2.6 Forest Transportation System Survey

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2.6.1 Introduction

The basic development of a forest with truck accessible roads is an important prerequisite for forest tending and cropping. With knowledge about the course and density of the forest roads, the expenditure for forest tending and cropping can be estimated. Precise knowledge regarding the state of, as well as changes in, the forest road construction is an important planning tool at both the national and regional levels.

2.6.2 Goal

The goal of the survey was to determine the state of the forest roads and changes within the forest roads of Switzerland. The survey was intended to give information about the length, density and distribution of the roads.

2.6.3 Background Information

In the first NFI the forest road survey was similar to the sample survey and the forester inquiry component of the fieldwork (ZINGG and BACHOFEN 1988). Together with the local forest service, the WSL recorded the most important roads for forest accessibility, classified them and drew them onto the national map with a scale of 1:25,000. At that time, these were the most up-to-date maps. The lines of the newly constructed roads and paths, which had not yet been updated, were drawn onto the map by hand using line of sight. This survey took place between the years 1983 to 1985. The length of the network of roads was determined in the first NFI, with the help of the point intersection method (STIERLIN 1979). For this, the number of intersections between the Swiss coordinate grid system and the roads were determined. The length of the roads was estimated based on the number of intersection points. This method was very time consuming and was also prone to errors.

In order to keep the updating expenditures for the second NFI as small as possible, the old maps of the first NFI were updated for the survey. These maps had been in use for the last 15 to 20 years. For a third NFI serious registration and updating problems would arise with these map sheets. These problems will be due to general changes of the road network in the course of three decades; thus a method had to be found to allow updating for future surveys (HÄGELI and ZINGGELER 1996). The decision to digitally record the forest road network was obvious. With the digitization, updating was made more simple and it was possible to analyze the data directly. By recording the road data in vector format it was possible to carry out the analysis, which had not been possible in the first NFI (e.g., the calculation of the oblique distance). Another advantage to the computer assisted analysis of the data was the massive reduction of the analysis time.

2.6.4 Data Collection

Data

The roads were measured on the maps of the first NFI. With this it was also possible to record the state of the roads at the time of the first NFI. Since the roads were also digitized with the same criteria and classification principles as in the first NFI, it was possible to assess the changes.

Only roads that were accessible by truck and located completely or partially in the forest were recorded. Freeways and highways were not included, and class one roads were recorded only if, according to the forest service, they served to access the forest. Since roads that were

accessible by tractor and four-wheel drive were only of minor importance for the entire country of Switzerland, they were not updated. As an additional attribute the surface type of the road was recorded. An important difference between the first and second inventory was that, even if truck accessible forest roads were interrupted by bottlenecks that were too narrow to be accessible by truck (e.g., a bridge that will not support heavy vehicles), they were still classified as such. This modification was brought about because the sections of the road behind the bottleneck were truck accessible and, therefore, needed to be classified as access roads. However, as a consequence of this modification, the change to the access roads was slightly overestimated.

The attribute catalog of the road survey in the second NFI encompasses eight categories for the road type and the construction date (NFI1 or NFI2); four categories relating to the position of the roads in respect to the forest; the road class according to the national map; as well as the presence of tunnels (see Table 1 and ZINGGELER 1993).

Table 1. Attribute catalog for the forest road survey.

Attribute	Observation
Road type	Existing road network NFI1 with water bound surface. Existing road network NFI1 with bitumen bound surface. Existing road network NFI1 with hydraulic bound surface. Abandoned/renaturalized roads. Misclassification NFI1. Newly built roads or road improvements with water bound surface. Newly built roads or road improvements bitumen bound surface. Newly built roads or road improvements with hydraulic bound surface. In the forest.
Location of the road to the forest	At the forest edge. In open stands. In the non-forest area.
Road class	Similar to the road classification of the Swiss Federal Office of Topography (BUNDESAMT FÜR LANDESTOPOGRAPHIE 1989).
Tunnel	Tunnel present. Tunnel not present.

Survey Methods

According to a study conducted by HÄGELI and ZINGGELER (1996), the roads should not be directly digitized from the national maps. They concluded that the maps had been affected by map sheet distortion due to their age or wear and tear and, therefore, were no longer sufficiently correctable. The local forest service drew the road data by hand onto the old maps, so that very often the roads did not follow the exact course of the roads on the current maps.

In order to avoid any impact on the analysis as a result of the distortion of the old maps and other inaccuracies, a digitizing table was not used.

The data was entered with the help of a GIS (Arc/Info) system. The digital pixel maps that were without contour lines (see Chapter 2.7 External Data Source) from the Federal Office of Topography were employed and served as the information base for recording the geometric data. They were displayed as background information on the computer screen. The most up-to-date pixel maps were used in each case. An additional information base represented the NFI road maps on which the forest road network was supplemented by the forest service (ZINGGELER 1993). During the time the data was digitized, both sources of information had to be considered. The digital maps delivered the information about the precise position of the individual roads (road positions in the field and road positions with respect to the forest) and their classification. The NFI road maps showed which roads were important for forest access and what type of surface they had. The roads were registered as a continuous line within one attribute combi-

nation and between intersections. The attribute data was assigned to the individual roads or line section (e.g., the surface type) after cleaning the polygons, as well as examining the intersection between map sheets

Currently, the Federal Office of Topography is digitizing all maps at a scale of 1:25,000 in vector format. A small portion of their maps were used so that those maps did not have to be digitized (BUNDESAMT FÜR LANDESTOPOGRAPHIE 1996).

2.6.5 Derived Attributes

Since the forest road survey was, in essence a census, a way had to be found that assigned a certain road length to each sample plot without losing the advantages of a census.

In order to accomplish this a grid was placed over the entire data set. The cell size of the grid was a maximum of 25 hectares, which meant that each cell had a side length of 500 m. Cells which were cut off by the national border represented a smaller area. The midpoints of the individual cells corresponded to the respective sample plot center of the NFI grid. By overlaying this grid with the data from the road survey, it was possible to assign to each cell a certain road length (Figure 1).

Total Road Length

The total road length matched the sum of the length of all recorded road segments. Determination of the road length was conducted directly through the GIS. For calculating the total road length, the lengths of all roads running through the forest were added up. These included class 0 (labels which represented new road segments that were not yet recorded by the Federal Office of Topography), as well as classes 3, 4, 5, and 6 (Bundesamt für Landestopographie 1989).

Horizontal Distance Sample Plots – Access Roads

The horizontal distance is the shortest connection between a sample plot point and the closest forest road accessible by truck. Therefore, the distance was calculated without considering the topography.

In the first NFI, the distance from the sample plot to the closest accessible forest road for trucks was measured with a ruler placed directly on the national map. To reconstruct this distance, and in order to determine changes during the last ten years, this distance was also calculated in the second NFI. The determination of the distance was largely simplified due to the employment of GIS.

These calculations were determined with the GIS Arc/Info by ESRI (ESRI 1992). The software had the algorithm ‘near’ implemented, which calculated for each sample plot point the perpendicular line to the access roads. The shortest perpendicular line corresponded to the desired distance. In order to reduce the computing time, the search of the shortest distance was restricted to a radius of 15 km around the sample plot center (Figure 2).

For these calculations a point data file was created, which included the sample plot points of the NFI 500 m grid. A second file contained all digitized roads. The calculated distances were subsequently stored in a database. The calculations were performed twice; once for roads, which already existed in the first NFI (code of the road type: existing roads plus abandoned/ renaturalized roads, Table 1), and a second time for the second NFI (code of the road type: existing road plus newly build roads). For both of these calculations, the misclassifications in the first NFI were ignored. Because of the double calculation, it was possible to determine the change during the last ten years.

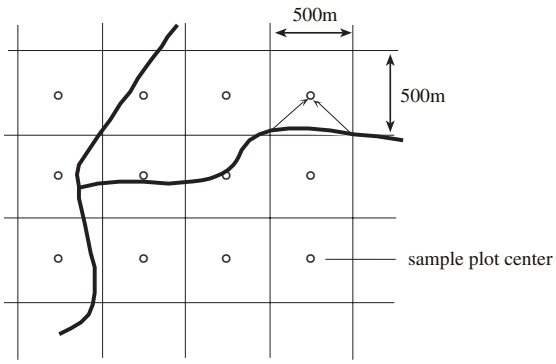

Figure 1. Assigning road sections to the sample plots.

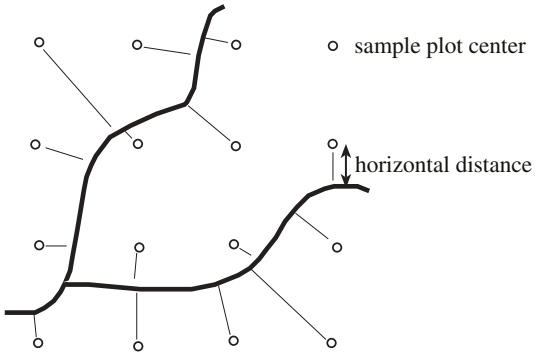

Figure 2. Calculating the horizontal distance from the sample plot center to the next forest road.

Oblique Distance Sample Plots – Access Roads

Horizontal distances provided only insufficient information about how accessible roads really were; however, using oblique distances appeared to approach the true circumstances.

Starting with the horizontal distance (Chapter 2.6.5.2), the oblique distance was calculated by using a digital terrain model (see Chapter 2.7, External Data Source). For this, the co-ordinates of the point, where the perpendicular line intersected with the access road (see Chapter 2.6.5.2), were overlaid with the digital terrain model to determine the elevation above sea level. Since the elevation of the sample plot center was also known, the oblique distances were calculated very easily with the help of the Pythagorean theorem. Similar to the work of HEINIMANN (1997; HEINIMANN 1986), the oblique distances were divided into the following classes:

– From the road directly within reach of the cable traction (100 m)
– From the road directly within reach of the mobile cable-crane (500 m)
– From the road directly within reach of the conventional cable-crane (1000 m)

Road Density

The road density was characterized by the forest road length in meters per forest hectare.

This attribute was not calculated by using GIS, but with the Statistical Analysis System (SAS). The necessary data for this were calculated in the GIS and inserted into the database. The calculated data were road lengths per grid cell (see Chapter 2.6.5.1), and the forest area was determined using the same method. The forest area had to be taken from the national map, since the NFI could not provide complete coverage. For calculating the forest area per grid cell, the continuous green area which represented the closed forest area, was taken from the pixel map (see Chapter 2.7 External Data Source) and intersected with the grid. A forest area of up to 25 hectares was therefore assigned to one grid cell. The results of both calculations were inserted into the database. In addition, each road length was weighted according to its position in the forest. (That is to say those roads which were on the forest edge were multiplied by a factor of 0.5, while roads in the forest and in open forest stands were fully counted.) Using this formula, it was possible to calculate the forest road length in meters per forest hectare.

2.6.6 Time Expenditure

Depending on the map sheet or the road density, the time expenditure for digitizing varied between 2 hours in the mountain regions and 25 hours in the densely developed Plateau. After the digitization, the attributes were assigned. The entire recording (digitization and attribute assignment) took on average approximately 15 hours per map sheet. Two hundred and forty-nine map sheets cover the entire country. The total expenditure of about 3,735 hours corresponded to 440 working days. In addition, approximately 3 hours per map sheet were spent in order to control the data. Detailed description, with respect to the time expenditure, can be

found in HÄGELI and ZINGGELER (1996). In comparison, the expenditure of working time for calculating the derived attributes was relatively small and consisted mainly in writing programs to calculate these attributes.

2.6.7 Outlook

The area of data gathering will be greatly simplified and shortened in future surveys. Only changes will have to be recorded in the survey. Updating the road network on hand is going to be largely simplified and expedited by using the vector data from Federal Office of Topography, since time intensive digitization can be omitted. The classification of roads in the future can be performed directly by the field team who are on the spot with the help from a portable computer which has a GIS installed. With this, the step of drawing the roads on the map can be dropped. This is certainly a factor that can greatly reduce the costs for subsequent surveys.

Another possible use of the data set is the development of a timber transport system. The employed GIS (Arc/Info) offers this option. For this system all road sections will be connected to one network. With this information, it will be possible to calculate the actual distance that has to be covered in order to drive from one point to another. By determining the shortest transportation road it will be feasible, for example, to minimize the transportation time and thus reduce the cost of the transport. By adding other attributes (e.g., how steep the terrain is; and the cost of the timber harvest), the timber harvest planning can be optimized. This system could also be used for planning the employment of the transportation vehicles.

2.6.8 Literature

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