THE HISTORICAL DEVELOPMENT OF RURAL ROADS IN THE BASILICATA REGION, SOUTHERN ITALY

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Abstract
The rural road network is an inseparable part of the landscape and a fundamental mean for agricultural and forest management. The aim of this study was to analyze the historical development of the rural road network in relation to its density and distribution. The evaluation of the rural road network development includes an assessment of whether and how the road layout changed in time. For this study, a part of the hydrographic basin of the Bradano River (Basilicata region, Southern Italy) was selected. The basin map was created in ArcGIS environment the single map layers from the years 1829, 1875, 1955 and 2013 were imported. Vector layers of rural road network and basin boundaries were created in each of the maps for the rural road network density calculation, defined by the ratio of the length of hauling roads (in meters) to the basin area (in hectares). For the calculation of its distribution in the study area, the methodology commonly used for forest road network evaluation - based on average geometrical skidding distance and theoretical skidding distance - was applied. The analysis shows that the roads were constructed gradually, with an abrupt increase after the Second World War.

Key words: rural road network, historical cartography, Geographic Information System, rural landscape

Introduction

The analysis of rural land modifications, as well as the wider environment and landscape context in which they take place, is important in order to understand the dynamics connected with human intervention and natural events (Statuto et al., 2017). The current state of the landscape and the road network are based on traditional land use, which was applied over the decades. The technology development and GIS environment are the key tools for multi-temporal and multidisciplinary analyses of landscape. One aspect that can be analyzed is, for example, terrain accessibility in a forest or poly-functions of the forest stands (Hrůza and Vyskot, 2010). As well as in many rural landscapes, this is an essential component for a quality forestry and agricultural management. This article deals with the quality and distribution of rural and forest roads in the area of the "Forenza" Municipality. The identification of best management strategies could be based on the evaluation of wide time landscape modifications (Statuto et al., 2018). Also for this reason, historical maps can be used for land cover and settlement pattern analysis (Pindozzi et al., 2016; Olišarová et al., 2018). In this article, historical maps from 1829 to 2013 were analysed.

Materials and methods

Study area

The study area (Fig. 1) covers one part (about 18 km^2) of the Municipality of “Forenza” (Basilicata region – Southern Italy).

The altitude of the study area ranges from 450 to 920 m a.s.l.; the population density is 17.4 inhabitants per square kilometre. The soil structure has characterized the various orography of this area, which is influenced also by the socio-economic activities, mostly based on agriculture (Statuto et al., 2016). Major dominant of the forest represents oak wood, while there are some allochthonous conifer species into an artificially afforested area. There are several watersheds, which flow into the “Bradano” River.

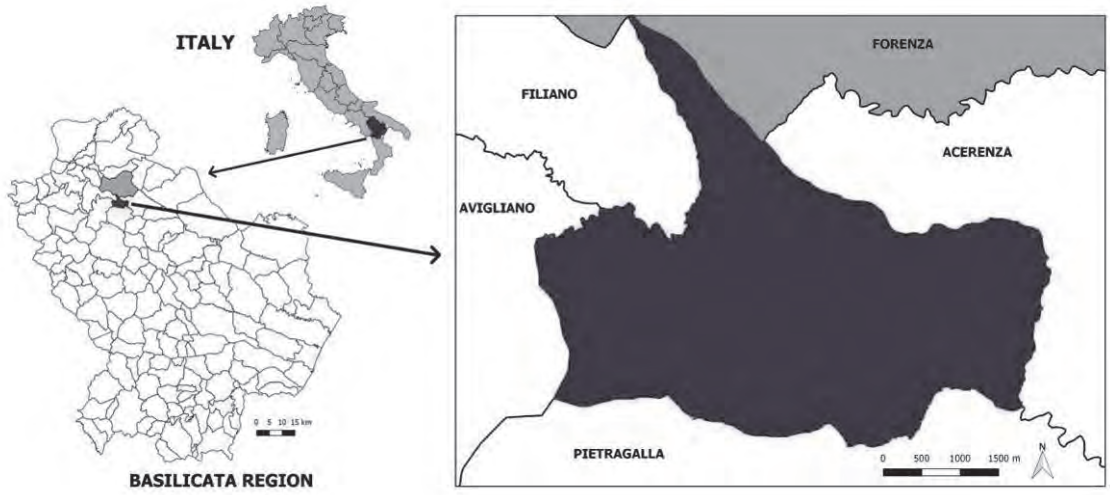

Fig. 1: Location of the study area (40° 47' 57" N, 15° 51' 39" E – WGS84)

Cartography

Changes in road distribution through the years were analysed in four different historical maps (1829, 1876, 1955 and 2013). The map of 1829 was produced by legal experts after border disputes to solve division of ownership between municipalities private owners. The scale of this map is 1:30 000. On the contrary, other map corresponds to scale 1:50 000 (1876) and it was produced by the Italian Topographic Military Institute after national unification. For land use of 1955, two aerial photograms were taken by the Italian Aeronautics Group, on behalf of the Italian Geographic Military Institute (IGMI) and the USA Army Map Service, were used. A scale of this photos is 1:33 000. For the year 2013 (1:50 000), orthophotos in GeoTIFF format from the open geo-database of the Basilicata Region were used. Each map has been elaborated separately and with different techniques to obtain information on land use and road networks (Statuto et al. 2018).

Rural road network evaluation

Road network was evaluated by Beneš methodology presented in 1986 (Beneš, 1986). The method was originally developed for forest haul road network evaluation. The practical application consists in the road network optimization in the various morphologic areas (flatlands, uplands and mountains). We used a part of this methodology focused on the road distribution in the access area expressed by its efficiency *U*. Other criterion for the road network evaluation is *the road density*. It is often considered as the main criterion to evaluate access standard. The road density *H* is given by equation:

$$H = \frac{D}{S} \quad [m \cdot ha^{-1}]$$

where *D* is the total road network length (in meters), and *S* is the accessed area (in hectares). Anyway, since this parameter does not provide for any information on the road network distribution, some additional parameters have been implemented.

The method deals with various types of skidding distances representing the traces of timber transport from the stand of harvesting to the haul road. Stands of harvesting are represented by 10 ha net area, and in the each stand they are marked in the centre of 10 ha square stand by the cross (Fig. 2).

We used the average geometric skidding distance xD_g and the theoretical skidding distance D_t due to calculation of the road distribution in the accessed area. The theoretical skidding distance D_t is an average skidding distance due to the optimal distribution of roads in the accessed area; it depends on the road density *H*.

The geometric skidding distance D_g represents the direct distance from the point of harvesting to the haul road. The average value of D_g depends on the road distribution and generally is higher than the theoretical skidding distance. The geometric skidding distances from grid points to roads were performed in QGIS software by vector analysis tool *Distance to nearest hub*.

Efficiency *U*:

$$U = \frac{D_t}{D_g} \cdot 100 \quad [\%]$$

Average geometric skidding distance xD_g

$$\overline{D_g} = \frac{D_{g1} + D_{g2} + \cdots D_{gn}}{n} \quad [m]$$

Theoretical skidding distance D_t

$$D_t = \frac{10000}{4H} \quad [m]$$

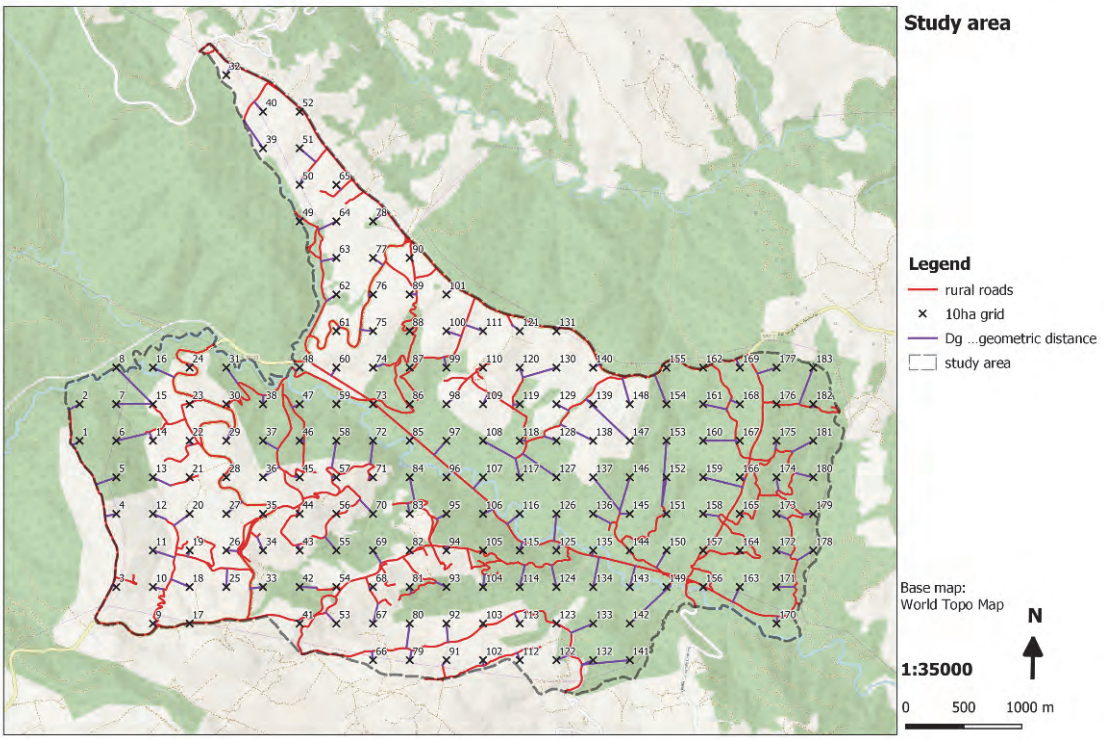

Fig. 2: An example of average geometric distance calculation of 2013 forest road network

Results and Discussion

In Table 1 some basic characteristics found from map data in different time periods are reported.

Tab. 1: Basic characteristics of the study area

Year	Length [m]	Area [ha]	Density [m/ha]	Efficiency [%]
1829	22744	1826,73	12	49
1876	28162	1826,73	15	44
1955	63451	1826,73	35	57
2013	69213	1826,73	38	55

The density of the forest road network was 12 m/ha in 1829; it has grown to 15 m/ha in 1876. Only in the second half of the 19th century, forest roads gained in significance. After the Second World War, the density increased to 35 m/ha in 1955. Then the rural road network density has stagnated (38 m/ha in 2013). Surprisingly, the road network distribution has not changed much in time, fluctuating within a range between 43 and 57%. These are realistic values commonly achieved in practice, which means that the rural roads were constructed throughout the entire study area during time.

Not all of the original roads detected in the year 1829 are present today. From a comparison of the rural road network in the year 1876 and in 2013 (Fig. 3), it is possible to notice that most of the roads present in the past are even present in 2013, and an expansion of the same occurred especially in the areas that were previously inaccessible.

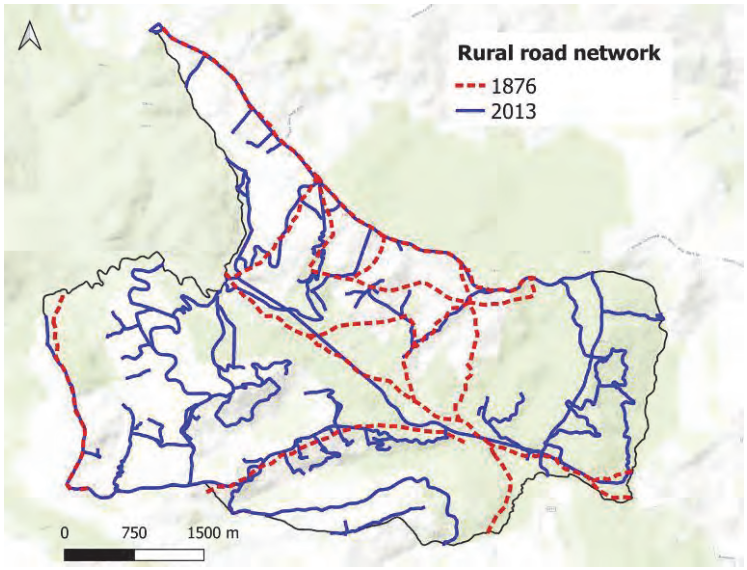

Fig. 3: Comparison of the rural roads in the year 1876 and in 2013

Conclusion

The original use of the forest road network assessment method was generally verified on rural roads in the landscape, to assess the development of its accessibility. The results show that the expansion of road construction occurred after World War II and the situation was stable in other periods. The actual road density is reasonably high, but the efficiency reaches just 55%. The value indicates the distribution of rural roads in study area would be improved, so as to develop the fundamental function to proactively support agricultural and forest management, while contributing to a sustainable evolution and environmental protection of the rural landscape.

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Souhrn

Účelové komunikace jsou nedílnou součástí krajiny a základní prvek pro zemědělské a lesní hospodářství. Cílem této studie bylo analyzovat historický vývoj zpřístupnění krajiny z hlediska hustoty

a rozložení cestní cítě v čase. Jako zájmové území byla vybrána část povodí řeky Bradano v oblati Basilicata jižní Itálie. Mapové podklady území byly vytvořeny v prostředí programu ArcGIS a jednotlivé mapy pochází z roků 1829, 1875, 1955 and 2013. Následně byly z mapových podkladů vytvořeny vektorové vrstvy cestní sítě daného období.
Vektorové vrstvy byly použity pro výpočet hustoty sítě účelových komunikací, která je definovaná jako poměr celkové délky cest v m k ploše území v ha. Výpočet míry rozložení cestní sítě v řešeném území byl proveden pomocí metody běžně používané pro hodnocení lesní cestní sítě, založené na průměrné geometrické přibližovací vzdálenosti a teoretické přibližovací vzdálenosti. Analýza zkoumaného území prokázala, že účelové komunikace byly v rámci řešeného období budovány postupně, avšak s prudkým nárůstem výstavby po druhé světové válce. V roce 1829 byla hustota cestní sítě 12 m/ha a v roce 1876 15 m/ha. V druhé polovině 20. století účelové komunikace nabyly na významu. Po druhé světové válce hustota dosáhla hodnoty 35 m/ha v roce 1955. Poté hustota sítě komunikací stagnovala (38 m/ha v roce 2013).
Kupodivu účinnost zpřístupnění vyjadřující míru rovnoměrného rozložení cestní sítě se během času příliš neměnila a dosahovala hodnot 49%, 43%, 57% a 55%. Jedná se o reálné hodnoty běžně dosahované v praxi, z čehož vyplývá, že síť účelových komunikací byla postupně budována rovnoměrně v celém řešeném území. Všechny historické cesty z roku 1829 nebyly zachovány; rozložení cest vybudovaných před druhou světovou válkou se příliš neměnilo; po roce 1955 byla cestní síť pouze rozšířena v oblastech, které byly dříve nepřístupné.

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