

Evaluating the efficiency of the Swiss forest road network for timber harvesting and transport

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Abstract

The location and dimension of forest roads play an important role in timber harvesting and transport. In this study, forestry roads in the entire Swiss forest were mapped and analysed in a GIS. Our results show large differences in the accessibility of forests in Switzerland and a potential for the optimised use of harvesting methods.

Keywords: forest roads, trafficability, trucks, timber harvesting, network analysis, GIS

1 Introduction

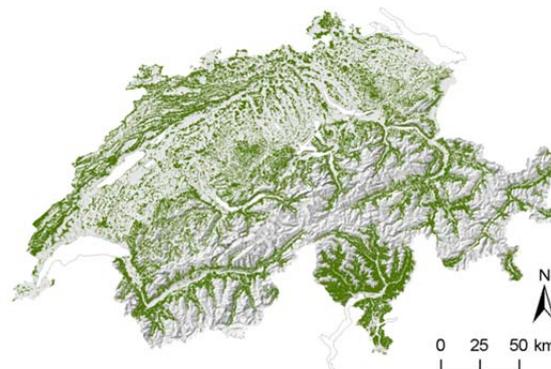
About 30% of Switzerland are covered by forest (Figure 1). Apart from providing habitats for animals and plants, its services include protection against natural hazards, recreation and timber production. Because of these different uses, economic, ecological and societal interests need to be weighed against each other. For the sustainable use of the forests it is necessary to have reliable information about the current condition of the forest and the way it changes over time.

In the Swiss National Forest Inventory (NFI), information about the forest has been recorded for more than 30 years, using a combination of remote-sensing data, field surveys on sample plots and enquiries at the local forest services (Brändli 2010). The collected data include the forest roads (for trucks) in the entire forested area in Switzerland. These roads are used for forest management, recreation or disaster control, i.a., and they are particularly important as an essential element of timber transport.

Timber transportation is a significant contributor to the total wood production costs in Switzerland. On one hand, the density and spatial distribution of forest roads defines hauling distances and transport lengths; on the other hand, the road dimensions, e.g. their width and carrying capability, affect the number of trips necessary for wood transport. Thus, detailed information about the position, dimension and trafficability of forest roads is an important requirement for the choice of an economic harvesting method and for finding the best transport route.

In this study, the forest road network in Switzerland is examined and its adequacy for efficient timber transport is evaluated, taking into account that each forest road is capable of carrying only vehicles of a certain maximum size.

Figure 1: Forest distribution in Switzerland.



Source: swisstopo/NFI.

2 Data and methods

Forest roads were mapped using the geometries from the road dataset in the national topographic landscape model swissTLM3D (swisstopo 2012). This dataset includes all roads and paths in Switzerland, from highways to mountain trails. Because in the previous survey (2004-2006), an older version of the national digital road dataset had been used, all attributes were first transferred to the corresponding new road geometries. This allowed direct comparison between the two surveys. The road network from the 2004-2006 survey was then printed on maps on which the local forest services mapped all changes (newly built roads, upgrades etc.) in writing. Roads were included in the survey if they fulfilled the required minimum transport capacity of a 10-ton axle load and

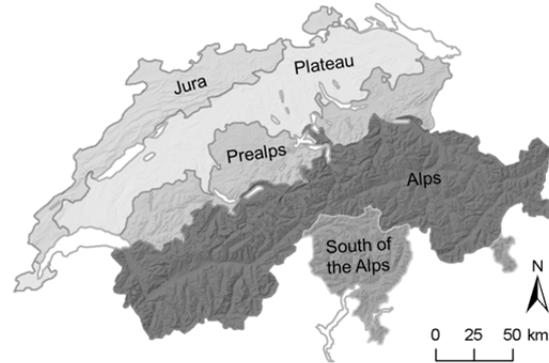
minimum width of 2.5 m, criteria that have been used consistently in all Swiss NFIs up to this point. In the most recent survey (2013-2014), roads with different suitabilities for specific vehicle categories were distinguished for the first time. In addition, roads connecting forest roads to main (usually cantonal) roads were mapped, together with the connection points (Müller et al. 2016). Much care was taken in defining codes and colours that can easily be distinguished. The mapped information was then digitised by attributing the new information to the existing road geometries. Various quality assurance mechanisms and consistency checks were applied to ensure consistency between regions as well as collaborators.

3 Analyses and results

In order to evaluate the accessibility of the Swiss forests and the adequacy of the forest road network, several aspects of the road distribution and connectivity were analysed. Road density in forested areas was computed as a first-order indicator of accessibility for different regions. To further characterise the road distribution, straight-line distance to the nearest forest road was measured from the NFI net of ~6500 sample plots. Using the topological road network, we then analysed the network distance from the sample plots to the nearest main road, with route selection depending on vehicle size. Together with information about the currently applied timber felling and extraction technique, available for every sample location, and terrain information (especially important for steep terrain), wood accessibility can be evaluated.

We found that although the Swiss forests feature relatively high road densities of up to 84 m/ha (Brändli et al. 2016), the densities vary strongly between regions, mainly as a result of topography. Accordingly, the horizontal distances from the sample plots to the nearest forest road show a strong variation, too. While about 80% of the sample plots are situated within a distance of no more than 500 m from the nearest forest road, the fact that many of these roads can only be used with small trucks often significantly limits the transport out of the forest. If accounting only for roads at least 3 m wide and suitable for a 4-axle, 28-ton vehicle, only about 60% of the sample plots were found to be situated within the same distance (Table 1). The network analysis also revealed some cases where forest roads of a higher category were isolated from the main roads by road sections falling into a lower category. We conclude that upgrading the road infrastructure in these areas should be considered. Applying alternative harvesting techniques could also in some cases substantially reduce costs for the forest enterprises.

Figure 2: Main wood production regions in Switzerland as used in the Swiss National Forest Inventory NFI.



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swisstopo data: Reproduced by permission of swisstopo (JA100118)

Table 1: Percentage of sampling points within a given distance from the nearest forest road

Forest road category / vehicle type	Distance to nearest forest road	Jura	Plateau	Prealps	Alps	South of the Alps	Switzerland
Width \geq 2.5 m / 2 axles, 20 t (or larger)	\leq 500 m	98	97	84	72	44	80
	$>$ 500 m	2	3	16	28	56	20
Width \geq 3.0 m / 4 axles, 28 t (or larger)	\leq 500 m	94	96	72	36	22	63
	$>$ 500 m	6	4	28	64	78	37