation cover have changed in the Black Sea coasts over the past 22 years. Moreover, spatial correlation analysis was used to examine the correlation between climatic factors and NDVI as a proxy of vegetation productivity. With growth rates of 0.003, 0.5°C, and 5.5 mm per year, respectively, the inter-annual variation of NDVI, temperature, and precipitation revealed a noticeably growing trend. At the seasonal time scale, a similar trend was observed, which was statistically significant in some cases. The spatial-temporal trend of NDVI showed a greening trend in the inter-annual and seasonal time scales (except autumn). The greening trend in vegetation refers to the increase in vegetation productivity and density over time. The authors conclude that the most effective factor in the vegetation greening process is an increasing trend in temperature and precipitation.

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INTRODUCTION

Climate change refers to the long-term changes in the Earth's climate patterns, and temperatures (Thuiller 2007; Loarie et al. 2009), primarily caused by human activities (Jiang et al. 2017; Huang et al. 2020; Gao et al. 2022) that increase the concentration of greenhouse gases in the atmosphere, leading to the enhanced greenhouse effect and warming of the planet (Zheng et al. 2019; Eskander and Fankhauser 2020). Climate change effects are already being noticed worldwide, including rising sea levels (Mukul et al. 2019), melting glaciers (Nabi et al. 2018), more frequent and severe heatwaves (Lhotka et al. 2018), droughts (Holden et al. 2022), floods (Liu et al. 2023), and storms (Leal et al. 2022). These impacts are projected to worsen in the future and have significant economic, social, and environmental consequences (Hoffmann et al. 2022; Abbas et al. 2023).

Vegetation plays a critical role in providing ecosystem services such as carbon sequestration, water regulation, and habitat for wildlife (Heilmayr et al. 2020; Di Sacco et al. 2021). One of the largest climate shifts is anticipated to have a big influence on vegetation and the ecosystems that depend on it (Afuye et al. 2021; Cui et al. 2022). Previous research discovered that climate change was having a significant impact on vegetation, such as reducing plant growth and productivity (Pouyan et al. 2022; Wang et al. 2023), changing plant phenology (Praveen and Sharma 2019; Chaudhry and Sidhu 2022), shifting species diversity and distribution (Richardson et al. 2013; Piao et al. 2019), increasing the risk of wildfire (Williams et al. 2019; Nasiri et al. 2022), increasing pest and disease pressure (Jiranek et al. 2023), changing carbon storage capacity (Gatti et al. 2021), and so on. Also, vegetation serves as an important indicator of climate change, because changes in the vegetation phenology, structure, diversity, distribution and productivity can all signal shifts in climate patterns (Morecroft and Keith 2009; Shen et al. 2023). Therefore, monitoring the effect of climate change on vegetation is critical for understanding the impacts of climate change on ecosystems, biodiversity, and human well-being, and for developing effective strategies to mitigate and adapt to these impacts.

The effects of climate change on vegetation have generally been observed at the landscape level, needing a long-term and extensive monitoring procedure that can detect changes in both climatic factors and vegetation dynamics (Bowman et al. 2015; Piao et al. 2019). However, such monitoring procedure at the landscape level using ground-based observations is challenging because of the large area, spatial heterogeneity, and accessibility of observation facilities. In the recent decades, with the development of satellite remote sensing, spatial statistical approaches, and computing platforms, large-scale monitoring and investigation of vegetation dynamics and its interactions with climatic conditions are now possible (Chen et al. 2023; Kolarik et al. 2023).

Remote sensing time series are the first component of any large-scale monitoring procedure. In this regard, vegetation indices (VIs) are widely used in monitoring vegetation dynamics (Wang et al. 2020; Chen et al. 2022). VIs are mathematical combinations of spectral reflectance values from different wavelengths of light, typically in the visible and near-infrared regions of the electromagnetic spectrum, which provide information about vegetation biomass, vigor, and health (da Silva et al. 2020; Khunrattanasiri 2023; Wu et al. 2023). Monitoring vegetation dynamics using vegetation indices involves comparing vegetation index values over time to detect their spatial and temporal variations. After constructing the vegetation index time series, spatial statistical methods such as linear regression or trend analysis can be used to detect changes and trends in vegetation over time (Zhou et al. 2021). In addition, the intermingling of these methods with climatic factors can be used to determine what type of variation occurred as a result of climate change (Wang et al. 2020). In this regard, some previous studies have used the tools