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| **Estimating Forest Biodiversity, Naturalness, and Old-Growth Status: Insights from National Forest Inventory Data** |
| Assessing the biodiversity (B), naturalness (N), and old-growth status (OG) of forests is essential in establishing sustainable forest management plans and achieving worldwide preservation objectives. In this context, National Forest Inventories (NFIs), the official source of statistics on the status and trends of forests at the national level, may play a crucial role thanks to the wide array of variables routinely measured. Here, the study aimed to test a set of NFI-based indicators (i) able to estimate the aggregated index of B-N-OG, (ii) be supported by scientific evidence, and (iii) be assessed using data currently sampled in existing NFI datasets.  Based on a comprehensive literature review, 18 single-variable indicators were used to estimate B-N-OG indexes - normalized in a 0-1 range - from tree-level data collected in 6563 field plots during the 2005 Italian NFI. Moreover, the Copernicus High-Resolution Layer Imperviousness Degree for the year 2006 was implemented to infer the distance of NFI forest plots from anthropic disturbance. Additionally, to investigate the potential correlation between B-N-OG indexes and ecological and management conditions, the Italian network of protected areas was included in the analysis. The database was finally examined to evaluate (i) the correlations between the 18 indicators and the three indexes, (ii) geographical trends in B-N-OG indexes across Italy, (iii) the impact of the network of protected areas, and (iv) the B-N-OG distributions across different forest types and management practices.  Across the single-variable indicators, forest structure components exhibited the largest significant positive correlations with deadwood (r=0.20) and composition indicators (r=0.14), while displaying a negative correlation with regeneration indicators (r=0.16). B and OG indexes also showed the largest correlation between aggregated indexes (r=0.81). At the geographical level, the largest B-N-OG estimates occurred in mountainous regions (Trentino Alto Adige and Calabria, above all), where forests are mainly dominated by coniferous species (especially fir, spruce, beech, larch, and stone pine) that also recorded the largest B-N-OG estimates across the NFI forest categories. These findings were consistent with observations of forest management practices, wherein high forests recorded the largest B estimates, followed by uneven-aged systems, with coppices ranking last. Additionally, among Natura 2000 habitats, temperate mountain coniferous forests exhibited the largest B-N-OG estimates (0.170, 0.101, and 0.132, respectively), whereas deciduous Mediterranean forests and sclerophyllous Mediterranean forests showed the smallest estimates across all three indexes. Lastly, despite protected and unprotected areas having similar mean B estimates, statistically significant - yet small - differences in mean N and OG estimates (p < 0.001 and p = 0.006, respectively) occurred inside and outside protected areas boundaries (N= 0.07 vs. 0.05, OG= 0.09 vs. 0.08, respectively).  This study highlights the role of routinely acquired NFI data for B-N-OG assessment. By integrating additional variables beyond traditional inventory objectives, the proposed set of indicators aims for multipurpose NFI surveys. Also, the B-N-OG indexes can offer enhanced design-based assessment at the national level, supporting NFI's contribution to conservation strategies and sustainable forest management. By comparing data from different sampling campaigns, this approach could also support trend analysis over time. |