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Modeling Biomass and Biodiversity across Environmental and Management Gradients in Temperate Grasslands with Deep Learning and Sentinel-1 and -2

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Abstract : Monitoring the trade-off between biomass production and biodiversity in grasslands is critical to evaluate the effects of management practices across environmental gradients. New generations of remote sensing sensors and machine learning approaches can model grasslands' characteristics with varying accuracies. However, studies often fail to cover a sufficiently broad range of environmental conditions, and evidence suggests that prediction models might be case specific. In this study, biomass production and biodiversity indices (species richness and Fishers' α) are modeled in 150 grassland plots for three sites across Germany. These sites represent a North-South gradient and are characterized by distinct soil types, topographic properties, climatic conditions, and management intensities. Predictors used are derived from Sentinel-1 & 2 and a set of topoedaphic variables. The transferability of the models is tested by training and validating at different sites. The performance of feed-forward deep neural networks (DNN) is compared to a random forest algorithm. While biomass predictions across gradients and sites were acceptable (r2 0.5), predictions of biodiversity indices were poor (r2 0.14). DNN showed higher generalization capacity than random forest when predicting biomass across gradients and sites (relative root mean squared error of 0.5 for DNN vs. 0.85 for random forest). DNN also achieved high performance when using the Sentinel-2 surface reflectance data rather than different combinations of spectral indices, Sentinel-1 data, or topoedaphic variables, simplifying dimensionality. This study demonstrates the necessity of training biomass and biodiversity models using a broad range of environmental conditions and ensuring spatial independence to have realistic and transferable models where plot level information can be upscaled to landscape scale.

Keywords : ecosystem services, grassland management, machine learning, remote sensing
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