Abstract title:		Integration of Small Area Estimation in Forest Management Planning
Take-home message:		*Design-based small area regression estimation has a great potential to increase the value of National Forest Inventory data by extending their use to unbiased estimation of forest attributes on small-scale forest management levels.*
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General topic, see website: (please double click on the check box and activate the relevant one)	☐	Improving future NFIs by learning from the past
	☒	NFIs today and in the future
	☒	Cutting edge and futuristic inventory techniques and technologies
Preferred presentation form:	☐	Oral presentation
	☒	Poster
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Integration of Small Area Estimation in Forest Management Planning

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Introduction: The state forest service of Rhineland-Palatinate (RLP, Germany) has increasingly been integrating remote sensing data in a decision support system for operational forest management planning. Within this framework, a recent study has evaluated whether a combination of remote sensing data and German National Forest Inventory (NFI) data via a double-sampling procedure can provide accurate timber volume estimations for small-scale forest district units. This information has so-far not been available due to high estimation uncertainties when exclusively using the German NFI data that are characterized by substantially small sample sizes within forest district units. Some federal states in Germany have responded to this issue by establishing a regional forest district inventory (FDI) with a much higher sampling frequency than used in the German NFI in order to base their regional and local management strategies on quantitative and accurate information. However, a cost-saving alternative to FDIs that has lately been demonstrated in Switzerland (Magnussen & Tomppo, 2014) and Norway (Breidenbach & Astrup, 2012) is to combine the available NFI data with remote sensing data by double-sampling small area estimation techniques. The study objective is thus to test whether double-sampling techniques can increase the value of the NFI data by extending their use to small-scale forest district units.

Materials and methods: Three design-based double-sampling small area regression estimators proposed by Mandallaz (2013a) and Mandallaz et al. (2013) were considered to be well suited for the study objective. In order to evaluate the performance of these estimators with respect to future large-scale operational use, the procedure was implemented and applied over the entire federal state forest area (8400 km^2). In this context, small area estimations were calculated for 400 forest district units to gain a representative idea of achievable estimation precisions. Explanatory variables were derived from two remote sensing sources, i.e., an ALS-derived canopy height model (CHM), and a satellite-based tree species map. Additionally, a canopy height model based on aerial images will be tested as a more-frequently updated alternative to the ALS-derived product.

Results: By application of the design-based estimators, it was possible to achieve an average estimation error of 11% on forest district level. This constitutes a substantial reduction of the average estimation error by almost 50% compared to exclusively using the German NFI data. Both the ALS canopy height model as well as the tree species classification map turned out to be valuable information for future double-sampling inventories. The use of the alternative aerial-image based CHM is expected to lead to very similar performances of the estimators.

Conclusion: The investigated design-based estimators show great potential to increase the value of the German NFI data by extending their use to estimation of forest attributes on forest district level. The estimation precision is also considered to further improve in future applications due to more-frequently updated remote sensing data. The latter also enables the method to be extended to the estimation of change. As the estimation method relies on a minimum terrestrial sample size within the units of interest, it is, however, not possible to use the NFI data also for estimation on forest stand level. Therefore, a follow-up study is currently planned to test a densified regional forest inventory that will also enable to apply the double-sampling procedure to forest stand units.

Selected References:

Breidenbach, J. & Astrup, R. (2012). *European Journal of Forest Research*, 131(4), 1255–1267;
Mandallaz, D. (2013a). *Canadian Journal of Forest Research*, 43(5), 441–449;

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