Towards a forest management sustainable for biodiversity

European forests provide habitat for biodiversity while meeting a growing demand for timber. Satisfying these two key forest functions in the face of climate change is a major challenge and will require careful forest management and planning. The EU Forest Strategy for 2030 aims to improve the quality of EU forests and strengthen their protection, restoration and resilience. Among others, protecting primary and old-growth forests, and reinforcing Sustainable Forest Management for climate adaptation and forest resilience are two major pathways towards these objectives. The former pathway calls for land sparing actions in synergy with the aim of the EU Biodiversity Strategy for 2030 to protect at least 30% of the EU land area, with 10% under strict protection. The second pathway builds on the land sharing approach vastly applied in Europe through, for instance, a voluntary certification scheme that rewards biodiversity-friendly practices with a EU quality label.

One potential approach to reconcile these two pathways is the so-called Triad framework, which divides the forested landscapes into discrete units that emphasize strict protection, extensive management, and intensive management[1,2].

State of the art

Based on the analysis conducted by the BOTTOMS-UP cooperation network, most countries in Europe are very far from a balanced Triad system of management (Fig. 1). In particular, the area of strict forest reserves, which represent key habitats for old-growth dependent species, is remarkably low across most of Europe.

As for extensively managed forests, specific silvicultural regimes and several habitat structures have been labeled as beneficial for biodiversity with the support of a wealth of local studies, both observational[3,4], or based on forest manipulation experiments[5] and meta-analyses[6,7]. However, broad-scale assessments based on field biodiversity data, which may drive landscape forest planning and stand scale management actions, are still lacking.

Through the harmonization of silvicultural terms used in biodiversity studies[8] and the establishment of a harmonized network of forest manipulation experiments[9] and observational data[10], the

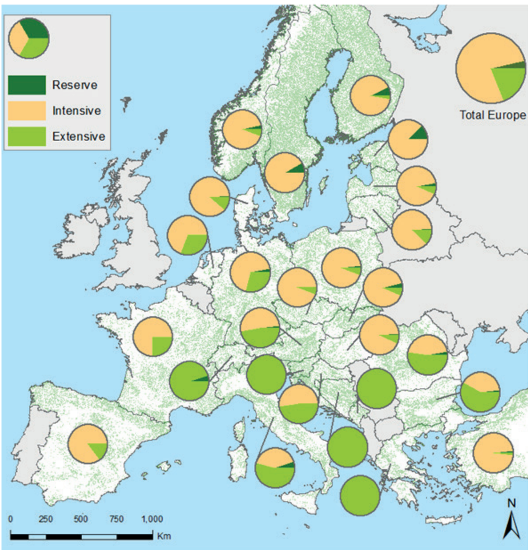

Figure 1. Current country level Triad zoning across Europe, showing the proportion of strictly protected forest reserves (i.e. no timber harvesting), intensively managed forests (i.e. even-aged, rotational management), and extensively managed forests (i.e. uneven-aged, continuous cover management) out of the total forest area (green background on map).

COST Action BOTTOMS-UP allowed the use of field biodiversity data across 13 European countries to model the biodiversity response to different planning approaches and provide guidance on best practices to be implemented at the stand level.

Landscape scale

At the landscape scale, it is important to define a balanced allocation of area for each management approach to achieve a given level of biodiversity, which, by the integration of socio-economic data, is crucial to design forest policies across different regions of Europe.

It is also relevant to know how management intensity affects the extent and the pathways through which forest biological communities respond to disturbances and environmental changes, i.e., their resilience.

Stand scale

At the stand scale, operational information is needed on the thresholds or ranges for sustainable forest management concerning forest biodiversity and climate objectives. Such thresholds or ranges should build on existing work and take into account forest variability, biogeographic regions and forest typology.

At the stand scale, forest manipulation experiments are extremely useful to assess the effects of different management regimes. However, such experiments are by definition local, and suffer from a high context-dependency. A coordinated network of such experiments overcomes these issues and upscale the lessons learned locally to the regional or continental scale.

Policy recommendations

Landscape scale

Ensure a proportion of unmanaged forests

Using the BOTTOMS-UP biodiversity database, we explored the contribution of unmanaged (UNM), extensively managed (EXT), and intensively managed (INT) forests to the total biodiversity of a Triad landscape. We tested how different proportions of the three zones in a (sub)montane eutrophic beech forest supported the biodiversity of vascular plants, epixylic bryophytes and lichens, wood-inhabiting fungi, saproxylic beetles, and birds.

The results (Fig. 2) showed that multi-taxonomic diversity was highest when a combination of intensively managed forest and forest reserves was employed. Conversely, extensively managed forests had little contribution. However, this approach would require allocating 60% of the landscape to unmanaged forest, a measure incompatible with wood production. In practice, while enlarging unmanaged forest reserves is imperative, extensive practices should prioritize the restoration of forest structures important to biodiversity to compensate for the lack of unmanaged forests.

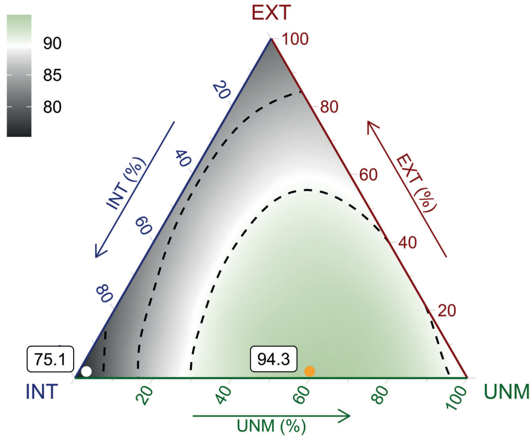

Figure 2. Multi-taxonomic diversity in (sub)montane eutrophic beech forests expressed as the percent of maximum diversity, along landscape compositional gradients: extensively (EXT) and intensively (INT) managed, and unmanaged (UNM) forests.

Create a mosaic of differently managed areas to boost forest resilience

Functional attributes of plant species are often used to measure resilience. We found that intensive forest management (e.g., clearcut) can help maintain forest functions even if some species are lost (high redundancy). However, this approach may limit the ability of the forest understory to adapt to environmental changes (low diversity). As changes become more significant, it is important to note that the highest levels of functional diversity were found in unmanaged forests (Fig. 3), or in forests managed with low to moderate intensity methods like selection cutting, shelterwood, and clearcutting with retention. These findings suggest that a variety of management approaches are needed to meet the diverse needs and benefits provided by forests[11].

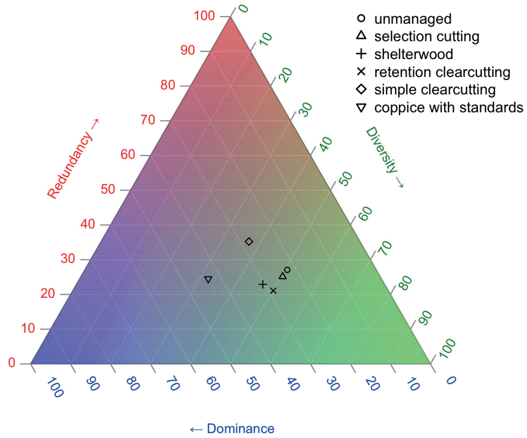

Figure 3. Ternary diagram of functional diversity, redundancy and species dominance across different silvicultural regimes.

Maintain a mosaic of forest stands with different standing trees' volume

Based on our data, in even-aged beech woodlands under shelterwood management regime multiple taxonomic groups exhibit significant, yet different, relationships with varying levels of tree volumes (Fig. 4). This is true also for other stand structure variables. By ensuring a forest landscape with heterogeneity in these structural elements will benefit forest biodiversity.

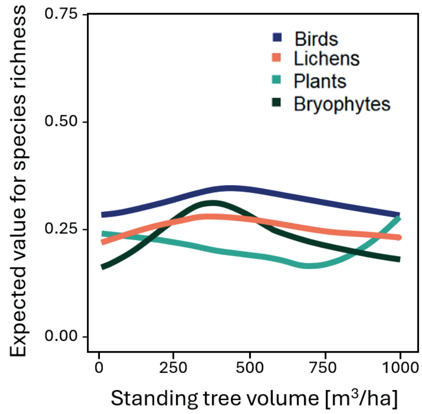

Figure 4. Relationships between standing tree volumes and species richness in even-aged beech woodlands under shelterwood system based on Generalized Additive Models.

Stand scale

Ensure critical amounts of deadwood in managed forests

Deadwood is recognized as a key habitat structure in managed forests, however operational guidelines on the amount of deadwood needed to sustain the diversity of saproxylic organisms are still lacking. Based on the harmonized BOTTOMS-UP data, we identified the deadwood threshold that allows for a fair representation of the diversity of six taxonomic groups. We found that at least 70 m³ per hectare of lying deadwood and 60 m³ per hectare of standing deadwood are needed to support the diversity of multiple taxonomic groups (Fig. 5).

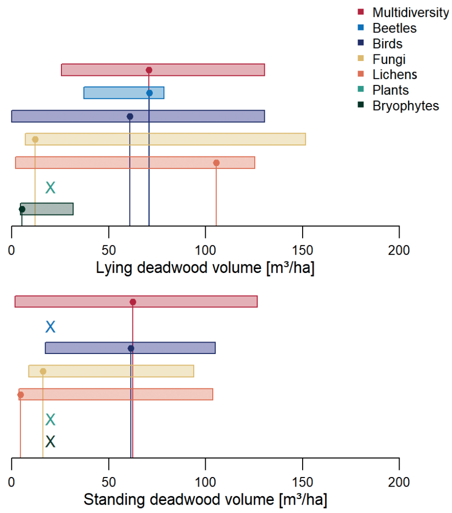

Figure 5. Thresholds (dots) and confidence intervals (bars) for deadwood volumes calculated using conditional inference trees.

Gaps and moderate thinning may enhance the diversity of multiple taxonomic groups

Manipulation forest management experiments are useful to disentangle and isolate different effects (e.g., canopy cover and deadwood volume). To provide a representative picture of the currently available information from Europe, we collected metadata on 28 multi-taxon and forest management experiments (Fig. 6). Innovative ways of performing traditional management techniques (e.g., gap cutting and thinning) and conservation-oriented interventions (e.g., tree-related microhabitat enrichment) provide the best opportunity for large-scale analyses.

Increased openness had a positive effect on the diversity of vascular plants, saproxylic beetles and ground beetles, while gap-cutting had a negative effect on birds and moths (Fig. 7). The interventions had no significant effect on bryophytes, fungi and lichens. Our results suggest that fine-scale opening of the homogeneous, closed canopy (either in a dispersed or aggregated way) can be a useful tool to increase the diversity of several taxa. However, it is also important to preserve areas with a closed canopy layer, as other forest organisms are adapted to these shaded environments.

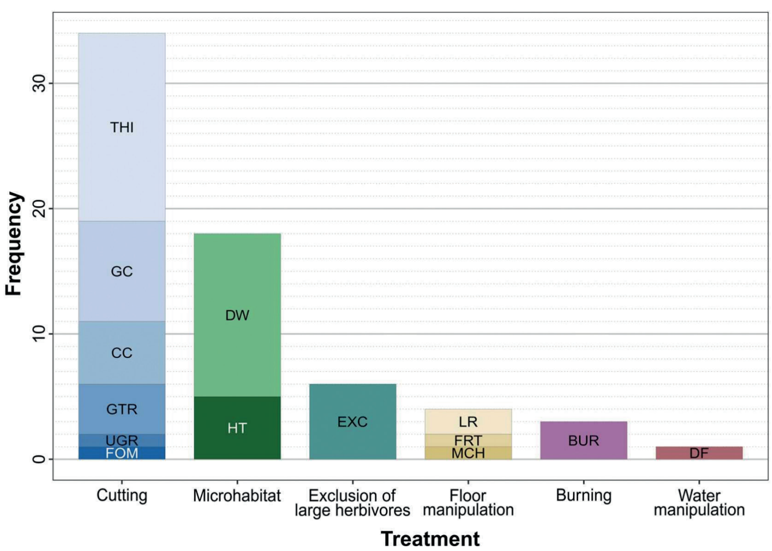

Figure 6. Frequency of different treatments in experiments related to forest management effect on biodiversity in Europe. Frequent subtypes: CC = clearcutting, GC = gap cutting, THI = thinning, DW = deadwood enrichment, HT = habitat tree enrichment, EXC = exclusion of large herbivores.

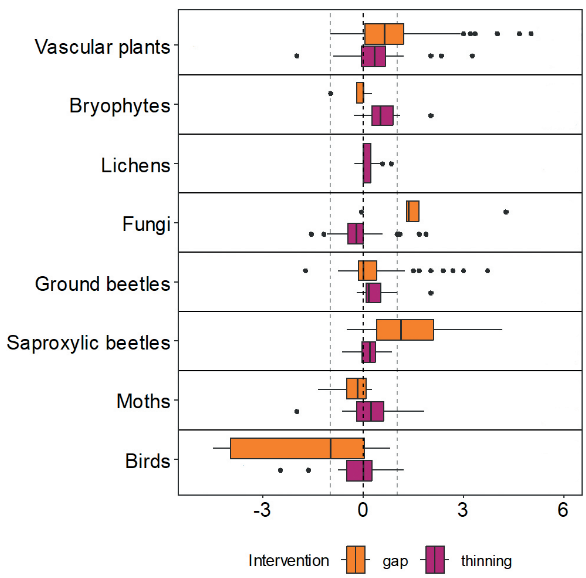

Fig. 7. Effect of gap-cutting (orange) and thinning (cherry red) on the species richness of different taxonomic groups compared to closed forest control in different experiments in Europe.

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