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# Quantifying vegetation and soil organic carbon and their drivers in dryland ecosystems of Northwest, China

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**Abstract:** Dryland ecosystems play a vital role in global carbon cycling, yet their carbon dynamics remain poorly understood, particularly under climate change. Most studies in dryland ecosystems have concentrated on soil organic carbon (SOC), with limited attention to aboveground (AGBC) and belowground biomass carbon (BGBC). This imbalance may result in systematic underestimation of the total carbon sink potential of these ecosystems. Accurate assessment of these carbon stocks and their driving mechanisms is crucial for understanding ecosystem functioning and guiding sustainable land management in arid regions.

In this study, we conducted a comprehensive assessment of organic carbon stocks in the dryland ecosystems of Northwestern China. By integrating 2304 samples points from 2000 to 2020, we developed predictive models with machine learning techniques for AGBC, BGBC, and SOC, respectively. The Shapley Additive Explanations (SHAP) method and structural equation model (SEM) were used to evaluate the influence of key drivers on AGBC, BGBC and SOC.

Our results indicate that machine learning models substantially outperformed multiple linear regression (MLR) in predicting AGBC, BGBC, and SOC. When assessing the influence of different predictors, we found that incorporating climate variables, atmospheric $CO_2$ concentration, and land use each improved model performance to varying extents. The highest accuracy was achieved when all three predictors were included simultaneously, with the random forest (RF) models explaining 71%, 74%, and 83% of the variance in AGBC, BGBC, and SOC, respectively. Land use (LU) emerged as the most influential predictor for AGBC, contributing 33.97% of the explained variance, while mean annual maximum temperature (TMX) and elevation (ELE) were identified as the dominant drivers for BGBC and SOC. Nonlinear relationships were evident between these key drivers and the three carbon pools. SEM further revealed that TMX exerted both direct and negative indirect effects on BGBC through its influence on soil properties and other environmental factors, whereas ELE consistently exerted dominant positive effects on SOC through its influence on vegetation. In the dryland ecosystems of northwest China, soil functions as the principal reservoir of organic carbon, with SOC comprising approximately 90% of the total ecosystem carbon stock. Over the past two decades, AGBC had the most pronounced increasing trend. Spatially, the highest carbon stock was predominantly concentrated in woodlands and grasslands of mountainous regions.

This work highlights the spatiotemporal heterogeneity and the difference of key drivers of AGBC, BGBC, and SOC in dryland ecosystems. These differences should be carefully considered in the development of climate adaptation policies and land management strategies. Our work offers valuable insights and methodological frameworks for evaluating carbon dynamics and identifying key environmental drivers of organic carbon variability in dryland ecosystems.

***Keywords:*** *Dryland Ecosystems, Organic Carbon, Machine Learning Model, SHAP, SEM*

 