FOREST AND RURAL DEVELOPMENT ASSESSMENT OVER A PERIOD OF 200 YEARS: A CASE STUDY IN THE SOUTH MORAVIAN REGION

Petr Hrůza[1], Lucie Olišarová[1], Petr Pelikán[1], Giuseppe Cillis[2], Dina Statuto[2], Pietro Picuno[2]
[1] Department of Landscape Management, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic
[2] School of Agricultural, Forest, Food and Environmental Sciences - SAFE, University of Basilicata, 85100, Potenza, Italy

Abstract
Historical maps are useful sources of geographical information for territorial research. The optimal distribution of the rural road network is a crucial tool for forestry and agricultural land management. This study provides a general framework for the assessment of the rural road network density and distribution in terms of historical development. The derived knowledge can be applied in the planning of the landscape in order to implement the study findings. For the study, a part of the hydrographic basin of the Svitava River (Blansko district, The South Moravian Region, Czech Republic) was selected. The examination of road distribution dynamics on the historical cartography over a period of almost 300 years was conducted. The basin map was created in ArcGIS software and the single map layers from the 2nd military mapping in years 1836 – 1852, as well as the topography mapping in 1952 and 2020 were used for comparison. Vector layers of the rural road network and borders of the area were created for the evaluation of their density and distribution. Macro analysis of the area identified that the density of the rural road network mostly increased in the period between 1952 – 2020.

Key words: Forest road distribution, GIS, Historical cartography, Landscape planning, South Moravian Region

Introduction

The use of historical cartography is fundamental to characterize the evolution of the territory and to quantify the impacts due to changes in land cover and use. Even if it is complex to be processed, this type of cartography allows the inclusion of the "time" factor in the methodology of forest and rural development analysis, which makes it possible to establish both the "how" and the "why" a land has been transformed so as to become as it appears in its present structure (Picuno et al., 2019). Thanks to the availability of an increasing number of historical archive cartographies and new GIS technologies, the assessment of the evolution in time of the rural territory has become more and more accurate. One of the fundamental components to understand the territorial dynamics is represented by road distribution dynamics. In this paper, a part of Svitava River hydrographic basin (South Moravian) has been considered as a case study. Using cartographies from three different years (1852 – 1952 – 2015), the density and distribution of forest and rural road network by GIS software were analyzed. After a quantitative evaluation by comparing the results obtained for the different years, the causes that determined the evolution of the road network were also analyzed. With this methodology it is possible to retrieve a lot of information about the original structure of the rural and forest road network to plan sustainable rural development actions and landscape enhancement.

Materials and methods

Study area

For this study, a part of the hydrographic basin of the Svitava River (Habruvka, Blansko district, South Moravian Region of Czechia) was chosen (Figure 1), which was frequently used for industrial purposes (Olišarová et al., 2018). The name of the main village close to the river (Habruvka) derives from the predominant tree species, hornbeam (*habr* in Czech) (Habruvka Official Website, 2008). The altitude of the study area ranges from 485 to 520 m a.s.l. The population density of Habruvka district is 43 inhabitants per hectare. The geological bedrock is formed by limestone and alluvial sediments (Geology, 2020).

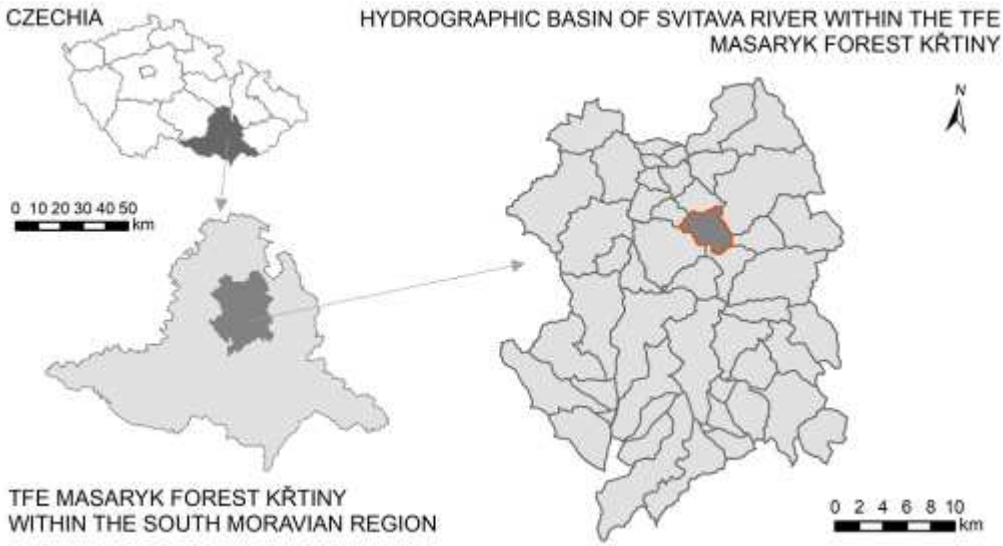

Fig. 1: Location of the study area (49.3035000 N, 16.7235144 E – WGS 1984)

Cartography

Data were analyzed on three single historical map layers. The oldest map dates back to the second military mapping – called "Francis" – which took place between 1836 and 1852. The map is in scale 1:28800 and the basis for its creation was a map of the Stable Cadastre in scale 1:2880, which also had a positive effect on the accuracy of maps (Oldmaps, 2017). The second map for the analysis was a topographic map in scale 1:25000, in the coordinate system S–1952, which was provided by the military topographic service as well after the Second World War. The photogrammetric measurement was used in the area of Czech Republic in bulk (KGM, 2015) as the third layer. A combination of basic map 1:10000, aerial and cadastral map of the area from present time was used for data evaluation. The hydrographic basin of Habruvka (ID 4-15-02-1000) of area 1023,29 ha, was used as the area border.

The Data Analysis Process

In order to determine the density and distribution of forest and rural road network in time for selected area, each map layer by ESRI's ArcGIS Desktop 10.5.1 software was analyzed.

At first, the borders of the forest, arable land, urban areas and permanent grassland polygons in each of the individual map layers for the Svitava river basin were marked.

Subsequently, linear vector layers of the road network on raster layers (separately for forest and rural lands) were created, according to the detail of the historical maps and relevant resolution enabling the identification of the forest roads. These data were used for the determination of forest and rural road length within the area of forest and agricultural land (arable land together with permanent grassland), for every time period. For the purpose of this study, a forest road means a road in the forest that allows a tractor skidding of timber as well as hauling the timber. This means skidding roads have been included in the current concept of the forest road classification. The data gained were used to calculate the density and distribution of forest and field road networks over time.

Road network by methodology of Beneš (1986) in each period and each map layer was evaluated. The practical application is usually used in the road network optimization of various morphologic areas (flatlands, uplands, and mountains). Although the method was originally developed for forest haul road network evaluation (Hrůza et al., 2019), this research also deals with the efficient distribution of rural roads to gain an equal parameter for comparison between forest and rural road networks.

A theoretical 10-hectare network was used to analyze geometrical distances to determine the road distribution, which is expressed by the following efficiency parameters (Beneš, 1986):

I) U = the efficiency distribution defined as: $U = \frac{D_t}{\underline{x}\, D_g} * 100$ [%], where:

D_t = theoretical distances [m];

$\underline{x}\, D_g$ = mean geometrical distance, defined as: $\underline{x}\, D_g = \frac{(Dg1 + Dg2 + \ldots Dgn)}{n}$ [m], *i.e.*: the arithmetic mean of geometrical distances [m];

D_g = geometrical distance, *i.e.*: the shortest distance from the theoretical 10-hectare network point to a road.
The efficiency distribution parameter U shows how regularly roads are distributed throughout the concerned area. The theoretical and mean geometrical distances and their efficiency were determined for individual map layers. This was done for the forest land (forest roads), arable land (rural roads), and arable land together with permanent grassland (rural roads), each layer separately.

II) *H* = density of the forest and rural road networks, defined as: $H = \frac{D}{S}$ [m*ha^{-1}], where: D = length of the roads [m]; S = size of the area [ha].

III) Dt = theoretical optimal distance, defined as: $D_t = \frac{10000}{4H}$ [m].

Results

After analyzing the basin area Habruvka on the Francis map (1852), we can state that the forest road network consisted of nearly 30 km of forest roads (29863 m) within a forest area of 775,20 ha. This represents the density of forest roads H = 38,52 m*ha^{-1} and the efficiency of distribution U= 45.07%. The length of rural roads reached about 8 km (8205 m) within an area of 234 ha of agricultural land with a density H = 46,55 [m*ha^{-1}] and an efficiency of distribution U = 36.56%. The efficiency does not change much or is even lower when we take into account the arable land only, which reduces the distribution efficiency U of rural roads used for pure agricultural production to 33.36%. Mean transport distance in the forest from the extraction site (harvesting place, in forest terminology known as "stump") to a forest road was 144 m, in the agricultural land (arable land together with permanent grassland) it was 195 m, and on arable land only 161 m.
Compared with the access situation in the landscape area of Habruvka after the Second World War in the year 1952, there has been a big increase in the forest road length by about 46% to nearly 44 km (43635 m) and a reduction of rural roads by about 14.7% to 7 km (6997 m). Due to the increased length of forest roads, the density of forest roads similarly increased by about 45.6% to 56.07 m*ha^{-1} with a similar forest land area of about 180.76 ha. The density of rural roads decreased by about 16.8% to 38.71 m*ha^{-1}. It is interesting that the efficiency of distribution of the forest road network increased by only about 17,8% to U = 53,08% and the efficiency of distribution of the rural road network on the arable land even dropped by about 54% to U = 15,34%, while the result was not better within the agricultural land as a whole, where the efficiency of distribution reached a value U = 19,42%. Mean transport distance in the forest stand to a forest road was shorter by about 41,7 m and reached 84 m; on the other hand, the mean transport distances in both arable and arable and permanent grassland were enormous, with values 421 m and 425 m, respectively (increased by about 161,5% and 117,9%, respectively).
Nowadays, we can see the same trend, with the forest and rural road length changes. The length of forest roads has increased to 56377 m (compared to the year 1952 it is by about +29.2%, but not as much as in the previous period), and the length of rural roads has gone down continuously to 5717 m (by about -18.3% compared to the previous -14.7%). This was reflected on the density of forest road network, which reached H = 70.56 m·ha^{-1}, but not in the density of agriculture land (H = 39,98 m*ha^{-1}), and arable land (29,73 m·ha^{-1}), which was particularly the same as in the previous analysed mapping. This can be explained by a decline of agricultural land in favour of the urban development of the Habruvka village and a large building-up of the arable area. Indeed, the development of urban area of Habruvka changes in individual years 1852, 1952, 2020 has been respectively equal to: +14,10 ha; +14,03 ha; +32,01 ha. The expansion of the built-up area after the Second World War was twofold. The important thing we can state here is that the efficiency of forest accessing with the constantly increasing length over years has been rising, with 59.05% now, the arable land kept its efficiency of distribution U =16,81%, while a big rise back in agricultural land occurred, thanks to permanent grassland accessing from 19,42% to 42,47%. The mean transport distance in the forest stand to a forest road was again shorter, reaching 60 m. The mean transport distances on arable land were still 372 m, but on the agricultural land (arable and permanent grassland) they dropped by more than a half to 192 m.

Discussion and Conclusion

As regards the forest road network, we can see that the forest roads were extended over time gradually, while historical roads were taken as a basis for this upgrade. The development after the Second World War was mainly related to the development of machinery for timber skidding and transport and its possible movement on difficult terrains. At the same time, we can see the efforts of forest managers to purposefully distribute forest roads by increased efficiency of their distribution in

forest stands and decreased clearance distances. We can see a significant effort to plan forest access network. The achieved density and geometric distances to forest roads show that there is no need for further access solutions for the forest in this area. The overall length of the rural roads was gradually reduced and some rural roads disappeared completely. This may be related to field merging and increased agricultural machinery performance. It is positive that the reduction of the rural road length does not further reduce the efficiency. Effective distribution of rural roads is currently an important parameter for agricultural land management. The data obtained from historical maps can help to identify the original routes of rural roads that have disappeared over time for various reasons. These data can be crucial to initiate their restoration in an effort to increase the diversity of soil units and the restoration of interactive features in this area.

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Souhrn

Historická lesní cestní síť tvořila základ pro současnou infrastrukturu. Po druhé světové válce jejich rozšiřování a distribuce souvisela s vývojem strojů pro těžbu a odvoz dříví. Z výpočtů vyplývá, že zpřístupnění lesa je dostatečné. Naproti tomu polní cesty postupně zanikají. Svůj podíl na tom neslo i scelování pozemků a vyšší výkon zemědělských strojů. Nejen pro obdělávání orné půdy je zpřístupnění důležité. Tato data mohou být rozhodující pro zahájení obnovy polních cest a interaktivních prvků v tomto území.

Contact:
doc. Ing. Petr Hrůza, Ph.D.
E-mail: petr.hruza@mendelu.cz