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A MULTI-LEVEL DATA FRAMEWORK FOR MONITORING INTRODUCED SPECIES IN MOUNTAIN PROTECTED AREAS

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The approach to collecting detailed vegetation data developed in this study was tested at two sites: Avrorin Polar–Alpine Botanical Garden–Institute (Khibiny Mountains) and Sochut Dendrological Park (Stepanavan, Southern Caucasus). Within the Botanical Garden, data were collected in the nursery of herbaceous introductions, the alpine rock garden, a forest plot, and permanent monitoring plots distributed across several altitudinal belts, using DJI Air and DJI Neo UAVs as well as smartphone cameras (iPhone 14, Samsung S23, Vivo V29e, and Xiaomi Redmi 12). In the Sochut Dendrological Park, data were collected for both the entire area and selected test plots using a micro-UAV DJI Neo, mini-UAVs DJI Mavic 2 Air and DJI Mavic 4 Pro, a Samsung S25 smartphone, and a Leica TS15 G R1000 total station. A two-level database structure is proposed for comprehensive monitoring of vegetation cover across both long-term and seasonal timescales. This multi-level structure enables the recording of a wide range of parameters and allows vegetation to be examined not only from above but also in vertical profile, thereby supporting multi-plane spatial analysis of the site. The data acquisition methodology integrates multiple sources of information on vegetation cover obtained from satellite, UAV, and ground-based platforms, including very-high-resolution satellite imagery, data acquired using mini- and micro-UAVs, photographs obtained with mobile devices, total station measurements, and climate sensor data. Very-high-resolution satellite imagery enables the identification of spatiotemporal patterns of vegetation distribution and seasonal dynamics across the entire protected area. Mini-UAV data provide a finer level of detail, allowing the derivation of morphometric and forest inventory attributes of vegetation, including stand parameters and the spatial structure of plant communities. The use of micro-UAVs and ground-based imaging with mobile-device cameras allows the lower vegetation layers and individual plants within permanent monitoring plots to be examined, providing insight into species composition, condition, and local vegetation dynamics. Total station measurements provide data on micro- and nano-relief for subsequent vegetation differentiation and the identification of distribution patterns. Climate sensor data supplement the dataset and support the analysis of spatiotemporal patterns in relation to abiotic conditions. This approach enables tracking of changes across multiple scales. The high spatial resolution of data collected at several levels supports the identification not only of individual structural and functional characteristics but also of seasonal changes in vegetation, including phenological transitions specific to each deciduous species, responses to changing climatic conditions, disturbance, and subsequent recovery processes.

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