MoBiTools – Monitoring Biodiversity with remote sensing Tools

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1. Introduction

Forest structures are essential elements of forests, which are linked to habitat requirements of many protected species. Which forest structures are decisive for the occurrence of bats, wild bees, breeding birds, woodcock, red fox or other species? How do forest gaps and open forests change over time, especially with regard to the habitat of capercaillie? How are forest areas connected? Where are suitable forests worth protecting? What can remote sensing reveal about inaccessible or unexplored forest areas? The MoBiTools project provides information that addresses a multitude of questions linking biodiversity and forest structures. It develops and operationalise methods for an area-wide, high-resolution mapping of forest structures using remote sensing. As state-wide information on forest structure has not previously been available, the MoBiTools maps aim to reveal essential structures for key forest dwelling species in different forest ecosystems and habitats on a regional scale.

2. Study site and datasets

The study site covers the forest area of Baden-Württemberg, Germany, with a total area of about 35,751 km² and 38.6 % (13,784.7 km²) forest cover. According the latest national forest inventory of 2022, the most common tree species are Norway spruce (*Picea abies*) with 31.1 %, European beech (*Fagus sylvatica*) with 22.8 %, Silver fir (*Abies alba*) with 9.0 % and oaks (*Quercus sp.*) with 8.6 %.

A majority of the MoBiTools maps were created using aerial images provided by the state agency of spatial information and rural development of Baden-Württemberg (LGL) as part of regular aerial surveys. These surveys covered an area of approximately one-half to one-third of the state area of Baden-Württemberg on an annual basis. The aerial images were acquired by 154 airborne image flight missions spanning the period from 2011 to 2024. Flight conditions such as day and time of the photo acquisition and corresponding weather conditions and well as flight settings, overlap and camera type varied between the flight missions. Furthermore, image-matching parameters and software versions used to derive digital surface models from overlapping aerial imagery were incoherent throughout the flight missions. Using aerial images, 1-meter resolution normalized digital surface models (nDSMs) and 20-centimeter resolution orthophotos served as the basis for mapping forest structures. A detailed description of the applied methods for deriving aerial image-based nDSMs can be found in Ganz et al. (2020). The nDSMs are the most critical input data of the MoBiTools maps. However, the map type determines whether to use nDSMs, orthophotos, Sentinel-2 satellite data, or a combination of these resources.

3. Forest structure maps

As part of the MoBiTools project, we develop methods for mapping various forest structures from remote sensing data (Figure 1). These include: i) Forest height (Kilian et al. 2017), ii) height heterogeneity, iii) gaps in low, high and open forests (Zielewska-Büttner et al. 2016), iv) structures relevant to capercaillie (*Tetrao urogallus*) (Coppes et al. 2019), iv) forest types, including beech, spruce, other deciduous, coniferous or mixed forest, v) standing deadwood (Zielewska-Büttner et al. 2020) and vi) the tree, stocking and forest cover layers (Ganz et al. 2020). The majority of the maps are created for the entire state and are constantly updated based on availability of the aerial imagery data. The maps indicate precisely where the different forest structures are located. This enables to quantify the structures and recognise trends across the entire state. The knowledge about the presence or absence of certain forest structures such as forest gaps, structurally rich stands, tall and presumably old trees, small forest islands, deciduous or coniferous trees, forest edges, as well as about their spatial and temporal changes allows for the description of the current situation and changes in a given area. Several habitat modelling studies of e.g. bats (Hendel et al. 2023), saproxylic beetles (Winiger et al. 2020), capercaillie (Kämmerle et al. 2020) and breeding birds have already shown that the MoBiTools maps depict valuable structures for various forest-related species.

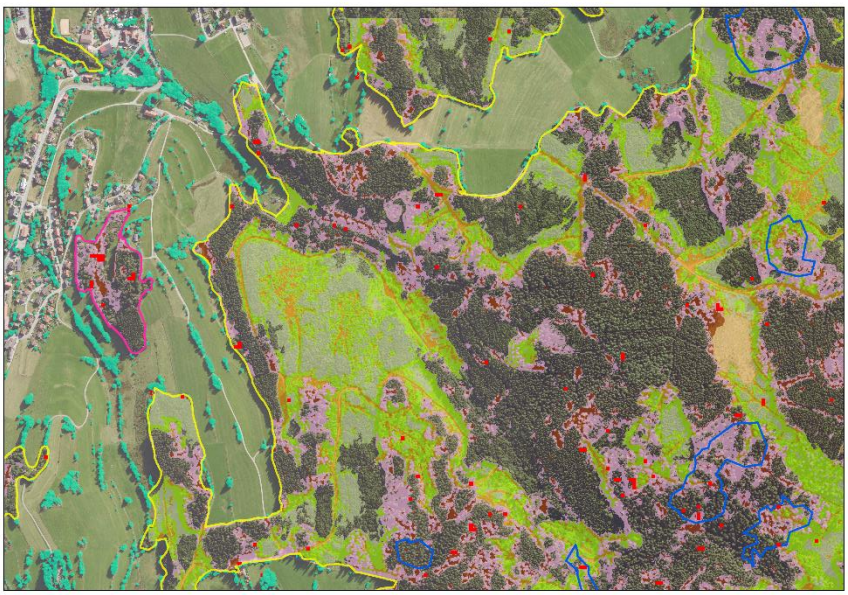

Figure 1. Biodiversity-relevant forest structures based on remote sensing data: Gaps in high forest (dark red) and low forest (orange), structurally rich low forests (bright green), structurally poor low forest (light green), open forest (light orange), structurally rich high forest (light pink), high trees (blue outline), standing deadwood (red), trees outside forest (cyan), forest edges (yellow) and forest islands (pink outline).

4. Conclusion

Remote sensing enables the observation of natural dynamics that make it a powerful tool for biodiversity-related studies. Regularly updated aerial images from public flight mapping campaigns bear the potential to assess changes in a cost-efficient way, especially when aiming at long-term monitoring. The maps offer the possibility to get an overview at landscape scale, for defined regions as well as for individual habitats. Although the time series of only ten years is still very short considering forest dynamics and climate change, it already contributes to an increase in information on ecologically important forest structures and habitats. In conclusion, the MoBiTools maps provide a valuable data basis from which various stakeholders such as the scientific community, forest

administration and management, land planning and consulting services, nature conservation as well as politics can benefit. In addition, MoBiTools offers a service that advises stakeholders on the interpretation and application of the maps and supports them with adapted tools for data analysis. Long-term, remote sensing-based biodiversity monitoring programs such as MoBiTools are crucial for forest ecology and biodiversity research as well as sustainable forest management and nature conservation at local and regional scale. The main value of this contribution lies in getting to know the forest structure maps, which can be made freely available to the stakeholders. The conference will also provide an opportunity to gather ideas for use cases of the maps or suggestions for deriving new maps from the available input data.

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